Report to Congress:

The State of Science to Support an Ecosystem Approach to Regional Fishery Management

Pursuant to the Magnuson-Stevens Fishery Conservation and Management Act, Section 406(f)

National Marine Fisheries Service

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
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NOAA Technical Memorandum NMFS-F/SPO-96
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U.S. Department of Commerce
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Preface

The exclusive economic zone (EEZ) and territorial waters of the United States cover more than 11 million square kilometers of ocean, making it the largest EEZ in the world. This immense area is home to an abundance of valuable marine resources that provide economic, ecological, and social benefits. These resources face increasing pressures as the human population continues to grow and global climate change becomes an escalating concern. These challenges call for innovative and comprehensive approaches to fisheries management to ensure sustainable harvest of the EEZ's valuable resources.

Traditional fisheries management focuses on single species, but this approach does not consider the reality and complexity of the marine environment. Fish, and the humans that harvest them, are part of a dynamic marine environment characterized by complex relationships between biotic and abiotic factors. Due to these complex relationships, human activities, including fishing, have direct and indirect effects on the ecosystem and such activities must be managed with these relationships in mind. Consequently, management efforts are moving away from single species management toward an ecosystem approach to management (EAM).

Congress acknowledged the importance of EAM when it directed NOAA's National Marine Fisheries Service (NMFS) to establish an Ecosystem Principles Advisory Panel (EPAP) through the Magnuson Stevens Fishery Management Conservation and Management Act. This was further reinforced in the 2006 reauthorization that mandated this report on the science needed to support EAM. Both the EPAP report and this document are designed to provide Congress with practical recommendations to advance the ecosystem approach in the context of the U.S. Fishery Management Council system. As demonstrated in this report, both NOAA and the Councils have made significant progress in implementing the EPAP recommendations. NOAA is fully committed to EAM and has reorganized its planning process and program structure to facilitate its implementation.

It is hoped this report will constitute a valuable contribution to the practical implementation of EAM in the marine waters of the United States.

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Executive Summary

Section 406 of the 2006 Magnuson Stevens Fishery Conservation and Management Reauthorization Act charged NMFS, in consultation with the Fishery Management Councils, to undertake a study on the "state of the science for advancing the concepts and integration of ecosystem considerations in regional fishery management." Section 406 specifies four objectives: 1) form recommendations for scientific data, information, and technology requirements for understanding ecosystem processes and methods for integrating this information from federal, state, and regional sources; 2) form recommendations for processes for incorporating broad stakeholder participation; 3) form recommendations for processes to account for effects of environmental variation on fish stocks and fisheries; and 4) describe existing and developing Council efforts to implement ecosystem approaches, including lessons learned by the Councils.

Regarding objective 1, the most important action should be to maintain and expand current fishery-dependent and fishery-independent surveys. These surveys provide the critical information on exploited and unexploited species required to support stock assessments, as well as long-term data on ecosystem status and trends. Most current surveys do not provide sufficient information to effectively manage all stocks, and there is a particular need to increase their spatial and temporal coverage. Additional time-series data on benthic environments are also needed to improve understanding of the relationship between habitat, benthic organisms, and fish species. Increased socioeconomic surveys are needed to help us understand and predict the behavior of harvesters, an important component of the ecosystem, with regard to different management options. Although we need improved ecological models to better understand dynamic ecosystem processes, in many cases modelers lack key ecological data, upon which predictive models depend. Research is needed to fill those gaps and the Comparative Analysis of Marine Ecosystem Organization (CAMEO) program has significant potential to do so. Finally, an ecosystem approach to management will require easily interpretable products to help integrate and convey complex ecosystem information to managers. Integrated Ecosystem Assessments (IEAs) will facilitate this information transfer, and it is recommended that IEAs be developed on both regional (large marine ecosystem) and sub-regional scales.

Regarding objective 2, broader stakeholder participation can be most effectively incorporated by expanding membership on Council committees to include non-fishing interests, and by increasing methods of communication among stakeholder groups and between these groups and the Councils. This broader stakeholder participation is needed to ensure that a more comprehensive ecosystem perspective is considered. It is also recommended that the rotation of Council meeting locations may help ease the cost and logistical burdens of stakeholder attendance and therefore encourage more stakeholders to participate. Stakeholder surveys should also be expanded to help ensure that a range of non-fishing views are considered in the fisheries management process. Previous survey results have demonstrated that stakeholders value ecosystem goods and services beyond fisheries and have resource use patterns that are important to consider in the management process. Finally, the level of interagency communication must be increased. Multiple

agencies have jurisdiction over various ecosystem components, and it is crucial for these agencies to communicate ecosystem knowledge with each other and coordinate their management actions from a holistic and integrated ecosystem perspective. To achieve this, these agencies must be involved in the Council processes.

