INTRODUCTION

Session 2
Advancing Ecosystem-Based Decision-Making

TOPIC 1 ASSESSING ECOSYSTEM EFFECTS AND ADAPTING TO CLIMATE CHANGE

TOPIC 2 FORAGE FISH MANAGEMENT

TOPIC 3 INTEGRATING HABITAT CONSIDERATIONS

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Fisheries affect, and are affected by, an ever-changing ocean ecosystem; and decision-makers must consider the relationships between managed species and their environment when setting policy and developing management strategies. Despite general acknowledgment of the concept and relevance of ecosystem-based management, the investment of hundreds of millions of dollars over the past decade, and notable progress in many arenas, agreement over exactly how to implement ecosystem-based management principles remains elusive. However, there is a strong agreement that more active consideration of ecosystem effects will advance the sophistication of fishery management decision-making, and thus the sustainability of fisheries and their attendant benefits to the nation.

Just as ecosystems are a whole comprised of many interacting parts, an exploration of ecosystem-based management should begin with an examination of its parts. This session addressed three of many possible topics that might be most effectively woven into the fabric of ecosystem-based fisheries management. The first topic focused on an emerging adaptive management tool, the Integrated Ecosystem Assessment (IEA), which is designed to help fishery managers recognize, understand, and respond to ocean ecosystem changes. While this tool is presented in the context of dealing with climate change adaptation, it applies to all three focus topics. The second focus topic covered the role of forage fish and directed forage fisheries in the ecosystem. The third focus topic discussed the integration of healthy habitat as an essential component of successful fishery management.

The three focus topics proved to be interrelated, with discussions of the other focus topics emerging naturally in each session. The climate change discussion recognized that the influence of changing water temperature, currents and chemistry affect the productivity and distribution of forage fish and habitat. The forage discussion raised the question of protecting habitat as a way to increase forage fish populations instead of simply focusing on reductions in catch. These are just a few examples of the intersections between discussions.

Many cross-cutting themes emerged from the discussions of climate, forage, and habitat. These common findings link the focus topics and provide overarching insight into ecosystem-based decision-making.

Consider a Broad Range of Ecosystem Processes

Fish populations influence and are influenced by their surrounding environment and ecosystem. Scientists and managers must shift from the single-species approach to consider a broad range of ecosystem processes and effects of harvesting fish species.

Evaluate Ecosystem Productivity Change

Fisheries managers must consider the productivity of our nation's fisheries and how that productivity is changing. Climate change is impacting fish populations, their productivity and distribution, and therefore impacting fisheries and fishing communities. Scientists should consider ways to incorporate this change into evaluations and stock assessments, while managers should include considerations of changing productivity in the decision-making process.

Evaluate the Effectiveness and Utility of Closed and Fixed Areas

The topic of fixed and closed areas arose in each of the three focus topics, both in terms of evaluating existing area-based protections as well as looking at the expanded use of this management tool. As the climate changes, scientists and managers need to think about the effectiveness of static closed areas amid changing ocean conditions and species distributions, as well as the value of closures for maintaining wider age structure to reduce vulnerability of certain stocks. Finally, many areas of the ocean have been protected for habitat, and scientists and managers should evaluate the efficacy of those closures as ocean conditions change.

Engage Across Disciplines and Increase Coordination

Ecosystem-based decision-making demands integration across disciplines, including ecology, biology, physical oceanography, climate science, economics, and social science. Fisheries management must find ways to break down the barriers between these disciplines. Similarly, ecosystem-based decision-making requires enhanced coordination across jurisdictions and between agencies. Participants noted the need to increase coordination between National Marine Fisheries Service (NMFS), Councils, states, science centers, stakeholders, and other Federal agencies, as well as internationally.

Leverage Opportunities for Industry Collaboration

All three of the focus topics touched on the need to increase the use of information generated by the fishing industry in response to a changing environment. In the climate session, participants suggested that a lack of flexibility in the Federal rule-making process may lead to a shift in roles of the Councils and industry. Industry may be called upon to develop and implement measures to meet management goals and performance criteria set by Councils. Additionally, industry may be able to help understand emerging trends and collect data to leverage limited resources. In some forage fisheries, fishermen want access to higher catches during years of high abundance. Industry-supported real-time data collection and dissemination may allow more precise and more adaptive management that would allow higher catches while ensuring the sustainability of the forage stocks. Finally, industry could expand data collection efforts to identify and classify habitat. Allowing greater flexibility for adaptation by fishers may require changes in management frameworks and will place a premium on sharing industry-provided data to evaluate the effectiveness of such strategies. In a time of budget constraints, a robust industry role in cooperative research may allow management to continue or expand research needs under limited resources.

Build Capacity to Advance Ecosystem-Based Decision-Making

Participants recognized the need to invest in ecosystem-based management. New tools and scientific models will be needed to continue advancements in our understanding and management capabilities. Analysts will be need training in applying the new models and integrating data across disciplines. Existing staff must be trained on the new capabilities and appropriate application of the new information emerging on ecosystem-based decision-making.

Participants recognized the need to integrate multi-species and ecosystem considerations into the decision-making process. Some Regional Fishery Management Councils have established Ecosystem Scientific and Statistical Committees (SSCs) or similar advisory bodies that have the expertise and mandate to evaluate ecosystem considerations and provide management advice. An Ecosystem SSC represents a forum to engage scientists across disciplines and jurisdictions to evaluate new ecosystem science and inform management.

Identify and Overcome Impediments to Ecosystem-Based Management

The transition to ecosystem-based decision-making is underway in the U.S., and in some regions and for some fisheries the implementation of ecosystem-based management is already advanced. Participants suggested that a next step for transitioning from single-species to ecosystem-based management is to learn from these examples by identifying and overcoming impediments.

Session 2 Topic 1

Assessing Ecosystem Effects and Integrating Climate Change

The relationships between marine resources and their habitat, fisheries, other ocean uses, and the ocean environment are characterized by change. In an ever-changing system, fisheries managers must continuously improve their understanding of the marine ecosystem and integrate current information in their decision-making. The deeper our understanding and the more developed our analytical tools, the better we are prepared to recognize ecosystem changes and adapt our management of fisheries resources in response. There is currently a great need to assess ecosystem change if sustainable fishery management is to be advanced to the next level, including the need for management systems to be able to adapt to climate-based changes in the ecosystem as they occur.

National Marine Fisheries Service is developing an adaptive analytical tool, known as an Integrated Ecosystem Assessment (IEA), which provides information about ecosystem relationships and interactions for use in fishery management decision-making (NOAA 2008). The IEA approach is a decision-support system that uses data and ecosystem models to forecast future conditions; evaluates alternative management scenarios; and assesses economic and ecological tradeoffs to guide decisions, implement, and evaluate management actions relative to objectives. IEAs hold significant promise. For example, an IEA for the California Current ecosystem could describe the effects of fishing Pacific anchovy on salmon stocks or marine mammal populations, and consequent effects on humans (NMFS 2011). Notably, the FY2013 President's requested budget proposed a significant investment for additional IEA development.[1] However, questions remain about how IEAs might be integrated in the Regional Fishery Management Council process.

While there is debate about the causes and parameters of climate change, no one claims ecosystems to be absolutely

1 Fiscal Year 2013 President's Request Budget, NMFS budget presentation and comparison to FY 2012. http://tinyurl.com/bafmvhy

stable. Climate-based ecosystem change has the potential to affect fish stock distribution, population size, productivity, and fishery yield. Informative and predictive indicators of natural variability, combined with an understanding of their effects on fish stocks, could improve fishery management and minimize harvest as a contributor to stock declines. With modern oceanographic observing systems, changes in parameters such as sea temperatures, ocean chemistry, and sea levels can be identified and measured; current data processing technology also allows for enormous amounts of information to be available for analysis. However, it is not clear what information fishery managers need to improve decision-making, or how they can best adapt regulatory approaches when presented with specific information about ecosystem change.

Discussion under this focus topic allowed participants to examine the emerging IEA analytical tool and consider findings about its application in fishery management decision-making. Participants also discussed climate-based ecosystem changes, the current status of scientific information available for use, ways to integrate large volumes of scientific data and projections into the management process, and uses of the IEA tool as it applies to the forage fish and habitat focus topics within this session.

Trigger Questions

1. What are IEAs capable of doing to enhance fishery management decision-making towards improved sustainability?
2. How could IEAs be integrated into the Council process?
3. How can fisheries management prepare and adapt to shifts associated with climate change, including distribution shifts of fish stocks across Council and international boundaries and changes in fish stock productivity?
4. What are successful examples of the utilization of climate information in decision-making processes, and what is necessary for wider application of these successful approaches?

Session 2 Topic 2

Forage Fish Management

Forage fish clearly play an important role in marine ecosystems. Scientists generally agree on the basic characteristics that define forage species: they are small in size, comprise a considerable portion of total ecosystem biomass, are found in the diet of other predators throughout their lifespan, mature early and have high inherent productivity potential, exhibit schooling behavior and can show high variation in inter-annual recruitment. Forage fish are an important linkage of energy and biomass between primary production and higher trophic levels. They are also the target of valuable and regionally important directed fisheries. As ecosystem-based management concepts have evolved in recent years, there has been a growing public focus on proper management of forage fish.

The competing interests of stakeholders result in widely diverging perspectives among environmental groups, recreational anglers, and those involved in the commercial fishing industry on what proper forage fish management means. Forage fish have traditionally represented an important resource for commercial fisheries, both for direct consumption and for the production of bait, fishmeal, and other valuable products. Many recreational anglers view forage fish as a food source for larger game species, arguing for greater protection of forage species to ensure more large fish to improve the angling experience. Some environmental groups believe that current forage fish fisheries, and the chance that these fisheries could expand, create a high risk of undesirable ecosystem effects.

Forage fishery conflicts have emerged on both coasts. On the East Coast, NMFS is considering a petition to list river herring under the Endangered Species Act as environmentalists fear that incidental bycatch is contributing to declining populations. Also on the East Coast, anglers and environmental groups argue that localized depletion of menhaden by large factory trawlers limits food available to predatory fish populations such as recreationally-important striped bass, sea birds, and marine mammals. Menhaden is the second largest fishery in the United States by volume and its products are used for aquaculture, livestock, and health supplements. Commercial fishermen argue that the removals are so small compared to the overall population biomass that they cannot cause a significant ecological impact, and note that it is ecologically safer to fish lower on the food chain than for predatory fish at higher trophic levels.

On the Pacific coast, some environmental groups worry that fishing levels for sardines do not adequately account for forage needs within the ecosystem. At the same time, there are those in the fishing industry who feel that ecosystem "set-asides" and low fishing rates represent more than sufficient protection. The many questions posed in various Council arenas around these complex considerations illustrate the importance of forage fishery conflicts.

In addition to concerns about existing fisheries, there are concerns about developing new fisheries for forage species. There are fears that the rising demand for aquaculture or terrestrial animal feed, or other markets, may result in initiation of new fisheries for species low on the food chain. There has been some action in this regard, such as the Pacific Council ban on krill fishing and consideration of additional forage species protections, and the North Pacific Council's Arctic Fishery Management Plan bans harvesting a variety of unfished species in the arctic area. Currently, regulations at 50 CFR § 600.747 define a process for Councils to consider new fisheries, but these regulations have not been updated for several decades and may not have sufficient flexibility for regionally-specific application.