Regarding objective 3, processes to account for the effects of environmental variation on fish stocks and fisheries must consider climate-scale variability. Climate change is a growing concern for marine ecosystem management, and climate-induced change is inevitable. Thus, it is recommended that collaborations with climate change researchers be maintained and that climate and ecosystems modeling efforts be strengthened. Simultaneously, efforts to better understand the role of non-climate, human-induced changes in coastal systems on fish populations also must be pursued with added vigor. Burgeoning populations in U.S. areas adjacent to coasts, estuaries, and rivers directly and indirectly impact habitats vital to harvested fish and their forage.

It is recommended that management strategy evaluations be used to determine the appropriate environmental variables necessary to improve stock assessment performance. Incorporating environmental variables or indices into stock assessments is not an easy task, and environmental indices need to be very reliable in order to offset the potential risk associated with erroneous predictions. Management strategy evaluations are a means of determining which indices are beneficial. To improve predictive models it is also recommended that there be a focus on understanding critical mechanisms underlying correlations between environmental variability and fish productivity. Programs such as FATE (Fisheries and the Environment) and NPCREP (North Pacific Climate Regimes and Ecosystem Productivity) are examples of programs aimed at such integration. Environmental variations can influence physiological conditions, such as growth and reproduction, and finer spatial and temporal scale sampling may help to clarify these relationships. Finally, while multi-species and ecosystem models are being developed and improved, there is a need to maintain conventional single-species stock assessments, as there is no indication these new models will reduce the need for conventional models in the near term.

Regarding objective 4, existing and developing Council efforts to implement ecosystem approaches vary by region and many challenges remain. While some Councils are actively moving forward with ecosystem approaches to management (EAM), others are awaiting more definitive national guidance. Efforts include establishing Fishery Ecosystem Plans (FEPs), holding public meetings and workshops to discuss EAM, conducting ecosystem user surveys, developing ecosystem models, and mapping essential fish habitat. It is also important to recognize that many existing Council management efforts (such as bycatch reduction, area closures, and fishing fleet reduction) already represent significant progress toward an ecosystem approach. Despite this progress, additional effort is required. One challenge is the lack of sustained, annual support for FEP development and implementation. Another challenge concerns the complex jurisdictional environment in which ecosystem components are managed. Multiple federal, state, and local agencies have authority over different aspects of the ecosystem, and these roles need to be further defined and coordinated at the agency, inter-agency,

and Council levels. Councils should consider ways to conduct more extensive outreach with these other entities to better incorporate their input into the Council process. Similarly, other entities should look for opportunities to engage the Councils, where appropriate, in their processes and issues. This will help to improve inter-agency communication and support a broad ecosystem perspective.

Introduction

In 1996, NOAA's National Marine Fisheries Service (NMFS) established the Ecosystem Principles Advisory Panel (EPAP) pursuant to Section 406 of the Magnuson-Stevens Fishery Conservation and Management Act. The panel was charged to submit a report to Congress that included: 1) an analysis of the extent to which ecosystem principles are being applied in fishery conservation and management activities, including research activities; 2) proposed actions by the Secretary and by the Congress that should be undertaken to expand the application of the ecosystem principles in fishery conservation and management; and 3) other such information as appropriate. The panel's report, submitted to Congress in 1999, outlined a number of principles, policies, and goals for ecosystem-based fisheries management as well as recommendations for practical steps that could be taken to implement an ecosystem approach (NMFS, 1999).

Now, 10 years later, Section 406 of the reauthorized Magnuson-Stevens Act charges NMFS, in consultation with the Fishery Management Councils, to undertake a study on the "state of the science for advancing the concepts and integration of ecosystem considerations in regional fishery management." To gather information for this study, a workshop was held at the NOAA Alaska Fisheries Science Center in Seattle on January 9–10, 2008. Workshop participants included a mix of ecosystem scientists from the NMFS Science Centers, NMFS Regional Offices, Councils, and some former members of the EPAP. This Report to Congress is based on the results of this workshop. Its structure speaks to the four overall objectives of Section 406 of the 2007 MSFCMA.

1. Recommendations for scientific data, information, and technology requirements for understanding ecosystem processes, and methods for integrating such information from a variety of federal, state, and regional sources

Recommendations in the 1999 EPAP Report addressed scientific data, information, and technology requirements for understanding ecosystem processes. These recommendations included a call for a description of long-term data and how these data are used for monitoring and management, a description of habitat needs for different life history stages of living marine resources, development of a broad suite of indicators to monitor ecosystem status, and accountability for total fishery removals (NMFS, 1999). A number of efforts are underway to provide such information. NMFS has published a Data Acquisition Plan that details the routine fisheries-dependent and fisheries-independent data required to support U.S. federal marine fisheries management (NMFS, 1998). Additionally, programs such as the Integrated Ocean Observing System (IOOS) are prioritizing new data collections and providing the framework for improving access to those data. A new program, Comparative Analysis of Marine Ecosystem Organization (CAMEO), focuses on improving the science support for ecosystem management by uncovering how the structure and function of ecosystems respond to change, human impacts, and environmental variation. Such programs will help to provide some of the data called for by the EPAP, but additional data are needed for a full understanding of ecosystem processes. Some of the major data and information requirements, and recommendations to address them, are detailed below.