All of these uses and interests require careful consideration of forage fish management options, as management policies and goals are ultimately a reflection of the values placed on forage fish populations and their predators.

Trigger Questions

1. Do current characteristics of forage fish warrant a departure from the current management approaches, characterized by some as a traditional single-species approach?
2. Where on the trophic scale should we be harvesting and managing species? As societal targets change, is there a need to redefine optimum yield and what the Councils should be managing for?
3. Are current fishing rates for forage fish too high in U.S. fisheries?
4. How should management reconcile ecosystem services valuation and the economic value of forage fisheries? What are some of the tradeoffs?
5. How do inter-jurisdictional, including international situations, factors influence the protection and recovery of forage fish stock?
6. Are legislative changes necessary for Councils to best leverage their management objectives in the international processes (e.g. co-managed stocks, incidental catch)?
7. Do Councils have the flexibility to address emerging forage issues under the current law and regulations? Are MSA Section 305 and Administrative Rules § 600.747 obsolete?

Session 2 Topic 3

Integrating Habitat Considerations: Opportunities and Impediments

In 1996 when the Fishery Conservation and Management Act of 1976 was amended as the Sustainable Fisheries Act (also known as the MSA), the requirements for habitat conservation as a component of managing ocean fisheries were widely considered as one of the major accomplishments of the new legislation. In 2006, the MSA was reauthorized and further amended to include deep sea coral protection and research provisions in recognition of the special contribution deep corals play in ocean ecosystems. Councils and NMFS have made great strides to conserve important habitats since 1996. Councils have designated "essential fish habitat" for more than 1,000 managed species and have designated over 100 Habitat Areas of Particular Concern; review and update of these essential fish habitat designations occurs on a routine, periodic basis. Since 2004, NMFS and the Councils have protected over 700 million acres of ocean habitat essential to marine fisheries from damaging fishing practices, and NMFS conducts thousands of consultations with other Federal agencies on non-fishing impacts to habitat.

Despite the volume of important habitat conservation activity over the past two decades, there is a general consensus that additional habitat protection is necessary. Some fish stocks continue to show signs of distress even after substantial reductions in fishing intensity; and for some of these stocks, this distress may be due to a shortage of healthy habitat. As fishing is only one impact on habitats, Councils need to collaborate with non-fishing ocean users to protect and conserve important fish habitat. One impediment is a lack of shared understanding about how best and where to focus conservation efforts for the benefit of fisheries and ecosystems; without this focus, it can be very difficult for NMFS and the Councils to convince other ocean users to reduce their impacts on habitats. Without a stated habitat conservation objective, it also becomes challenging for the Councils to frame the value of their own habitat conservation efforts to minimize fishing impacts on the ecosystem. Some of these impediments are exacerbated by a shortage of habitat science and information. One might also question whether all of the necessary habitat policy and management pieces are in place within the MSA mandates and guidance.

These challenges and impediments are reflected in the NOAA Habitat Blueprint, a strategy to better align NOAA's habitat-related programs, use habitat as a fisheries tool more prominently within NOAA, and demonstrate the impact and value of these programs. The National Ocean Policy also highlights, among other things, the opportunities and challenges that fisheries managers face in protecting fish habitat from non-fishing ocean uses. Additionally, there is debate about whether artificial habitat structures, such as off-shore gas and oil platforms, represent an opportunity or an impediment to habitat protection for sustainable fishery management.

This session explored regulatory and legislative measures to improve integration of habitat considerations into fishery management, through examining real-world examples. The discussion included how Councils might better engage and consult on the permitting of non-fishing ocean uses that impact fisheries habitat.

Trigger Questions

1. How effective are current consultations regarding non-fishing habitat impacts, and how can they be improved?
2. How can regulatory and legislative provisions support Council engagement in non-fishing ocean uses and minimize impacts on fisheries and habitat?
3. Is there a need for National Standards on habitat quality, productivity, or allowable degradation? Should a maximum sustainable yield-equivalent standard be established for habitat "removal"?
4. What is the proper role of non-natural habitat structures, such as off-shore petroleum platforms and artificial reefs, in optimizing habitat for sustainable fisheries?
5. Should habitat protection and improvements have a designated role in fish rebuilding programs? If so, what are meaningful alternatives?

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MANGROVE ROOTS PROVIDE HABITAT FOR NUMEROUS MARINE ANIMALS. HAWAII. PHOTO: CLAIRE FACKLER, CINMS, NOAA

PAPERS

Session 2
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Topic 1
Assessing Ecosystem Effects and Adapting to Climate Change

IMPLICATIONS OF CHANGING ECOSYSTEMS FOR FISHERY MANAGERS: CORA CAMPBELL

ASSESSMENT AND MAINTENANCE OF ECOSYSTEM HEALTH IN THE FACE OF A CHANGING CLIMATE: PHILLIP S. LEVIN

EFFECTS OF CLIMATE VELOCITY ON FISH AND FISHERIES: MALIN PINSKY

Implications of Changing Ecosystems for Fishery Managers

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Abstract

Changing ecosystems are increasingly recognized as a driver in fishery trends and considered by policy makers in annual and long-term management decisions. Regional Fishery Management Councils and fishery scientists have made strides in developing methods for incorporating climate change information into stock assessments and decision documents, but comprehensive strategies for giving climate related issues full consideration remain to be developed. The actions taken thus far by managers in the North Pacific to respond to changing climate trends, both through long-term management actions and incorporation of ecosystem information into annual decision-making, can serve as a basis for discussion of similar action in other regions. In particular, attention should be paid to responsible management of rapidly changing eco-regions, the challenges a changing ecosystem poses to designing catch share programs and protections for vulnerable species or habitat, recent trends in climate related Endangered Species Act listings, and the value of long-term planning for climate change.

Discussion

Recent Climate Trends

Although many states are facing implications from a changing climate, Alaska is often described as being on the front lines of climate change. The Arctic climate is changing more rapidly than any other region of the United States, and the changing ecosystem is driving coastal erosion, increased storm activity, loss of seasonal sea ice cover, and dramatically increased interest in Arctic access and development by many nations. Open waters for several months in the summer have led to increased vessel activity in the area; commercial, recreational, and research vessels are all transiting an area with no port of refuge, no permanent Coast Guard base, and limited assets for either search and rescue or environmental mitigation should an incident occur. Much of coastal Western Alaska and the Arctic lack sufficient baseline data and infrastructure to adequately address these challenges, and not nearly enough is known about current conditions or what the future holds for this vast, remote area.

The State of Alaska has consistently recommended increased investment in the Arctic region in the form of additional ice breaking capability, greater Coast Guard resources, development of ports and harbors, adequate mapping, and increased research on both baseline environmental conditions and fish and wildlife in the area. Among the many priorities for an open Arctic, the State of Alaska and Federal managers have been carefully considering potential impacts on fish stocks that may currently, or in the future, be found in Arctic waters. Given the incomplete information on the complex interactions among ecosystem components, the state has been strongly supportive of research efforts to guide future development.

Currently, university, Federal and state scientists are collaborating to gather baseline data on all major components of the marine ecosystem through the first comprehensive oceanographic and fisheries survey of its kind in the Arctic. This ongoing project spans three years and will provide a comprehensive assessment of the northeastern Bering Sea and Chukchi Sea ecosystems, from the physical environment, through the primary and secondary producers that support Arctic marine food webs, to the numerous fish species utilizing the area. The study will provide an unprecedented baseline for understanding Arctic marine and coastal communities and for assessing the potential effects of future development and climate changes on fisheries resources and the marine environment in the region.[1]

Precautionary Management for a Changing Climate

In the North Pacific Ocean, an ecosystem-based fishery management approach has been adopted for managing Alaska groundfish fisheries by the North Pacific Fishery Management Council (Council). The stated management policy is to apply judicious and responsible fisheries management practices, based on sound scientific research and analysis, proactively rather than reactively, to ensure the sustainability of fishery resources and associated ecosystems for the benefit of future, as well as current, generations (Heltzel et al. 2011). This policy has been implemented through a variety of measures to achieve specified goals, but one of the best examples is the Council's management action in the Arctic.

The Council was early to recognize that a changing Arctic, if left unregulated, had the potential to allow exploratory fishing and commercial exploitation of stocks about which very little is known. In 2009, the Council adopted and the Secretary of Commerce approved the Arctic Fishery Management Plan (FMP), which took proactive and precautionary action to close U.S. Federal waters of the Arctic Ocean to commercial fishing until such time that sufficient data has been accumulated to allow for responsible management and exploitation of fish stocks in the area. This management policy directly recognizes the need to balance competing uses of marine resources and different social and economic goals for sustainable fishery management, the complex interactions among ecosystem components, and the need to base future management measures on the best scientific information available (NPFMC 2009).

The protection of the Arctic FMP, however, stretches only out to 200 miles. Beyond are international waters that are outside the exclusive economic zone (EEZ) of any Arctic nation. It is likely that Arctic stocks straddle the boundary between the U.S. EEZ and the "donut hole" that is currently unregulated. The precautionary approach taken in U.S. Arctic waters should be extended through treaty negotiations to international waters, similar to the treaty that protects international waters, and the stocks therein, in the Bering Sea and provides a mechanism for international cooperation on research, enforcement, and management actions.[2] In addition, the U.S. should use diplomatic measures to encourage other Arctic nations to take a similar approach within their own EEZs, thereby guaranteeing continued protection for transboundary stocks.

In 2008, at the recommendation of the Council, the Northern Bering Sea Research Area (NBSRA) was established, prohibiting bottom trawling in the northern part of the Bering Sea. It was part of a larger package of precautionary Bering Sea habitat conservation measures recommended by the Council in 2007 that included freezing the footprint of bottom trawling in the Bering Sea, with the understanding that the ranges of specific fish species may be shifting northward due to changing climate and ocean temperatures. The measures prohibit bottom trawling in the deep slope and basin area as well as shelf waters north of St. Matthew Island, over 132,000 nm^2 overall (NOAA AFSC 2012a).

In setting aside the NBSRA, the Council's goal was to allow development of a research plan that would provide information on the impacts of bottom trawling and catalog sub-areas that may be of interest for future fisheries by learning more about stock distribution and benthic habitats within the area. The closure identifies areas that will remain closed to bottom trawling regardless of research design or outcomes, in order to protect crab habitat and

1 State of Alaska Coastal Impact Assistance Program, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, Arctic Ecosystem Integrated Survey project description, Dr. Franz Meuter.

2 Convention on the Conservation and Management of Pollock Resources in the Central Bering Sea, June 16, 1994.

subsistence fishing and hunting in the area.

By freezing the footprint of the fleet to areas previously subject to bottom trawling, the Council has considerably constrained the ability of the fleet to react to changing patterns in fish distributions or reductions in sea ice without substantial further research into the effects of bottom trawling on previously untrawled areas and the distribution of fish stocks and marine mammals in this region.

There is high uncertainty in predicting ecosystem trends, and the potential changes in fish stock distributions and biomass that may result. The Arctic and Northern Bering Sea present one type of management challenge, where previously unexploited stocks and areas were thought likely to become available to and sought after by an existing, highly capable fleet of vessels due to an ecosystem that is changing very rapidly. This approach represents a tradeoff between allowing for continuation or expansion of commercial fisheries in a changing climate and a more precautionary approach that favors conservation measures in the face of uncertainty and requires a significant investment in new research before allowing fishery expansion.

Adaptive Management for a Changing Climate

In other scenarios, potential shifts in fish stocks, fishing areas, and ecosystems are more gradual, or affect stocks that already support established fisheries. In these cases, a blanket moratorium or establishment of extensive closures to allow for increased research and data gathering would likely not be considered a responsible or desirable response to climate change. Therefore, consideration of other methods is necessary.

In many areas, Regional Fishery Management Councils have relied on a system of fixed closure areas to protect important habitat and core distributions of sensitive species. As a changing climate influences stock health and distribution and fleet behavior, these fixed closures can diminish in effectiveness and must either be constantly reexamined or replaced with a more flexible system of protection.

In the North Pacific, both the Council and the Alaska Board of Fisheries have relied heavily on fixed area closures to provide additional protections to areas thought to be especially important or vulnerable. In total, more than 665,000 square nautical miles off Alaska are closed to some or all fishing.[3] However, fixed area closures may or may not continue to be appropriate in changing conditions, depending on the species or habitat being protected. For example, fixed area closures to protect salmon in the Bering Sea have been limited in their effectiveness over time, given the annual variability of salmon distribution.

In order to facilitate moving toward a more adaptive management approach for crab, National Marine Fisheries Service (NMFS) scientists are researching how oceanographic currents and the extent of the Bering Sea cold pool affect distribution of female red king crab and therefore location of larval release. As this research progresses, the North Pacific Council is monitoring the results to evaluate whether the existing crab protection closure areas effectively protect the stock in all temperature regimes. Although there is interest in development of adaptive management triggers tied to environmental variables, further work is needed to determine how such a trigger might be incorporated into NMFS' regulatory framework.

As conditions continue to change, it is likely that other fixed area closures may need reevaluation and modification to remain centered on core areas of stock distribution. For salmon, the North Pacific Council allows for a "rolling hot-spot" system of short-term, flexible closures that respond to bycatch rates over a given period of time. This type of flexible closure system, although effective, may challenge the ability of the Federal regulatory system to be responsive within a season or fishing year, and managers may need to consider implementation through industry agreements, with the Council's role shifting to evaluation of effectiveness and requiring accountability.

Harvest limits on prohibited species that are not indexed to population abundance may also need to be reevaluated

3 NMFS GIS data, 2012.

as ecosystem conditions change, and if possible, be established at a level that is appropriate for the current distribution and abundance of the stock. Rapidly changing conditions challenge the slow-moving and deliberative Federal regulatory process, and flexibility is needed to respond to newly available scientific information about species distribution, abundance, and reaction to climatic variables.

Designing Flexible Management Systems

Climate change, although currently the topic of much discussion, is not a new phenomenon. The climate has been changing throughout recorded history and will continue to change in the future. In the past, when fish stocks shifted across areas or when one stock became more abundant and another declined, the reaction of the industry varied. In general, when markets, economics, and regulations allowed, the fleet often either moved to a new area or learned to exploit more abundant species, allowing the fleet and fishery dependent communities to continue to thrive.

For example, the community of Kodiak once relied heavily on a red king crab fishery in the Central Gulf of Alaska that supported a local fleet of crabbers. In the early 1970s crab stocks declined in abundance. The reasons for the decline are not fully understood, but it is thought that one of the primary drivers was a regime shift in the North Pacific Ocean that resulted in more favorable conditions for groundfish and less favorable conditions for shellfish. In response, many in the Kodiak crab fleet either shifted efforts to participate in Bering Sea fisheries, which remained relatively abundant, or shifted to participating in local groundfish fisheries. By adapting to changing conditions, much of the fleet was able to survive in the face of a changing climate regime.

In that era, entry requirements were rare and investment in a vessel and gear was often all that was required for a fisherman to move to a new area or target a new species. In a similar scenario today, the displaced fleet would see significantly increased costs of entry into both the Bering Sea groundfish and crab fisheries and the groundfish fisheries in the Gulf of Alaska, as a result of license limitation and catch share programs that, while valuable in meeting certain objectives, have significantly reduced the fleets' flexibility to adapt to changing conditions.

Since the advent of limited entry in Alaska's state managed fisheries in the 1970s and various catch share programs in Federal fisheries beginning in the 1990s, entry into new areas and fisheries has become significantly more expensive. Other regions have also developed and implemented catch share programs. To change one's fishing operation may require purchase of a permit or catch share privilege, which many times is specific to one species and area. Despite these limitations, it is likely that catch share programs will continue to be considered for their potential benefits to stability, bycatch reduction, conservation, management, and safety.

The halibut and sablefish individual fishing quota (IFQ) program in the North Pacific is a good example of a catch share program which provides many economic and conservation benefits, but has limited the ability of the fleet to respond to changing conditions. In 1995, this program awarded fishermen the privilege of catching a certain share of the quota in one of the International Pacific Halibut Commission regulatory areas off Alaska. The structure of the program is fairly rigid, not only in specifying the area to be fished, but also in designating quota by vessel size and dividing it into blocks to limit consolidation (Fina 2011). The program allowed for delivery of halibut throughout much of the year, slowing processing and allowing for additional fresh shipments and improved product forms. The result has been a substantial increase in the price paid to harvesters and a related increase in the price of catch shares for these fisheries (NPFMC 2010).

When the International Pacific Halibut Commission shifted from a closed area assessment to a coastwide assessment of halibut biomass, the percentage of harvest allocated to each regulatory area shifted substantially. This shift coincided with decreased estimates of exploitable biomass partially driven by observations of reduced size at age in the halibut stock, a phenomenon thought to be related to changing environmental conditions.

As quotas shift and decline, fishermen who once would have had little investment beyond a vessel and gear now find themselves with hundreds of thousands of dollars invested in catch shares that represent far fewer pounds of harvest than in previous years. They are unable to move among areas in the Gulf to respond to changes in distribution without engaging in a complex purchase and sale of quota share.

As Councils consider future catch share programs, consideration should be given to possible future impacts of climate change. Flexible program design that will reduce the cost of entry and allow the fleet to adapt to climate-driven changes in the ecosystem should be a paramount consideration. The benefits of programs that significantly increase the cost of entry and limit fishermen to a single species and area must be weighed against the likelihood that such a program will continue to be beneficial in the future if ecosystem factors change significantly. Similar consideration should be given when other management measures are designed, such as prohibited species catch reduction programs, and Councils should realize that frequent reexamination of such programs may be required to respond to changing environmental conditions.

Incorporating Climate Data into Management Decisions

Given the current attention to a changing climate and the development of a more advanced understanding of the interactions between climate and stock health, managers are faced with the challenge of how best to incorporate uncertainty related to future climate variables into today's actions. For example, in the North Pacific, significant research has been done on the relationship of productivity of certain species with ocean temperature, and stock assessment scientists incorporate environmental information into annual stock assessment and fishery evaluation documents, which are used to establish allowable catches.

In the North Pacific pollock fishery, much thought has been given to how a reduction in sea ice and a corresponding increase in ocean temperature might affect the spatial distribution of the pollock stock. The pollock fishery is one of the world's largest, and the stock straddles the international boundary between Alaska and Russia. Concern that changing conditions would shift more of the stock into Russian waters led to initial research that revealed the cold pool in the Bering Sea in some years limits the Northwestward movement of the stock. In 2012 however, stock movement appeared to be less inhibited by the existence of the cold pool (NOAA ASFSC 2012b).

Fishery managers carefully consider these dynamics when setting annual catch allowances, but have not yet had to reduce pollock catches in the U.S. fishery as a result of stock movement. Careful monitoring continues, and managers will need to react if stock distribution shows a notable change that could increase the vulnerability of the stock to exploitation in Russian fisheries.

The mechanisms for coordination and cooperation in management of transboundary stocks will be tested as climate change continues to drive changes in species abundance and distribution across jurisdictional lines. Attention should be paid to mechanisms for cooperation between state managers, between state and Federal managers, and between neighboring nations to ensure that assessment programs are coordinated and harvest levels are appropriate as stocks shift.

In both the North Pacific and other jurisdictions, efforts have been made to develop stand alone ecosystem plans or assessments. Although these are useful as reference documents and for long-term strategy and coordination, they are somewhat removed from the day-to-day actions of fishery managers, and further effort is needed to fully incorporate ecosystem and climate change information into decision-making documents rather than stand alone documents.

Within the decision-making process, managers should be careful not to unnecessarily forego available sustained yield opportunities in the short term based solely on precautionary principles. For some species, impacts from climate change are distant and in the proximate timeframe the species are expected to remain abundant and robust. Allowing harvest opportunities in the short term provides essential economic benefits to fishermen and local communities that should not be foregone unless sacrificing short term yield will benefit the long-term viability of the stock.

Climate Change and the Endangered Species Act

The section above discusses how climate science and environmental variability are incorporated into stock assessment to allow for continued responsible management. However, some stakeholders are pushing for an approach to future uncertainty that would have far greater impacts on fishery managers' ability to optimize yield and on fishery dependent communities' ability to thrive. For example, in the North Pacific, the National Marine Fisheries Service recently received a petition to list 44 species of corals under the Endangered Species Act (ESA). Unlike most traditional ESA listings, the petition does not allege that the coral species are unhealthy, or point to a trend of decline. Instead, the petition points to possible future impacts of climate change and ocean acidification as a justification to list the species now and provide additional protections (Center for Biological Diversity 2012).

Surely, it was never the intent of the ESA to be used to protect a healthy and abundant species that might face a threat in the distant future. If so, the other management frameworks that are intended to apply to most known species would have no place. However, the coral petition is not a new approach to ESA listings in Alaska. Already, the stable and healthy polar bear population has been listed as threatened based solely on untested models of future sea ice loss, despite evidence that the species has survived prior warming periods.[4] And last December, NMFS announced their intention to list ringed and bearded seals, which have populations that number in the millions and hundreds of thousands, respectively, based solely on speculation about future sea ice loss and despite the fact that the agency itself acknowledges there is no immediate threat to these abundant animals.[5]

Given precedents such as these, it is questionable which species would not qualify for an ESA listing. If indeed a healthy population, in some cases numbering in the millions of animals, is subject to listing without any evidence of a declining trend, what role remains for fishery managers, fishery Councils, and state fish and wildlife agencies in determining appropriate protections for species under their traditional authorities?

The Magnuson-Stevens Fishery Conservation and Management Act and the very constitution of the State of Alaska require that species be managed for sustained yield and that appropriate protections be provided. In the North Pacific, the Council and the State of Alaska have mechanisms in place to protect species and manage in a precautionary fashion using the best scientific information available, but these traditional management authorities will be irreversibly eroded if Federal agencies continue to use speculative future impacts from climate change as a justification to bring healthy and abundant species under the daunting and burdensome umbrella of the ESA.

Federal agencies should instead respond to such concerns with detailed and rigorous plans for both individual species and ecosystem monitoring, and research to ensure early detection of any real world change to the health of the species. Planning processes could be put in place to ensure that more precautionary measures are readily available should they become necessary. Avoiding this potentially more challenging task and instead moving directly to burdensome regulatory requirements will only serve to remove management authority from existing bodies with the necessary expertise; it is a mistake with grave implications for the future of fisheries in a changing climate.