The role of surveys, assessments, and other routine data collection efforts and analyses in understanding marine ecosystems

Surveys, assessments, and other routine data collection efforts and analyses play an important role in understanding marine ecosystems. Currently, fishery-independent surveys provide vital information on the relative abundance and ecological characteristics of many fish and invertebrate stocks as well as non-fishery species (such as marine birds, turtles, and mammals) in U.S. marine ecosystems. Zooplankton and ichthyoplankton surveys provide long-term time series data for early life history stage abundances of exploited and unexploited species. Programs such as the California Cooperative Oceanic Fisheries Investigations (CALCOFI) surveys off California, Marine Resources Monitoring Assessment and Prediction (MARMAP) and Continuous Plankton Recorder surveys in New England, and Fisheries-Oceanography Coordinated Investigations (FOCI) surveys in Alaska provide the basis to monitor secondary production and fish recruitment dynamics in those regions and provide essential ecosystem information. Fishery-dependent sampling provides key information on the effects of fishing on exploited and unexploited species and includes collecting landings data from commercial and recreational fisheries, logbook reporting, and vessel monitoring systems. In part as a response to the EPAP, a comprehensive Observer Program has been implemented in all regions of the United States to monitor the amount of catch discarded at sea so total removals of fished species can be calculated. Each of these survey types provides the basis for long-term time series of information critical for monitoring of ecosystems.

Despite the useful information provided by such surveys, notable gaps still exist in necessary scientific data. Most surveys target exploited open ocean species and species that co-occur with such exploited species. As a result, some fish stocks, especially those in nearshore habitats and their forage, remain virtually unsampled. An unrelated issue pertains to survey frequency. In some regions, surveys are conducted only every third year, which does not provide the necessary data to detect annual fluctuations. Additionally, lack of time-series data on the benthos and the failure to understand the detailed topography of fishing areas, how exploited species (all life history stages) are distributed relative to such features, and how fisheries species and their forage gain benefit from their habitats are daunting impediments to understanding relationships between habitat, benthic fauna, and fish species. It has limited the ability to determine the effects of mobile fishing gear on habitats and to fully appreciate both the benefits and impacts of Marine Protected Areas (MPAs). Knowledge about the benthos is also important for understanding energy flow and food web dynamics, including benthic-pelagic coupling and benthos as prey of commercially important species. Expansion and development of such surveys will also provide useful data on biodiversity, a fundamental property of ecosystem structure. Another notable gap is in socioeconomic collections, which are a key component of ecosystem analysis and management. Understanding the behavior of harvesters and predicting their responses to changes in management measures and associated costs is critical.

Research and technology requirements needed to understand critical ecosystem processes

Marine ecosystem management can be improved through research that elucidates underlying dynamics at a variety of scales and increases understanding of critical ecosystem processes. A critical area of research is the development of a variety of modeling methods, such as MPA site-selection models, statistical models, and/or theoretical models. In most cases, modelers lack important ecological information, and research is required to fill these gaps. For MPA site-selection models, appropriate distribution and abundance data on most ecological groups are lacking. For these models, intensive small-scale surveys of all ecosystem components, ranging from physical conditions to marine mammals, and socioeconomic data on the human drivers and management impacts are necessary. Statistical models will improve understanding of links between habitat and demographic rates of marine organisms, functional feeding responses of predators, strength of ecological interaction, biodiversity, and connectivity among local populations, but to improve these data-driven models, process-oriented studies of ecological interactions and the increased use of lab, small-scale field, and management experiments are needed. Theoretical models are important for the development of ecological forecasts and IEAs but further information on ecological mechanisms is needed. For example, robust data on variation in demographic rates, functional responses, mechanisms limiting or generating change in population size, ecological interactions, and the combined effects of density-dependent and density-independent processes are needed.

This ecological modeling effort will provide a greater basic understanding of ecosystem processes and practical tools for evaluating the effectiveness of ecosystem-based management efforts, but there is also a need for a variety of technologies required to efficiently expand data collections to meet these needs. New sensor capabilities are necessary to realize the full potential of *in situ* ocean observing networks and satellite-based observations in implementing EAM. Technological advances for rapid measurement and integration of surface and subsurface chlorophyll concentrations are needed for improving estimates of sustainable carrying capacity of ecosystem goods and services. Moored and autonomous instruments can vastly increase spatial and temporal resolution of ecosystem monitoring data. Further development and adaptation of Automated Underwater Vehicles (AUVs), Remote Underwater Vehicles (ROVs), autonomous underwater gliders, and vehicle types yet to be described, specifically for deployment of EAM advanced sensors, are also needed. There is also a need to increase the capacity to sample adaptively. Critical events affecting recruitment may be short-lived and/or localized. This requires flexible vessel resources and instruments designed to sample when a trigger threshold is crossed. Programmable drifters with behavior and trigger released drifters to sample eddies are being developed and can increase sampling of key oceanographic features at a relatively low cost. Increased deployment of autonomous smart instrumentation can supplement and extend coverage by ship-based surveys. Continued support of research to develop these innovative sensors is critical. Remote sensing data are available from the U.S. National Aeronautic and Space Administration, as well as NOAA, and the continuation and development of remote sensing capabilities is essential. Continuity of high-resolution, reliable, remote sensing

data (sea surface temperature, sea surface height, ocean color) under the next generation of sensors is fundamental for EAM.