Alaska Department of Fish and Game Strategy

In 2010, the Alaska Department of Fish and Game adopted a strategy for responding to climate change and its impacts on fish and wildlife species under our jurisdiction (ADFG 2010). The strategy includes identified expected climate impacts to fish and wildlife and their uses across Alaska, focusing on those impacts that are expected to occur within the next 20-25 years. Identified key impacts include altered hydrologic conditions; altered sea ice conditions; ocean acidification; changing species distributions, abundances, and phenologies; invasive species; impacts on existing harvest opportunities; impacts on existing regulatory structures; and impacts of development of "clean" energy alternatives. For each identified key impact, key strategies were identified to address the impacts.

4 73 FR 28212, May 15, 2008. http://tinyurl.com/6hjjda

5 NOAA Fisheries Alaska Regional Office, Endangered Species Act Listings for Bearded and Ringed Seals, (website), http://tinyurl.com/mdtzmcw.

The strategy also identified research as a key element towards understanding and predicting impacts and assessing strategy implementation. Identified areas of needed research include improved downscaled (local) climate models, need for research and monitoring to define the baseline, improved baseline mapping, improved research infrastructure, improved data integration and sharing, need for adaptable legal and policy frameworks, and education and outreach. Finally the strategy identifies management principles, key strategies, and key initial actions.

Key strategies the department is now implementing include filling information gaps related to climate change on Alaska fish and wildlife populations, working with the University of Alaska to develop scaled down climate change scenarios, and establishing partnerships with other agencies evaluating climate change impacts.

Other resource agencies and governments have undergone similar planning processes and developed strategies and recommendations for responding to climate change. Further planning of this type is recommended to embrace the reality of climate changes, identify reasonably foreseeable impacts, and prioritize research that will assist in identifying and responding to changing conditions.

Conclusions

Throughout this paper, it has been noted that the most pressing need to effectively respond to a changing climate is better information for managers. Recommendations include infrastructure and research in the Arctic, increased research into interactions between climate variables and fishery stocks, and research and planning for protection of species that are the target of ESA petitions. However, concern exists that the current Federal fiscal climate is a barrier to implementation of these recommendations. Our Federal managers struggle to maintain funding for core stock assessment work, even as dollars are expended on new initiatives such as aquaculture development or national oceans policy. In order to equip managers with the information needed to respond responsibly to the threats and opportunities brought about by a changing climate, it is paramount that the appropriators fully understand the resource needs of Federal agencies and that the agencies themselves are disciplined in allocating funding to core responsibilities and research priorities rather than funding new initiatives that do not address these pressing needs.

Recommendations

- Additional investment in the Arctic, particularly for additional fishery research and stock assessment science and research infrastructure.
- Precautionary management should be extended to the Arctic donut hole and other Arctic nations' EEZs. Generally, precautionary management is a recommended approach when rapidly changing conditions expose new areas or stocks to significant commercial effort.
- Consideration of climate-driven ecosystem changes in designing catch share programs, habitat and species protections, and annual quota setting.
- Increased coordination between jurisdictions to ensure transboundary stocks are adequately managed and protected when distributional shifts occur.
- Do not unnecessarily forego available sustained yield opportunities that provide essential economic benefits to fishermen and local communities in the short term in the absence of evidence that such actions will benefit the stock in the future.
- Consistency in ESA listings based on present stock status and conditions. Potential future climate-driven impacts should be a key focus of research and management but should not serve as criteria for listing.
- Jurisdictions should develop strategies for responding to climate change that identify critical needs and prioritize research and resources.
- Federal agencies must focus on core stock assessment responsibilities in times of reduced Fed-

eral budgets as these services are critical sources of information needed to manage responsibly in a changing ecosystem.

Acknowledgments

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Assessment and Maintenance of Ecosystem Health in the Face of a Changing Climate

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Abstract

Integrated Ecosystem Assessments (IEAs) provide a structured approach to ecosystem evaluation that serves as an integrative complement to single-species and single-sector assessments now applied in resource management. IEAs provide assessments of status and trends of key ecosystem components as well as the environmental, social, and economic causes and consequences of these trends. They forecast the likely status of key ecosystem components under a range of policy and/or management actions, and identify knowledge gaps that will guide future research and data acquisition efforts. In this paper, I highlight how the IEAs can be brought be used to inform fisheries management in an era of rapidly changing climate. Using examples from the U.S. Pacific Coast, I illustrate how ecosystem indicators, risk assessments and scenario analysis can be used to develop fisheries management that is robust to climate change. Importantly, IEAs not only provide information about fisheries, but analyze the full breadth of ocean uses. Thus, they consider sectoral trade-offs that may emerge or be amplified as a consequence of climate change. The challenge for IEAs to inform the multitude of ocean uses against a backdrop global change is great; however, sustainable resource management requires that we bring science to the fore to confront this challenge.

Introduction

The need for a more holistic and integrated approach to management of ocean resources is now widely appreciated, and in recent years, NOAA has been developing scientifically-based ecosystem management strategies by advancing, integrating, and expanding our science to enable an ecosystem-based approach to management (EBM). The objective of EBM is to make management of natural resources more effective. It takes a step beyond traditional management that considers single issues, species, or functions independently, and instead takes into account the richness and complexity of the interactions between them. Additionally, EBM considers the inherent links between human activity and wellbeing and the condition of the ecosystem and its parts. Importantly, rather than replacing existing management structures, and the science that informs that management, EBM builds on these and develops them further. Finally EBM cannot be realized without a solid science core—one that provides an understanding of the ecological systems, including individual components within a system, as well as the social elements.

Implementing EBM requires a framework to assess the status of marine ecosystems in relation to specific management goals and objectives and to evaluate the probable outcomes of alternative management strategies. IEAs are intended to provide just such a framework. IEAs provide a structured approach to ecosystem evaluation that serves as an integrative counterpart to single-species and single-sector assessments now applied in resource management.

The fundamental structural elements of NOAA's IEA framework have been previously described (Levin et al 2008, 2009). Here, we briefly outline NOAA's IEA approach and describe how IEAs can assist fisheries managers as they prepare for ecosystem changes associated with climate change and ocean acidification.

What is an Integrated Ecosystem Assessment?

An IEA is a formal synthesis and quantitative analysis of existing information on relevant natural and socioeconomic factors in relation to specified ecosystem management objectives. It brings together citizens, industry representatives, scientists, and policy makers through established processes to evaluate a range of policy and/or management actions that are relevant to a diversity of environmental objectives.

An IEA results in the following products:

- Identification of key management or policy questions and specification of ecosystem goals and objectives
- Assessments of status and trends of the ecosystem
- Assessments of the environmental, social, and economic causes and consequences of these trends
- Forecasts of likely status of key ecosystem components under a range of policy and/or management actions
- Identification of crucial gaps in the knowledge of the ecosystem that will guide future research and data acquisition efforts.

A Step-Wise Process for Developing an Integrated Ecosystem Assessment

Step 1: Define Ecosystem Goals and Targets

IEAs are driven by clearly defined management objectives; consequently, the IEA approach purposefully begins with the scoping step to clearly identify priority management objectives to be addressed. Scoping the IEA requires that scientists, managers and stakeholders work together to define the broad vision and objectives of the IEA, the spatial scale of the IEA, and the ecosystem components and ecosystem threats that will be included in the effort.

Step 2: Develop Ecosystem Indicators, Reference Levels, and Assess Ecosystem Status

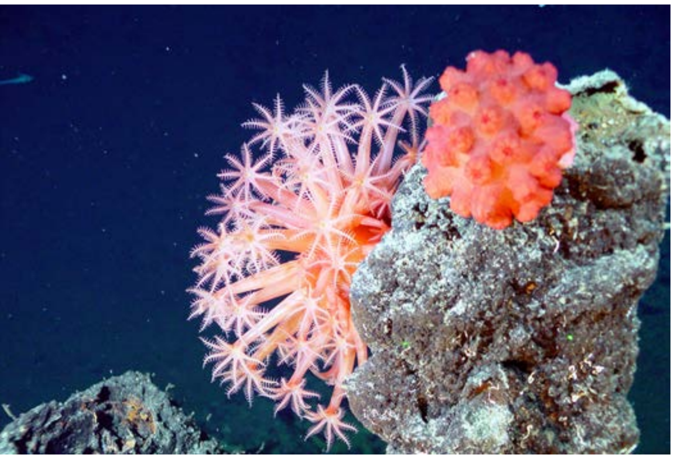
A critical step in the IEA process is to select indicators that capture the key ecosystem states and processes that underlie healthy ecosystems. Effective indicators serve as measures of the many of the ecosystem services that concern policy makers and stakeholders (Link 2005), and are one of the primary contact points between policy and science.

Establishing a set of indicator values that reflect progress towards specific management objectives is critical for successful EBM. Reference levels provide context for evaluating performance and progress towards EBM goals. They can be diverse and include both ecosystem state variables of interest (e.g., habitat area, measures of diversity, etc.) as well as metrics of ecosystem pressures (e.g., shoreline development, nutrient or contaminant input, etc.). These levels can be drawn from the underlying properties of the natural and human systems or they can be designated as part of the process of setting management goals. Establishing a reference level is informed by science, but ultimately reference levels are set to achieve a desired policy outcome.

With ecosystem indicators and reference levels in hand, it is possible to assess the state of the ecosystem. In general, this can be expressed as the value of the indicator relative to a desired future state.

Step 3: Risk Analysis—Impacts of Natural Perturbations and Human Activities on Ecosystem Status

Once ecosystem indicators and reference levels are selected, IEAs evaluate the risk to the indicators posed by human



activities and natural processes. The goal of these risk analyses is to qualitatively or quantitatively determine the probability that an ecosystem indicator will reach or remain in an undesirable state (i.e., breach a reference limit). Risk analysis must explicitly consider the inevitable uncertainties involved in understanding and quantifying ecosystem dynamics and their positive and negative impacts on social systems. An ecosystem risk analysis requires an understanding of the distribution and intensity of land-, air- and sea-based pressures, as well as their impacts on ecosystem components.

Step 4: Evaluation of Management Strategies for Protection or Restoration of Ecosystem Status

The next step in the IEA process uses simulation, analytical or conceptual modeling to evaluate the potential of different management strategies to influence the status of natural and human system indicators, and to achieve our stated ecosystem objectives.

Systematic scenario analysis is increasing being used as an approach to evaluate management options. Scenario analysis generates multiple alternative descriptions of potential outcomes, including processes of change, thresholds and uncertainties (Alcamo 2008). Scenarios explore alternative perspectives about underlying system processes and can illuminate key issues, by using a consistent set of assumptions about the system state to broaden perspectives (Raskin 2005, Refsgaard et al. 2007). They generate alternative, internally consistent, logical descriptions of the future. Scenarios can be qualitative, in which "storylines" are developed, or quantitative, in which the outcomes of numerical models are explored (Refsgaard et al. 2007). Scenarios typically include assessments of the ecosystem state variables and driving forces, descriptions of critical uncertainties, and approaches for resolving them (Swart et al. 2004). One unique attribute of scenarios is that they acknowledge the interdependencies of system components. The advantages of qualitative scenarios include more flexibility to incorporate multiple stakeholder perspectives and greater capacity for creative thinking. Quantitative scenarios can provide geographical and numerical specificity to the concepts provided by qualitative scenarios (Alcamo et al. 2005).