Integrating ecosystem information from various sources to improve management

There is an ongoing need to integrate the ecosystem information collected by multiple institutions to improve ecosystem management. Partnerships with state and local government agencies, research institutions, and universities will be the key to integrating information effectively. Programs, such as IOOS, have been initiated to establish an integrated and sustained coastal ocean observation system capable of meeting diverse regional and national information requirements for the purposes of advancing ocean science and resource management. The focus of NOAA's IOOS plan is to improve access to high-quality, integrated data, and to enhance data products and decision support tools (National Ocean Service, 2007). Support of integrated information systems, such as IOOS, is essential to the development of the data needed to conduct EAM.

The current implementation of IOOS and related observational efforts needs to be augmented to focus more fully on environmental/habitat conditions in nearshore waters, estuaries, and coastal rivers; changes in land use and land cover; alterations in freshwater delivery to coastal systems via rivers and groundwater; and atmospheric delivery of substances that affect ecosystem functioning and the ability of coastal systems to sustain harvestable populations of fish and shellfish. Burgeoning populations in U.S. areas adjacent to coasts directly and indirectly impact habitats vital to harvested fish and their forage. The resulting alterations frequently are regional in scale and are capable of inducing changes as profound in intensity as climate alteration.

There is also a growing need to integrate and deliver ecosystem information to managers and stakeholders in a broad array of products (websites, reports, briefings) to facilitate information transfer. Novel ways of distilling information into easily interpretable products are important. The development of such information products (e.g., IEAs) is the key to addressing the needs of data integration and production of useful products to decision-makers and stakeholders. An IEA is a formal synthesis and quantitative analysis of information on relevant natural and socioeconomic factors in relation to specified ecosystem management goals (Levin et al., 2008). IEAs involve and inform citizens, scientists, managers, and policymakers through formal processes to contribute to attaining the goals of EAM. IEAs should be developed on a regional and sub-regional scale. They will provide a framework into which various forms and sources of ecosystem data can be integrated on a large marine ecosystem scale.

Recommendations

- Maintain and expand current levels of fishery-dependent and fishery-independent data collection activities.

- Expand surveys collecting benthos and habitat-related data (e.g., area of coverage, scale of data collection, and focus on habitat use by resource and forage organisms) and increase socioeconomic data collection efforts.

- Accelerate the development of ecosystem models. The CAMEO program has the greatest potential to contribute to the development and improvement of experimental and operational ecosystem models.

- Develop and implement the next generation of sensors and undersea vehicles to fulfill the increased data needs for EAM. Deployment of innovative technologies such as autonomous smart instrumentation will supplement and extend coverage by ship-based surveys. Flexible and increased vessel resources will also be needed to allow adaptive sampling as well as the intensive sampling needed for understanding processes and rates. Continuity of high-resolution, reliable, remote sensing data also needs to be maintained.

- Support the continued development of integrated information systems, such as IOOS, which are essential for the provision of data needed to conduct EAM.

- Enhance data collection and analyses in near coastal, estuarine, and riverine systems to capture effects of coastal population growth on fishery production.

- Develop and implement integrated ecosystem assessments (IEAs) on regional (large marine ecosystem) and sub-regional scales to provide a practical framework for the integration of ecosystem data and a means to make informed ecosystem-based management decisions.

2. Recommendations for processes for incorporating broad stakeholder participation

The 1999 EPAP report recommendations addressed the need for broad stakeholder participation in effective ecosystem approaches to management. Effective EAM relies on the participation, understanding, and support of a broader suite of stakeholders than that currently participating in the fishery management process. In particular, the EPAP noted that effective EAM would require including stakeholder groups indirectly affected by fisheries as well as industry sectors that indirectly affect fisheries (e.g., through water quality). The full participation of all stakeholders, including the interests of future generations, was noted by the EPAP as likely to result in policy development and implementation that is more fair and equitable.

Many of the Councils have conducted workshops and outreach activities to educate and inform constitutients on the ecosystem approach to fisheries management. Surveys have also been implemented to gather public input on a variety of ecosystem-related issues. Such actions are designed to reach beyond the fishing industry to incorporate a broader range of stakeholders into the EAM process.

Current stakeholder involvement and mechanisms for broadening stakeholder participation in an EAM are outlined below.

Major ecosystem stakeholders already participating in the fisheries management process and those missing from the process

EAM, by its nature, requires participation of a broad range of stakeholder groups to provide for a more holistic ecosystem perspective. This effort must move beyond fisheries interests alone to adequately address all emerging management concerns and efforts. One possible vehicle for this expansion is the Council process, which may allow for increased participation by state and federal representatives. In the current advisory capacity of the Council process, there are meetings, hearings, science and statistical committees (SSCs), advisory panels (APs), and other committees. These processes can be broadened through the expansion of current bodies to enhance representation, creation of new committees, or development of ecosystem advisory panels.

Some but not all ecosystem stakeholders are currently participating in the fishery management process. Organizations such as coastal groups, coastal developers, regional watershed resource managers, and energy companies/organizations may have an interest in Council activities and/or may be undertaking activities that affect fisheries. For example, with the exception of the Coast Guard, the U.S. military is often missing from the process even though their activities can have ecosystem effects and they can be an important source of oceanographic and hydrographic information. The U.S. Geological Survey (USGS) and Minerals Management Service (MMS) are also important agencies to involve based on their data/scientific expertise (USGS) or their management goals (MMS), which might be in conflict with fishery management goals. Currently, the representation of such agencies on Councils varies regionally. Even the participation of mandated organizations, such as the U.S. Fish and Wildlife Service, varies regionally

according to the specific management concerns being addressed. Successful EBM will necessitate two-way communication between the Councils and this broader base of stakeholders. It will be important for the Councils to seek and be given the opportunity to provide input into the management activities of these stakeholders as well. The Councils should seek to establish additional forums to engage various other federal and state agencies as they pursue their legislative mandates in order to broaden coordination and align management and science programs.

Effective means of bringing stakeholders and their interests into the current management council process to provide a broader ecosystem perspective

Several means exist to incorporate a broader stakeholder base into the current management council process. An improved system of outreach and notification to pertinent stakeholders could encourage increased participation. Current means of public notification and communication could be expanded to include these other stakeholder groups to ensure that they are aware of the schedule and agendas for Council meetings and/or ecosystem advisory group meetings and of the various ways they can participate in the Council process. Similarly, other stakeholders and management entities should look for opportunities to engage the Councils in their processes and issues. Council meetings are generally rotated among various locations, although the locations may be limited due to cost or other logistical issues. The rotation of meeting locations allows participation of more groups by relieving some of the financial burden associated with traveling to meetings.

Statistically based surveys of the general public and/or more targeted studies of particular stakeholder groups may serve as another means of increasing stakeholder participation by evaluating societal values and resource use patterns. A number of these surveys have recently been implemented to obtain information on ecosystem attitudes, preferences for management options, and valuation surveys on MPAs, protected species, and corals. These have included non-market valuation surveys of public willingness to pay for Steller sea lion recovery (NMFS, 2007) and studies that have looked at the current Council composition and voting relative to various issues (Ellis, 2008). Results have demonstrated that the public values marine resources and has preferences on use patterns.

NOAA's vision for EAM specifically includes the need to consider stakeholder requirements in science and management. Information-sharing among affected agencies may assist managers in planning and choosing among management options that affect various stakeholder groups. There is a significant need for an overall increase in the level of inter-agency communication and collaboration to help decision-makers gain a holistic perspective, but some Councils have expressed frustration with the lack of communication. Increased communication may need to be accomplished through establishment of formal structures and may need high-level intervention to facilitate cooperation among agencies. In Alaska, there are some efforts to implement this recommendation through the Ecosystem Committee of the North Pacific Fishery Management Council, the Alaska Marine Ecosystem Forum, and fishery ecosystem plans

that involve multiple agencies in development and implementation (NPFMC, 2008).

Recommendations

- As appropriate, expand Council APs, SSCs, and other committees to include relevant ecosystem stakeholders and/or create new ecosystem committees or advisory panels.

- Develop methods for communicating with stakeholders, including rotating Council meetings or Council committee meetings among coastal communities. Increased communication will encourage broader participation and the rotation of meeting locations will ease the logistical burdens of stakeholders interested in participating.

- Increase surveys of stakeholders and the general public (consider cross-agency surveys and other information sharing) to provide information on and increase knowledge of societal values and resource use.

- Increase the level of agency-to-agency communication/collaboration. This may need to be done through establishment of formal structures and may need high-level intervention.

3. Recommendations for processes to account for effects of environmental variation on fish stocks and fisheries

Recommendations in the 1999 EPAP report focused mainly on general ecosystem issues, and were silent with regard to detailed modeling of environmental effects, especially in single-species assessments. Since that time, global climate change has emerged as a significant threat to marine ecosystems and fisheries, and will be an important consideration in EAM. NOAA is developing strategies for addressing the impact of climate on living marine resources and coastal ecosystems (Griffis et al., 2008). Consideration of the effects of environmental variability on fisheries will need to include an explicit emphasis on climate-scale variability and change. NOAA needs to maintain collaborative interactions with global climate change researchers, and climate and ecosystem models need to be strengthened.

The influence of environmental variability on fish stocks is an area of active scientific research. Over the past 10 years, the National Research Council, often commissioned by NMFS, has published a number of reports discussing the incorporation of environmental variability into stock assessments and the associated difficulties, indicating the importance and complexity of this topic (NRC, 1997, 1999, 2002, 2006). NMFS has also conducted a variety of workshops covering this topic (Mace, 2003; Watters, 2004; Methot, *in prep*). As climate change continues to threaten marine ecosystems, understanding relationships between environmental influences and fish productivity will continue to be important.