Step 5: Monitoring and Evaluation

Monitoring and evaluation of chosen indicators and management strategies is an integral part of the IEA process. Monitoring and evaluation is necessary to determine whether management strategies improve ecosystem services and sustainability, and quantifies the trade-offs that have occurred since implementation of the management strategy.

At its core, monitoring is straightforward; it is the collection of biotic, abiotic and human dimension data. In the context of IEAs, monitoring is the systematic collection of data to reliably answer clearly articulated management questions (Katz 2013). In the case of IEA indicators, monitoring must directly address the operational objectives developed as part of the scoping process. Successful monitoring depends on developing efficient sampling programs that allow a cost-effective determination of the state of the ecosystem and the effectiveness of management actions. Importantly, monitoring includes not only measurements of the biophysical environment, but also includes social and economic systems.

A status evaluation is focused on giving an interpretation of where an ecosystem component is at a particular time. Impact evaluations are generally one-time assessments frequently performed at the conclusion of a management project is complete. The goal of impact evaluations is to determine how well a particular project performed. Adaptive management is an iterative process that integrates the design of management strategies and monitoring to systematically evaluate management actions, and is obviously related to evaluation. The goal of adaptive management is to learn and then adapt ongoing management. Adaptive management thus can be viewed as a way of "learning by implementing."

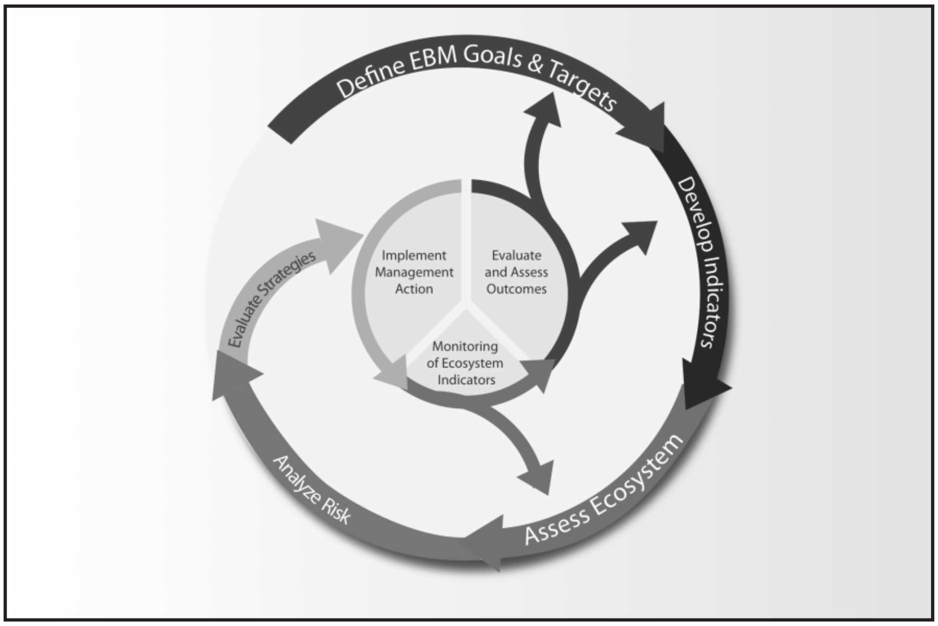


Figure 1. A schematic view of the Integrated Ecosystem Assessment process that begins with scoping the goals and targets of Ecosystem-Based Management, and continues to the development of indicators, an assessment of ecosystem status and risk. It then forecasts likely status of key ecosystem components under a range of policy and/or management strategies.

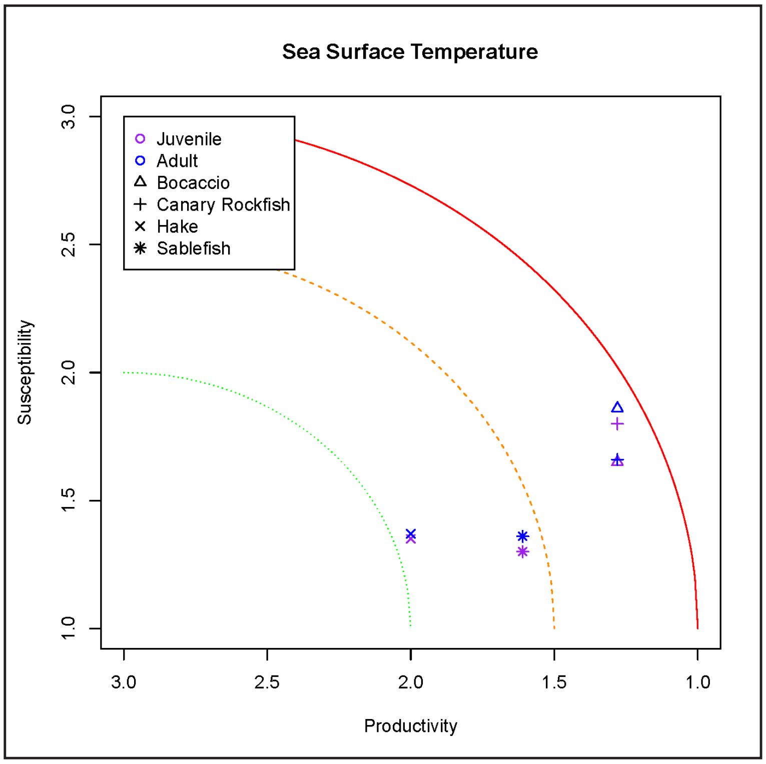


Figure 2. Productivity-susceptibility analysis plot for the eight species/life stages relative to sea surface temperature as a threat. The susceptibility axis represents a relative score among species and stages but not among threats, though values near one indicate little to no impact in all cases. Where the adult and juvenile Susceptibility scores are identical, the symbols are on top of each other and only the adult values are visible. Reprinted from Levin and Wells (2013).

Integrated Ecosystem Assessments, Climate Change, and Ocean Acidification

In the oceans, global warming may lead to a 1.8–4°C (3–6°F) increase in sea surface temperature this century. This may cause northward shifts in species ranges and migration patterns, changes in growth and reproductive rates, and 1–7 percent reductions in the oxygen content of water, particularly in nearshore areas. These hypoxic areas may lead to local die-offs of crabs or other species with limited mobility. Primary production (phytoplankton) may increase, but smaller phytoplankton may be favored, leading to less food availability for large zooplankton (e.g. krill) but more for smaller zooplankton (e.g. copepods).

Increasing fossil fuel emissions and the resulting increase in atmospheric CO_2 levels will likely lead to a decline in seawater pH of 0.3 by the year 2100. Changes to seawater pH and the saturation state of aragonite and calcite (the minerals many organisms use to build protective structures) could lead to reduced populations of marine species including corals, crabs, shellfish, benthic invertebrates, and plankton groups such as krill. There is considerable uncertainty regarding which species will be impacted, and to what extent.

IEAs have the potential to inform fisheries management in the face of a changing environment. Below we provide examples from the California Current IEA to illustrate the way IEAs can inform fisheries management in a changing climate.

Indicators

Low dissolved oxygen concentrations in coastal and shelf waters of the California Current ecosystem is a relatively recent issue and is dependent on a number of climate-mediated processes. Monitoring of indicators of dissolved oxygen has revealed that increased low dissolved oxygen events in the northern California Current, with impacts on fish and benthic invertebrate communities off Oregon (Keller et al. 2010). For example, during a severe anoxic event in August 2006, surveys found an absence of rockfish on rocky reefs and a large mortality event of large benthic invertebrates (Chan et al. 2008).

Risk Assessment

Quantitative risk assessment is a general analytical approach for describing the likelihood and magnitude of adverse consequences due to exposure to particular threats (and, if possible, cumulative impacts of multiple threats. A recent development in the use of risk assessment in fisheries management is the productivity-susceptibility analyses that have been used as an evaluation of the vulnerability of fish stocks to current fisheries management practices, based upon their susceptibility to the fishery and a suite of life history traits that indicate productivity.

Figure 2 shows the relative risk faced by four species of groundfish to changing sea surface temperature. Such analyses reveal that adult bocaccio and juvenile canary rockfish are at higher risk to changing climate relative to adult or juvenile hake or sablefish. Given overfished status of bocaccio and canary rockfish, this added risk is of concern.

Scenario Analysis

As part of the California Current IEA (Levin and Schwing 2011), Ainsworth et al. (2011) attempted to reproduce ecosystem changes associated with climate change using Ecopath with Ecosim models. They examined changes in fisheries landings as a function of climate-induced changes in primary production; range shifts, size structure of zooplankton, ocean acidification, and dissolved oxygen. Model simulations predicted that the performance of fisheries and the relative abundance of species in the northern California Current are expected to change, but not in a uniform way. Despite the implementation of mainly negative forcing functions (that reduce productivity), many fisheries and species benefited because of indirect feeding relationships. However, the cumulative impacts of all climate effects reduced landings by 40 percent (Figure 3). The impacts were even more severe when range shifts were included in the cumulative impacts scenario.

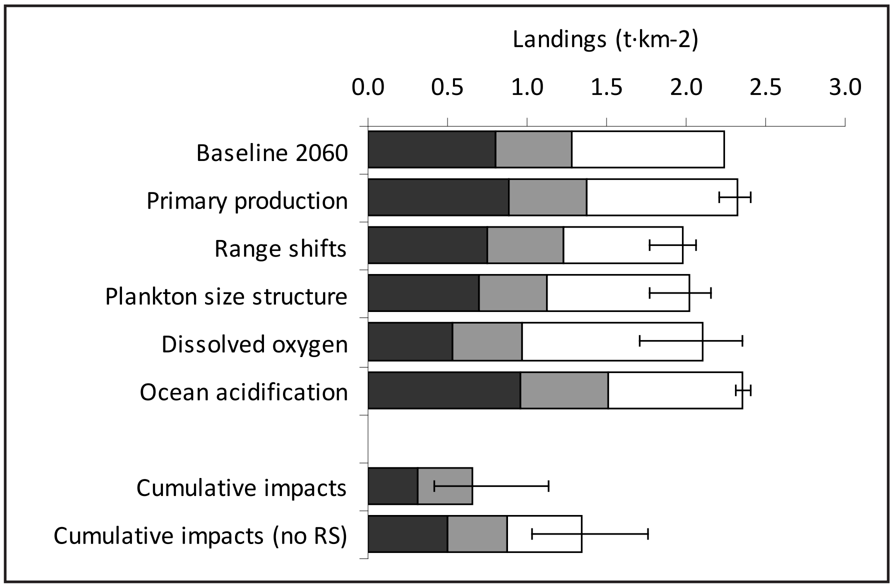


Figure 3. Projected fisheries landings in the northern California Current (2060). Baseline shows projected landings without climate change. Error bars show the range of outputs predicted using three effect sizes (nominal, moderate and substantial); bar shows median. Dark grey: demersal fish; light grey: pelagic fish; white: invertebrates. Based on Ainsworth et al. (2011); reprinted from Levin and Schwing (2011).

Integrated Ecosystem Assessments Link Ecosystem Science to Fisheries Management in a Changing Climate

The rate of climate change in the last 100 years is greater than any other change experienced over the last 10,000 years (Marcott et al. 2013). There is no question that Regional Fishery Management Councils will be challenged to implement policies that are robust to the combined effects of fisheries extraction and climate change. The aim of IEAs is to synthesize the best available science about climate and harvest impacts on fish stocks, and to project the efficacy of different management approaches for achieving management goals. It is clear that climate change will affect the distribution, abundance, growth and species composition of our Nation's fisheries (Ainsworth et al. 2011), and that management that does not consider such changes will fail (Kaplan et al. 2010).

The situation becomes more complex because we, of course, manage the ocean for many uses and these may conflict with fisheries. The impetus for alternative energy including wind, wave and hydropower that impact fisheries will increase as human populations grow, and society seeks energy that does not emit green house gases. Conservation concerns may increase as climate change affects habitat, prey and risks facing protected species. IEAs can provide the information needed to carefully consider trade-offs between fisheries and other ocean uses, and they can assist policy makers to develop plans that attempt to meet society's cross-sectoral objectives. The challenge for IEAs to inform the multitude of ocean uses against a backdrop global change is great; however, sustainable resource management requires us to confront this challenge.

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Effects of Climate Velocity on Fish and Fisheries

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Abstract

By 2100, global temperatures are projected to be 2–4°C warmer and ocean waters are expected to be substantially more acidic than they are today, with profound effects on natural ecosystems and human societies. Climate drives clear changes in fish populations and communities, including alterations in abundance, productivity, distribution, and species composition. Both in the U.S. and around the world, clear indications can be found of population shifting to follow changes in temperature. Fisheries respond to these changes in the ecosystem, including by following fish poleward and by changing the mix of species caught in any particular location. Despite the clear impacts, climate is not explicitly considered in traditional fisheries management and a range of opportunities exist for fostering "climate-ready" fisheries in the future. Adapting fisheries management will likely require two parallel and complementary approaches: 1) anticipating climate impacts where possible to guide preparations, monitoring, and long-term planning, and 2) maintaining management flexibility, ecosystem monitoring, and rapid-response capabilities to adapt quickly when ecosystems change unexpectedly. One useful approach is to test alternative fisheries management methods and choose the strategy that performs the best under a range of possible future conditions. Preparing climate impact assessments (including online interfaces and regular reports to fishery management Councils) that summarize existing climate states, predicted future conditions, and their regional impacts on fish and fisheries will provide resources for managers to make informed decisions and help to educate stakeholders. Shifts in species distributions that affect international agreements appear particularly difficult to negotiate. Given the clear signals from past climate impacts and the strong importance of fisheries to our coastal economies, efforts to adapt fisheries to climate impacts will be most effective if they begin as soon as possible.

The Pace of Climate Change in the Oceans

By 2100, global temperatures are projected to be 2–4°C warmer and ocean waters are expected to be substantially more acidic than they are today, with profound effects on natural ecosystems and human societies (Caley et al. 1996; IPCC 2007). The world is now committed to at least a substantial portion of these changes even if rapid mitigation measures are taken, and society must consider not only what impacts to expect, but also how to adapt to those impacts.

Climate velocity measures the speed and direction that species would have to shift to maintain a constant temperature (Fig. 1). Climate velocities are as fast, and sometimes faster, in the ocean than they are on land (Burrows et al. 2011). Median velocities from 1960-2009 in the ocean have been 21.7 km/decade, but reached 200 km/decade near the tropics and in the sub-Arctic (Burrows et al. 2011). Velocities in the ocean are 2-7 times faster than on land in the topics and the sub-Arctic, but similar to those on land at most other latitudes (Burrows et al. 2011).

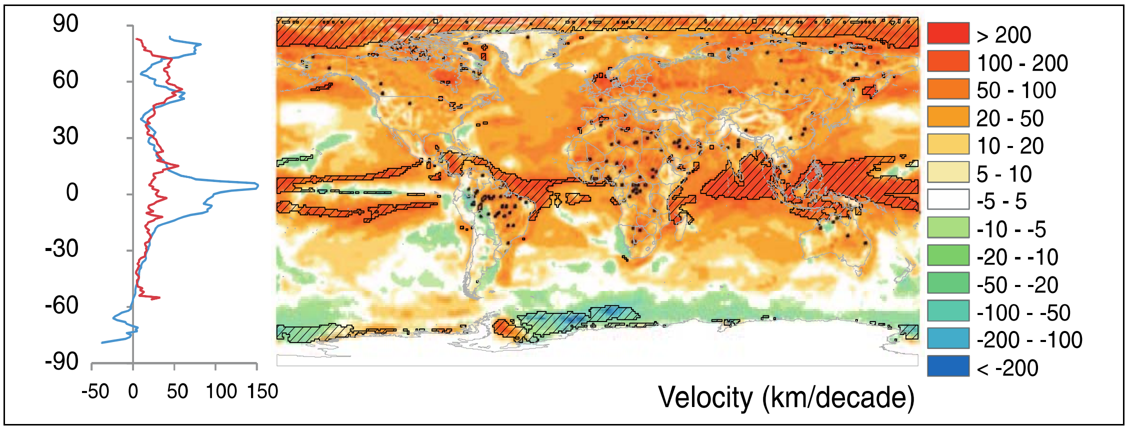

Figure 1. *The velocity of climate change represents that pace at which species would have to move to maintain a constant temperature (i.e., it does not consider the ability of species to move). Rates on the map are expressed in km/decade and are for 1960-2009. Velocity is positive in areas of warming and negative in cooling areas (e.g., Southern Ocean). The graph on the left shows averages for land (red) and ocean (blue) by latitude. Figure reproduced from Burrows et al. 2011.*

It is important to recognize that there is much variation in climate velocity from region to region and through time. For example, though the global ocean has been, on average, warming rapidly for the past three decades, the California and Humboldt Current ecosystems have been cooling (Belkin 2009). This appears to result from climate variability (e.g., Pacific Decadal Oscillation and El Niño), and so may reverse in the future (Chavez et al. 2011). Other regions, such as the northeast U.S., have been warming rapidly in recent decades (Belkin 2009). Over multiple decades, however, the impacts of climate variability average out, leaving the long-term warming signal from climate change clearer.

Observed Responses of Marine Fish and Invertebrates

Fish appear to respond quickly and often quite predictably to changes in water temperature. There are physiological reasons to expect this effect, including the concept of a "thermal envelope" within which fish have sufficient oxygen for growth and survival (Pörtner & Knust 2007). These envelopes vary among species, and marine species distributions match closely to their physiological limits, including more closely than on land (Sunday et al. 2012).

Observed changes over the past few decades support this view of strong temperature effects on marine species. For example, from 1980-2008, southern species increased in abundance and northern species declined throughout the northern European shelf as temperatures warmed (Simpson et al. 2011). Elsewhere, many new species are appearing in ecosystems and becoming available to fisheries in ways that appear linked to changes in temperature. In the United Kingdom, sea bass (*Dicentrarchus labrax*), red mullet (*Mullus barbatus*), John dory (*Zeus faber*), anchovy (*Engraulis encrasicolus*) and squid are now sparking new fisheries (Cheung et al. 2012). There have been a wide range of similar observations around the world, with species generally shifting poleward (Murawski 1993; Nye et al. 2009; Perry et al. 2005; Sorte et al. 2010).

Predicted Responses

A direct consequence of shifting species distributions is that many traditional fisheries will decline, while new opportunities for fisheries will emerge. In the northeast U.S., for example, cod, pollock, and haddock appear unlikely to be available to fisheries by the end of the 21st century (Lenoir et al. 2010), but Atlantic croaker and blue crab are predicted to become more abundant (Hare et al. 2010; Najjar et al. 2000). Globally, fish are projected to shift 45-49 km/decade poleward under a moderate climate-warming (A1B) scenario (Cheung et al. 2009).

Basic population ecology suggests that fish populations are particularly vulnerable when they colonize new territory. Delaying the start of new fisheries (e.g., NPFMC 2009; Stram & Evans 2009) until newly colonizing species fully establish a population appears to be a strategy that will allow species to adapt more smoothly to climate change.

Aside from specific changes in distribution, an important question is which species are likely to survive well under future climates and which will do poorly. Research from species invasions predicts that species with lower dispersal abilities and slower population growth rates (usually those species with longer lifespans) will have more difficulty keeping up with rapid climate velocities (Hastings et al. 2005; Zhou & Kot 2010). Species with lower dispersal abilities are also more likely to be out-competed by those that disperse further, since the former tend to lag behind their optimal thermal environments (Urban et al. 2012).

Finally, those species facing the fewest additional stressors will have the greatest capacity for adapting to climate change. Fishing, for example, typically truncates the age structure of exploited species, reduces their within-species diversity (life history, geographic, and genetic diversity), and causes their geographic range to contract. All of these factors reduce resilience to climate impacts and can increase the magnitude of population fluctuations (Brander 2007; Hsieh et al. 2006; Rouyer et al. 2011). For example, the high geographic and habitat diversity of Bristol Bay salmon appears to have reduced the risk of a fishery closure in any given year to less than 4 percent, a ten-fold reduction in risk compared to a less diverse set of populations (Schindler et al. 2010).

While all predictions about the future have uncertainty, scientists are more confident in some predictions. For example, climate-driven shifts in species distributions tend to be more predictable than changes in abundance, recruitment, and productivity (Walters & Collie 1988). This effect may occur because climate is a dominant factor in population dynamics at range edges, while fishing and other impacts are stronger elsewhere in fish ranges. Compared to patterns on land, it appears that range shifts will be more predictable in the ocean because there are fewer microclimates and fewer barriers to dispersal in the ocean, two key factors that complicate predictions on land (Robinson et al. 2011). In addition, marine species' ranges generally conform to species' physiological thermal limits more closely than do terrestrial species, again implying that climate impacts will be more predictable in the ocean (Sunday et al. 2012).

Effects on Fisheries and Fisheries Management

Range shifts have important implications for fisheries and fisheries management. As species in the northeast U.S. have shifted to higher latitudes, fisheries have shifted poleward as well except where regulations or other economic and social factors have impeded these shifts (Pinsky & Fogarty 2012). Shifts in stocks require re-evaluation of stock boundaries, population productivity, and allowable catches (Link et al. 2011). As discussed above, range shifts can lead to newly emerging fisheries in new areas. If not considered explicitly in fisheries management, shifts can lead to the over- or under-estimation of population biomass or the rate at which a population can be harvested (e.g., maximum sustainable yield). Shifts can also reduce the effectiveness of existing management measures. For example, offshore shifts in North Sea plaice (*Pleuronectes platessa*) have made a closed area (the "Plaice Box") largely ineffective (van Keeken et al. 2007). Permanent closed areas may be warranted in other cases to protect previously de facto refugia. The North Pacific Fishery Management Council set up Marine Protected Areas for blue king crab in the Bering Sea to protect habitat from shifts in the location of bottom trawling (Stram & Evans 2009).