Some of the major challenges associated with accounting for environmental variability and the ability of current stock assessments to account for this variability are discussed below.

Major challenges in accounting for the environmental variability on fish stocks and fisheries

Accounting for the impact of environmental variability on fish stocks is not an easy task, and many challenges still exist. Including environmental explanatory variables may potentially improve predictions, but this also allows greater scope for erroneous predictions, with a corresponding increase in risk. The few relevant simulation studies agree that an environmental variable must be a very reliable predictor for the benefit to outweigh the risk, and in practice this reliability standard can seldom be met (Basson, 1999; Kell et al., 2005). Simulation studies or "management strategy evaluations" need to be conducted to determine which environmental variables in stock assessments improve performance and which degrade performance.

Improvement of predictive models is dependent on increasing the current level of understanding of critical mechanisms influenced by environmental variability. For example, the capability to predict recruitment will require further understanding of environmental mechanisms underlying spatial and temporal fluctuations in fish production, combined with local ocean circulation models (e.g., Regional Ocean Modeling System models), and will most likely need to be done on a case-by-case basis. Additionally, there are environmental influences on physiological condition relating to growth, maturation, fecundity, and timing of reproduction, but these climate-related properties are seldom being monitored in annual fish catches or surveys. Increased ecological monitoring and modeling will potentially improve understanding of fluctuations in natural mortality rates. There is a need to maintain emphasis on understanding critical mechanisms, especially those underlying apparent correlations between environmental conditions and fish stock productivity as well as increased monitoring of annual fluctuations in growth and reproductive condition. Current programs, such as FATE (Fisheries and the Environment) and NPCREP (North Pacific Climate Regimes and Ecosystem Productivity), are examples of programs aimed to provide such critical information. Further understanding may require finer spatial and temporal resolution of physical and biological conditions. As researchers and managers consider the possible impacts of global climate change on marine ecosystems, it will become increasingly important to understand these relationships.

Ability of existing stock assessments and/or harvest advice processes to adequately account for the effects of environmental variability on fish stocks and fisheries

The present ability to account for environmental effects is minimal. It has been repeatedly shown that under conventional single-species management approaches, there is little benefit in anticipating year-to-year fluctuations unless those predictions are more reliable than can be achieved currently (Walters and Parma, 1996; Myers, 1998; Stokes et al., 1999; Patterson et al., 2001). Current multi-species models have very limited predictive accuracy, and ecosystem shifts can generally be recognized only after they have happened. It will be more beneficial to shift from focusing on inter-annual variability to low frequency or inter-decadal environmental variability and to

understanding and better predicting the nature and intensity of habitat changes resulting from human activities. To improve understanding of inter-decadal variability, it will be important to continue to capture relevant existing historical datasets, as sources are discovered and opportunities arise. The NESDIS Climate Database Modernization Program, run by the National Climatic Data Center, has been performing an especially valuable service in this regard.

Although the importance of habitat is widely recognized, scientists lack the quantitative ability to model, assess, and anticipate changes in resource productivity resulting from habitat alteration, habitat loss, and habitat restoration. There is a need for further understanding of anthropogenic effects (e.g., degraded water quality, habitat loss, and water diversion) and for improving the quantitative basis for assessing habitat. Anthropogenic habitat alterations, such as salinity alterations associated with changes in regional water usage and enhanced sediment and nutrient loads caused by wide-scale changes in land use patterns, are capable of inducing changes as profound in intensity (although not in geographic scope) as climate alteration. Another area where much could be gained from better understanding of habitat factors and environmental effects is that of stock rebuilding, especially where there is reason to believe that the present ecosystem and habitat may be different from the historical conditions used to develop rebuilding targets and expected rebuilding times. In the worst cases, such as catastrophic loss of habitat (e.g., Sacramento winter run Chinook salmon), it may not be possible to rebuild a stock to historical levels, but it will be necessary to be able to provide a basis for an appropriate rebuilding target.

As NOAA continues to move forward with ecosystem-based management, it will be important to maintain single-species stock assessments. Although environmental and ecosystem relationships may have promise, such improvements can only be built upon a firm single-species foundation. A plan needs to be developed and implemented articulating the steps for moving from single-species to ecosystem-oriented management. In its 2008 evaluation of the state of the use of ecosystem models (Townsend et al. 2008), NMFS recommended an enhanced program to develop, test and implement promising new classes of such models.

Recommendations

- Maintain collaborative interactions with global climate change researchers and strengthen climate and ecosystem models.

- Conduct simulation studies or “management strategy evaluations” to determine when including environmental variables (including those pertaining to habitat) improves stock assessment performance.

- Maintain emphasis on understanding critical mechanisms, especially those underlying apparent correlations between environmental conditions and fish stock productivity. This may require measurements of physical and biological conditions at finer spatial

and temporal scales.