Even for individual populations, shifts in climate and species ranges can complicate basic fisheries monitoring, and therefore management. In the Aleutian Islands, the bottom trawl survey has a harder time catching yellowfin sole in cold temperatures, and so survey abundance indices are now adjusted to account for temperature (the Plan Team for the Groundfish Fisheries of the Bering Sea and Aleutian Islands 2012). In the northeast U.S., survey indices for butterfish populations fluctuate widely, but much of this variation appears to result from migration of the butterfish population into and out of the survey extent from year to year (J. Manderson, personal communication).

Shifts of species across national or management boundaries raise complex issues of coordination and equity. If populations shift enough to straddle management boundaries, fishing in both regions can create a situation of "double jeopardy" that is not sustainable. For example, both Iceland and the U.K. want to fish mackerel stocks that have shifted into Icelandic waters, and the combined harvest threatens to cause overfishing (Anonymous 2010; Cheung et al. 2012). The disagreement among the two countries has been dubbed the "Mackerel Wars" (Anonymous 2010). Pacific salmon harvest in the U.S. and Canada may become a similar case (Miller & Munro 2004), and cross-boundary groundfish populations in the northeast U.S. and eastern Canada raise similar issues. Pre-agreements, perhaps involving side payments, are one method for avoiding destructive conflicts that would otherwise arise without proactive negotiations (Miller & Munro 2004).

Climate change also has important implications for stock rebuilding plans, since these have the long time horizons over which climate effects are most likely to accumulate (MacCall 2002). For example, even lower fishing rates than currently considered would be needed to achieve rebuilding goals for depleted west coast U.S. rockfish if spring transition dates are delayed by climate change (Holt & Punt 2009). Climate change may also mean that rebuilding goals for cod are simply unachievable and that new, lower rebuilding goals will be needed (Mieszkowska et al. 2009). However, managers will have to be very careful not to use climate change as an excuse to avoid the hard work of rebuilding or managing fisheries sustainably. Coupling projections of climate to observations and monitoring will be critical for deciding when and if to initiate action.

The climate-driven shift of populations out of a management zone can actually alter the fundamental incentive structure of fisheries. While individual transferable quotas and other secure rights systems normally increase the incentives for stewardship, this incentive may evaporate when a stock is expected to shift to another region. In that case, the incentive can instead become the exact opposite: one rational response is to harvest as hard as possible before the population leaves (Silvert 1977). This course of action would clearly have negative consequences for the harvested species and for stakeholders on the receiving end of the shifting population.

Detecting Changes

A range of tools exists for detecting changes in climate and subsequent impacts on fish populations. Fishery-independent surveys, for example, have already been used in many regions of the U.S. for detecting changes in fish distributions (Mueter & Litzow 2008; Murawski 1993; Nye et al. 2009). The wide spatial extent and long history of bottom trawl surveys have made these surveys in particular quite useful, but other surveys can also be analyzed to detect changes in spatial distribution. Fishery-dependent surveys may also be useful when other information is lacking, though care must be taken to consider other impacts on where fishermen fish (e.g., changes in closed areas).

Other tools can be very useful for detecting changes in the marine environment, but are only beginning to be used in fisheries management. Remote sensing of temperature, primary productivity, and sea ice cover can all provide evidence of current environmental conditions, including the amount of habitat available for different species. Regional hubs for the U.S. Integrated Ocean Observing Systems initiative (http://www.ioos.gov) provide remotely sensed data, as well as temperature and other data from buoys, robots, and sensors in the coastal ocean to management bodies and to the public. Dynamic ocean models are increasingly being used to fill in data gaps in real time, such as subsurface ocean conditions.

One key tool for detecting climate impacts is regional calculations of expected climate impacts. When and how much is temperature expected to change? Will primary production, ocean currents, and oxygen concentrations change? Which species are expected to appear, or disappear? Rapid progress in being made on downscaling global climate models to the regional scale of fisheries management and linking these projections to consequences for fisheries (Ainsworth et al. 2011; Hare et al. 2010; Hare et al. 2012; Kaplan et al. 2010), but such efforts need to be scaled up substantially. By knowing which physical and ecological factors are most likely to change, monitoring efforts can be tuned to detect these impacts earlier and with more certainty.

Potential Adaptation Options

As described above, global climate change is expected to strongly affect the distribution, abundance, and persistence of marine fishes and of the fisheries that rely upon them. Such impacts can be subtle in any particular year, but these impacts will accumulate over time to threaten the sustainability and effectiveness of current fisheries management. The traditional approach to fisheries management focuses strongly on the impacts of fishing, largely or even entirely ignoring the impacts of climate. While this is starting to change in a few jurisdictions and for a few fisheries, much more widespread adaptation will be needed in the coming years and decades. Below are a series of approaches for adapting fisheries management to the impacts of climate change. The approaches are not mutually exclusive, and in fact, many, if not most, of them may be needed.

Integrate Climate-Relevant Monitoring into Fisheries Management

To guide climate adaptation in fisheries, a wider range of ecosystem monitoring tools can be integrated into fisheries management, including biophysical information (temperature, acidification, phytoplankton, etc.), remote sensing, oceanographic models, and climate-focused biological monitoring. For example, changes in spatial distribution are a common climate impact and yet not a routine part of fisheries monitoring. Spatial distribution can be extracted from existing bottom trawl, mid-water trawl, hydroacoustic, and aerial spotter surveys (Azarovitz 1981; Mueter & Litzow 2008; Nye et al. 2009). Where these surveys exist, an important step is to summarize range shift information for fisheries managers and incorporate this information into the management process.

Annual reports on the state of the climate and the ecosystem would help to identify when sudden climate events may necessitate a management response. Early examples of these reports include the Ecosystem Considerations report for the North Pacific Fishery Management Council, Integrated Ecosystem Assessments underway in the California Current and the northeast U.S., and the Ecosystem Advisories issued for the northeast U.S. Publicly available and easily understood websites would be an important part of this effort, similar to the Integrated Ocean Observing initiatives (http://www.ioos.gov). More widespread adoption of these reports and increased attention to improving their focus and explicit ties to management would help to integrate climate considerations into fisheries management. More broadly, the potential for changes in climate to affect the productivity of fish populations needs stronger recognition within the annual cycle of fisheries management, and regular reports can help to raise that awareness.

Build Rapid-Response Methods into Management

Despite the many predictable impacts of climate change, other climate impacts on fisheries will be unpredictable over the annual time-horizons of fisheries management. One method for dealing with this uncertainty is to react quickly as soon as impacts become apparent, even when the full mechanism is not understood (Peterman 2009). Fisheries scientists are beginning to develop methods for detecting and responding to changes in stock productivity and growth as part of the stock assessment process (Haltuch & Punt 2011; Peterman et al. 2000). The ecosystem monitoring and real-time synthesis of such data, as discussed above, is also a crucial first step in a rapid response.

Avoid Bycatch and Re-evaluate Closed Areas

Shifts in species distributions have particularly strong impacts on spatial fisheries management, including closed areas and bycatch avoidance. As described earlier for the Plaice Box in Europe, species may shift out of closed areas designed for their conservation and management (van Keeken et al. 2007). If such shifts are detected or predicted, it may be necessary to move closed areas to follow shifts in species.

Habitat models that incorporate temperature, bottom habitat, currents, oxygen, or other oceanographic conditions can be used to forecast future distributions as well as identify current habitats (Cheung et al. 2009; Lenoir et al. 2010). Real-time habitat distributions can be particularly useful for avoiding bycatch of protected species. The TurtleWatch product, for example, uses remotely sensed Sea Surface Temperatures and ocean currents to identify regions where interactions between long-line fishing vessels and loggerhead turtles are particularly likely (Howell et al. 2008). In these regions, it is recommended that fishermen avoid using shallow-water sets.

Assess Management Strategies Under Climate Change

Even from detailed regional climate models, it is important to note that precise predictions of future conditions will not be possible and there will always be a chance of unexpected transitions. Such uncertainty is not a reason for inaction: instead, it means that a range of potential future scenarios must be explored and management strategies evaluated against them. Scenario-building and evaluation is now recommended as a routine part of climate adaptation in terrestrial conservation (Gillson et al. 2012), and the process of testing management strategies under a range of future scenarios can be applied much more widely to climate change questions in fisheries. The best management approach is often defined as the one that will do the best across the range of possible futures, or alternatively, the one that is least likely to do poorly. By choosing management approaches that are robust to a wide range of possible futures, the consequences of ecosystem surprises can also be minimized.

As one example, Kaplan *et al.* evaluated alternative individual fishing quota management options under ocean acidification scenarios for west coast U.S. groundfishes. In this case, individual fishing quotas outperformed status quo in all scenarios and appeared to be a robust management decision (Kaplan et al. 2010). Similarly, Kaplan et al. (2012) used an ecosystem model to evaluate gear switching and spatial management options at various scales for the west coast U.S., including an evaluation of tradeoffs between fisheries and conservation. Their paper did not consider climate impacts, but the model was designed so that it could do so in the future.

Maintain Resilience of Fishing Communities

Adapting fisheries to climate change is not only about fisheries management; it is also about social and economic transitions for coastal towns and cities that rely on fishing for their culture, identity, and economy. Fishing communities exploit particular regions of the ocean (St. Martin & Hall-Arber 2008b), and climate change is nearly certain to change the fishing opportunities available to these communities, including through range shifts that move some species away and bring others close enough to exploit. These shifts will require adaptive responses from fishermen and fishing communities, which may include increased travel to new fishing grounds, switches to fishing new species, development of new business and social networks, or decisions to transition out of fishing altogether (Coulthard 2009; McCay 2012; Pinsky & Fogarty 2012; St. Martin & Hall-Arber 2008a). Highly specialized fisheries with low flexibility are less likely to adapt smoothly to the challenges of climate change. In Maine, for example, the lobster fishery has been proposed as a "gilded trap" that encourages over-specialization and over-investment, leaving a large swath of the coastal economy and society exposed to the possibility of a lobster crash (Steneck et al. 2011). On the West Coast, in contrast, a diversity of fishing options has fostered greater social resilience by allowing fishers to switch among species and buffer themselves against fluctuations in any one species (Norse & Crowder 2005). In some cases, individual transferable quotas and the increased complexity of regulation have reduced flexibility in fisheries (Murray et al. 2010), and this process appears likely to make future adaptation more difficult. More generally, societies and communities adapted to climatic variability (e.g., El Niño/La Niña cycles) appear more likely to have the flexibility and adaptability to cope with climate change, while those used to targeting long-lived, stable species like cod may have fewer coping mechanisms (Perry et al. 2010).

In light of these coming societal transitions, actions that enhance the flexibility of the fishing industry in a region will be important (Coulthard 2009). Co-management, or the sharing of regulatory decision-making between the government and fishing stakeholders, has been suggested as one mechanism for enhancing the ability of fishing communities to cope with change (McCay et al. 2011). Secure and exclusive fishing rights also promote future-oriented action that can help with difficult transitions (McCay et al. 2011), though these must be approached carefully in the context of climate change so that they don't remove the flexibility that will be needed for fisheries adaptation.