- Increase routine monitoring of annual fluctuations in growth and reproductive condition. This is a mundane and low-tech aspect of fish stock monitoring with very high potential for improving understanding of environmental effects.

- Shift from focusing on interannual variability to focusing on low-frequency or interdecadal variability (i.e., long strings of good or bad years). This may include trends in physical and biological patterns as well as shifts at an ecosystem level.

- Enhance understanding of anthropogenic effects on habitat and fishery productivity. Anthropogenic effects may be more influential in some regions and fisheries than others, but increasingly are being seen as regional rather than local in scope. They represent some of the most promising opportunities for effective science-based anticipatory actions leading to management control.

- Maintain the emphasis on supplying adequate information for conventional single-species stock assessments. There is no indication that an ecosystem approach will reduce the ongoing need for conventional stock assessments in the near term.

4. Description of exisiting and developing Council efforts to implement ecosystem approaches, including lessons learned by the Councils

The 1999 EPAP report concluded that the eight Councils are implementing many ecosystem principles, but these principles are not applied comprehensively or evenly across Council jurisdictions. Below, the Councils' efforts, successes, and challenges associated with implementing EAM are discussed.

Current and developing Council efforts to implement ecosystem approaches

The eight Councils are at differing stages of progress and have taken different paths in developing an EAM. All Councils recognize the mandate to incorporate ecosystem principles into fishery management, but lack the understanding and tools to do so fully. The necessary steps for implementing EAM are not always clear, and some Councils are not attempting formal implementation, but rather have proceeded cautiously, awaiting national guidance. At least two Councils, however, have actively moved forward with implementing EAM. The North Pacific Fishery Management Council (NPFMC) has established a Fishery Ecosystem Plan (FEP) for the Aleutian Islands (NPFMC, 2007); and the Western Pacific Regional Fishery Management Council (WPFMC) has formally established an ecosystem policy to develop FEPs according to a place-based approach (WPFMC, 2007).

Councils that have not implemented FEPs have taken a vareity of steps towards EAM. The Pacific Fishery Management Council (PFMC) has moved to begin development of an Ecosystem Fishery Management Plan that could be patterned after the NPFMC FEP

and is envisioned to take the form of an umbrella plan that integrates ecosystem considerations across existing FMPs. PFMC has held multiple public Council sessions and advisory body meetings on the topic and is currently seeking funding to convene a plan development team. The New England Fishery Mangament Council (NEFMC), Mid-Atlantic Fishery Management Council (MAFMC), South Atlantic Fishery Management Council (SAFMC), and the Gulf of Mexico Fishery Management Council (GMFMC) used 2004 congressional funding to solicit constituent views about EAM and to support local ecosystem-related projects. The NEFMC conducted public meetings, workshops, and surveys on fishery values, management objectives, and tradeoffs between potential loss of total allowable catch relative to allocations for ecosystem needs. The MAFMC conducted educational workshops and activities to acquaint Council members, constituents, and the general public with the new emphasis on EAM and discuss options relative to implementation. Such education and outreach efforts have proven to be beneficial. Other Councils have used the funds to focus on modeling and field efforts to support EAM. The SAFMC has begun the development of an FEP using EPAP guidance and, like the GMFMC, has been exploring fisheries-based ecosystem modeling and other trophic models. The Caribbean Fishery Management Council (CFMC) conceived an ecological approach to fishery management as early as the 1980s, but funding limitations and FMP requirements did not allow for development of FEPs at that time. The CFMC has since concentrated on mapping and characterization of essential fish habitats (EFH), and is currently exploring ecosysytem modeling for fisheries management.

Successful Council steps toward EAM implementation

The 1996 Magnuson Stevens Act requirements, including the National Standards, and other requirements such as the National Environmental Policy Act (NEPA) and the essential fish habitat provisions, have resulted in fishery management actions that can be considered progress toward the implementation of EAM. In addressing requirements relative to bycatch, overfishing, protected species, EFH, and cumulative effects assessment, the Councils have implemented gear restrictions, time and area closures to protect spawning populations, conservative and environmentally influenced harvest policies for forage species. These policies include harvest prohibitions, protection of habitat areas of particular concern (HAPCs), catch quotas, and bycatch and fishing effort restrictions. Some Councils have become involved in understanding and protecting non-fishery species, such as corals, marine mammals, sea turtles, and seabirds. All of these actions have indirect, if not direct, EAM implications. Councils cite success in the ending of overfishing of certain species, reduction of fleet capacity, and moving from single species to multi-species management as moving toward EAM. Mapping and characterization of habitats by Councils and development of EFH amendments to the FMPs also exemplifies the ecosystem approach.

Councils have taken different approaches toward ecosystem mangement and establishment of an ecosystem policy; FEPs by the WPFMC and NPFMC provide examples. The WPFMC is transitioning from FMPs to FEPs. The new FEPs are place-based in consideration of differing local conditions and cultures. The NPFMC has established an FEP for the Aleutian Islands without replacing existing FMPs. The FEP is

comprehensive in providing the best available science on understanding the ecosystem as a framework within which to make fishery management decisions. The PFMC is in the early stages of developing a similar umbrella type plan. These two differing approaches offer potentially viable options for the other Councils.

Challenges associated with ecosystem implementation

EAM is a more complex and information-intensive process than traditional fisheries management approaches and will require dedicated resources to implement effectively. At present, Councils cannot undertake EAM as a dedicated programmatic task and NMFS is unable to provide the required environmental and fisheries data and associated predictive analyses.

Another major challenge to implementing EAM relates to jurisdiction and authority. Many ecosystem attributes, such as water quality, are impacted by activities regulated by other agencies. While Councils can certainly include such ecosystems components in their management considerations, they currently do not have authority over many important ecosystem components. If the Councils' responsibility is extended to encompass ecosystem issues beyond target fishery species and their habitat, these jurisdictional issues need to be addressed. Legislative change that grants additional jurisdictional authority may be needed to allow the Councils to manage more broadly. Furthermore, most Councils prioritize their responsibility under the Magnuson-Stevens Act to achieve fisheries harvest at optimum yield. Finding a balance between achieving a beneficial fishery harvest and protecting marine ecosystems continues to be a challenge. Jurisdictional authority needs to be redefined at the agency, Council, state, and national level.

In summary, common EAM issues exist across the Councils. Foremost among these issues is the lack of clarity among Councils as to how to implement EAM. The guidelines for implementation are ambiguous, and the role of the Councils in the context of ecosystem-based management is not defined. Moreover, the additional demands of EAM on staff and the funding limitations are major impediments toward progress on EAM and FEP within NMFS and the Councils. The Councils recognize that good science is crucial to providing the information and advice that will help address EAM, but the lack of dedicated funds to support the engagement of the scientific community is a problem.

Recommendations

- Provide each of the Councils with sustained, annual funding to develop and implement FEPs.

- Keep science at the forefront of the process in developing FEPs. The Councils strongly favor having the "best available science" to understand ecosystem attributes for making management decisions.

- Provide a better understanding of what constitutes an EAM, including more definitive and detailed guidance to Councils on how to develop FEPs.

- Develop FEPs incrementally, building upon each Council's past and current stage of progress moving toward EAM. Determination of what constitutes a successful FEP needs to be established.

- Clarify and redefine jurisdictional authority at multiple levels: 1) within NOAA, 2) within the Federal Government (both agencies and legislative mandates), 3) at the Council level and 4) with respect to the jurisdiction of states and other local authorities. Additional legislative authority may be needed if the Councils are to expand their role in EAM beyond fisheries and EFH.

- Increase opportunities for and develop Council processes, as appropriate, to increase and incorporate input from other federal agencies (such as the Department of the Interior and Environmental Protection Agency) and stakeholders with ecosystem interests.

Summary

NOAA and the Councils are continuing to incorporate ecosystem principles into fishery management efforts. As charged by Section 406 of the reauthorized Magnuson-Stevens Act, this report examines the "state of the science for advancing the concepts and integration of ecosystem considerations in regional fishery management." A variety of recommendations will need to be addressed to successfully and fully implement an ecosystem approach to management.

While an ecosystem approach to management does not require a complete understanding of each ecosystem, it does require fundamental knowledge of basic ecosystem principles. These principles, as outlined by the EPAP (NMFS, 1999), highlight the complex and dynamic nature of ecosystems and researchers' limited ability to predict change. With these principles in mind, scientific data, information, and technology requirements necessary to further understand ecological processes have been identified. This will require sustained ecosystem observations, process-oriented research, and integrative modeling in support of an ecosystem approach to management. Specific biological, socioeconomic, and climate/physical data needs should be addressed to strengthen EAM. The CAMEO program was created to strengthen the fundamental scientific basis for an ecosystem approach to management and will be an important ingredient to moving forward.

An ecosystem approach to management requires broad stakeholder involvement. Specifically, it should include the participation of stakeholders interested in the ecosystem and effects on the ecosystem, beyond fishing alone. These stakeholders should be engaged in the science and management of the resources. Reaching more

stakeholders can be done through a variety of means, such as improving communication methods, outreach, and agency-to-agency collaborations. EAM represents a more holistic approach to management and, consequently, a more holistic group of stakeholders should be identified.

An ecosystem approach to management should also seek to account for the effects of environmental variation on fish stocks and fisheries. Global climate change is a major concern and understanding environmental effects will become increasingly important. Emphasis should be maintained on understanding mechanisms underlying apparent correlations between environmental conditions and fish stock productivity as well as anthropogenic effects. Environmental variation is inherently difficult to predict, but increased monitoring and models will help to improve the understanding of environmental effects. Incorporating this knowledge into EAM will not reduce the need for conventional stock assessments, however, because future improvements will need to be built on a solid single-species foundation.

These recommendations will help guide NMFS as it strives to improve management policies. The waters within U.S. Government jurisdiction are home to valuable living resources that must be protected and conserved. These resources provide substantial economic, social, and cultural benefits. Currently, many of these resources are harvested at high levels, which necessitates conscientious management decisions.

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