Conclusion

Climate drives changes in fish populations and in fisheries that are already visible in the U.S. These changes, including shifts towards higher latitudes and changes in the mix of species available to fisheries, are likely to become much more pronounced in coming decades. Adapting fisheries management will likely require two parallel and complementary approaches: 1) anticipating climate impacts where possible to guide preparations, monitoring, and long-term planning, and 2) maintaining management flexibility, ecosystem monitoring, and rapid-response capabilities to adapt quickly when ecosystems change unexpectedly. Specific opportunities include

- More effectively provide and translate climate information for fisheries management
- Design management processes that allow rapid response when climate impacts are detected
- Consider shifts in species distributions in order to avoid bycatch and ensure closed area effectiveness
- Use future climate scenarios to evaluate the robustness of current and alternative management strategies
- Support economic and social transitions in coastal communities as they adapt to changing conditions

Given the clear signals from past climate impacts and the strong importance of fisheries to our coastal economies, efforts to adapt fisheries to climate impacts will be most effective if they begin as soon as possible.

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DISCUSSION SUMMARY
Session 2 Topic 1

Assessing Ecosystem Effects and Adapting to Climate Change

Speakers

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Discussion Summary:

Assessing Ecosystem Effects and Adapting to Climate Change

The following themes and findings emerged during the discussion during this session.

Address the Root Causes of Climate Change: Legislative Changes Beyond Fisheries

A key finding emerging from this session was the need to address the root causes of climate change. As the framework for Federal fisheries management, the Magnuson-Stevens Fishery Conservation and Management Act provides managers with tools for responding to the symptoms and impacts of climate change on ocean ecosystems, but it does not address the underlying problem. Fishery managers are already beginning to see climate change influence the effectiveness of management measures. As the velocity of climate change increases, it will grow even more challenging for fishery managers to respond to the impacts of climate change on U.S. fisheries. Members of Congress, the Administration, and other elected officials should address the root causes of climate change in order to protect and conserve our nation's fishery resources and ocean ecosystems.

Climate Change: Policy, Guidance and Best Practices

Evaluate and Incorporate Ecosystem Productivity Change Into Fishery Management

Climate change is affecting the productivity of our oceans and impacting fish populations. These ecosystem productivity changes impact the amount of fish the ocean can support and ultimately how many fish can be sustainably harvested. Fishery managers must evaluate ecosystem-level productivity change, consider how it affects managed stocks, and incorporate these changes into fishery management.

Facilitate Precautionary Management to Prepare for Climate Change Effects

The science is clear that climate change will affect ocean ecosystems, fish populations, and fisheries. Fishery managers can proactively prepare for these effects by incorporating precaution into their fishery management strategies.

UTILIZE A PRECAUTIONARY APPROACH FOR DEVELOPING AND EMERGING FISHERIES

Climate change can cause shifts in species distribution and other potentially unpredictable responses. As species migrate into new management areas and other changes occur, fishery managers may not have all the necessary information to sustainably manage these emerging fisheries. For example, anticipating reduced sea ice cover in the Arctic in the future, the North Pacific Fishery Management Council developed an Arctic Fishery Management Plan to preclude the development of new fisheries until sufficient data becomes available to make responsible management decisions. Managers must use precaution with emerging fisheries until comprehensive information is available on stock status and sustainability.

DEVELOP A COMPREHENSIVE NATIONAL PLAN FOR CLIMATE IMPACTS ON FISHERIES AND DEVELOP TOOLS THAT WILL FACILITATE REGIONAL CLIMATE CHANGE STRATEGIES

Fishery managers must plan now for the effects of climate change. The state of Alaska developed a climate change strategy that includes research priorities. Managers should engage in regional and national planning exercises to develop climate change strategies that will provide managers with the ability to respond quickly and mitigate rapid changes associated with climate change.

PROTECT THE MOST SENSITIVE SPECIES AND HABITATS

Managers should implement precautionary measures now to protect highly productive habitats and dependent fish communities. Coral reefs and reef communities, for example, support fisheries in many U.S. management regions and are particularly sensitive to climate change.

Implement Adaptive Management to Allow Rapid Response to Climate Change Effects

Scientists predict that the velocity of change associated with climate is likely to increase with time. Making changes to fishery management plans and regulations is a cumbersome and time-consuming process that may not be capable of responding quickly to change. Fishery managers should implement a framework for adaptive management that allows for rapid response to the effects of climate change.

MODIFY REFERENCE POINTS AS CLIMATE CHANGES

Climate change can affect the productivity and abundance of stocks. Managers may need to reconsider and potentially modify reference points over time in response to these changes. In some instances this may be a necessary precaution to account for uncertainty. In other cases it may be necessary to recalibrate maximum sustainable yield based on changing productivity in the ecosystem. Finally, the development of reference points should shift from a single-species approach to being calculated on an ecosystem basis.

ADDRESS REBUILDING REQUIREMENTS WHEN ENVIRONMENTAL CONDITIONS MAY BE A PREDOMINANT FACTOR IN A STOCK'S CONTINUING DECLINE OR NON-RECOVERY

Climate change may impact rebuilding of depleted stocks due to ecosystem shifts and changes in productivity. Managers must have sufficient flexibility with rebuilding requirements to develop and implement attainable rebuilding strategies that adapt to the new productivity potential of species when the ecosystem has fundamentally changed because of climate.

INCORPORATE AN ENVIRONMENTAL TRIGGER MECHANISM INTO THE FEDERAL FRAMEWORK TO INITIATE MANAGEMENT ACTIONS

As scientists continue to understand and anticipate the effect of climate change on fish stocks, it may be possible to incorporate environmental triggers into fishery management plans. For example, if we know that ocean temperatures will affect the distribution of a stock, managers can develop specific management actions contingent upon observed ocean temperature changes. Ocean acidification can also lead to lower productivity, therefore managers could create a framework tied to ocean chemistry. Managers can also develop triggers to react quickly to sudden events. For example, algal blooms can grow quickly and create more toxins in a high carbon dioxide ocean environment. By identifying and establishing a suite of management options in advance, management can respond quickly to an outbreak.

EVALUATE EFFECTIVENESS AND UTILITY OF FIXED CLOSED AREAS

Many fishery management plans rely on fixed area closures to meet conservation objectives. Climate change can cause fluctuations in abundance and shifts in the distribution of species. With these changes, place-based closed areas may no longer have the desired effect or serve the purpose for which they were established. Scientists should evaluate the effectiveness and utility of closed areas as species distribution changes and their value in supporting wider age structures of potentially vulnerable populations. Managers should consider other management strategies if closed areas no longer accomplish management objectives.

ALLOW FLEXIBILITY IN COUNCILS' ABILITY TO RESPOND TO SPATIAL, ALLOCATION AND DISTRIBUTIONAL EFFECTS OF CLIMATE CHANGE

Managers will need flexibility to respond to the spatial, allocation, and distributional effects of climate change. Managers should build flexibility into catch share programs that would allow the fishery to adapt to changes in abundance. Some catch shares constrain the ability of the fleet to shift in species, gear types, and areas; therefore the regulatory regime would hinder the fleet's ability to adapt to change. Similarly, as species distributions shifts, allocations of quota may be out of sync with species distribution.

ASSESS BARRIERS TO ADAPTATION

The changes caused by climate, including species distribution and productivity, can be costly, yet there are barriers that constrain the fishery management system's ability to adapt to changing conditions. An assessment should be conducted to identify and overcome these barriers.

DEVELOP DECISION SUPPORT TOOLS THAT ALLOW COUNCILS TO RESPOND TO RAPID CHANGES

The fishery management system must develop decision support tools that allow Councils to respond to rapid environmental and ecosystem changes. In some cases, the effects of climate change may outpace the timeline for traditional changes to fishery management plans and regulations. By developing decision support tools now, Councils will be better prepared to respond to rapid change.

Increase Coordination Between and Across Jurisdictions

Climate change is causing chemical, physical, and biological changes in marine ecosystems around the globe. Scientific studies have documented the shifts in species distribution and changes to ecosystem structure and function. These changes emphasize the need to increase existing coordination across the regional Councils, states, Federal agencies, and international governing bodies in order to effectively address climate change, and plan for anticipated changes and sustainably manage marine resources. Coordination is also needed to ensure that collective fishing activity across jurisdictions does not result in overfishing.

Support and Prioritize Science

Science has come a long way to develop tools and models that synthesize data, evaluate impacts, and predict future change. Sciences and managers must work together to identify the highest priorities for research in order to support management needs.

Assess the Efficacy of the National Ocean Policy as a Vehicle to Address Climate Change

Several different perspectives were raised about the National Ocean Policy. On one hand, the discussion raised questions about how to influence activities outside the authority of fisheries managers that have an impact on ocean ecosystems and fish populations. For example, agricultural activities in the Midwest contribute to the creation of the dead zone in the Gulf of Mexico. Fisheries managers have little influence on impacts that occur far beyond the coastal zone. The National Ocean Policy is a bottom-up process that allows everyone to have input. On the other hand, some participants felt the bureaucracy of the National Ocean Policy diverts limited resources and duplicates existing efforts.

Endangered Species Act: Base Listings on Actual Trends Rather Than Assumed Projected Trends of Climate Change

The National Marine Fisheries Service has received petitions to list species under the Endangered Species Act based on possible declines due to climate change for coral species. This follows a threatened listing for polar bears and an announcement that ringed and bearded seals may also be listed. Some participants felt that listings should be based on observed trends showing decline of a species' population rather than on an anticipated trend based on climate assumptions. Some felt this approach erodes the management authority of state and regional Councils who have the expertise and resources necessary to implement conservation measures for these species. Federal agencies should engage in a proactive planning process in collaboration with fishery management authorities when considering and responding to impacts and projected impacts from climate change.

Integrated Ecosystem Assessments

The ability to collect and analyze large volumes of data is expanding rapidly with current technology, and this information can provide us with resources for responding to climate change. By conducting integrated ecosystem assessments (IEAs), scientists and managers begin to highlight the costs and benefits of management options and search for win-win strategies.

Integrate IEAs and All Component Models into Management Process

IEAs provide fishery managers with a powerful tool to use a lot of data and information when making fishery management decisions. Wherever possible, fishery managers should integrate IEAs and component models into the management process. While IEAs are in development and will continue to evolve and expand, scientists must also derive less data and resource intensive tools for use in the management process today.

Develop Ecosystem Models, Tools and Assessments at a Regional Level

While IEAs provide the gold standard for integrating information, it will take time and resources to develop and implement them in all regions. In the meantime, scientists must continue to build tools that, like building blocks, will eventually support a more fully developed IEA. We need to change fundamental single-species stock model designs to be more flexible and allow more formulations. New models, tools and assessments should:

- Synthesize data from non-fishing sources and incorporate socioeconomic as well as ecosystem parameters. For example, one participant highlighted the expansion of the energy industry in the ocean and how this affects ecosystem sustainability and productivity when new devices are placed in previously undeveloped areas. The leases for energy have long time frames, so fishermen and fishery managers must consider not only where fisheries occur today, but where fish and fishing activity may be in the future.
- Respond to changing parameters. Climate change affects life history parameters and species distribution that should be captured in models in order to best reflect what's happening in the ocean.
- Predict future ecosystem states. Scientists should build predictive capabilities into modeling and assessments wherever possible. Fishery managers can prepare for anticipated changes and respond more quickly with predictions of future ecosystem states.
- Scientists should strive to include both short- and long-term guidance to managers. Managers need guidance for setting annual specifications, but also need to prepare for long-term management strategies that may be different than current conditions.
- Account for cumulative impacts of climate change. Cumulative impacts can have large ramifications. The changes happening in ocean ecosystems do not occur in isolation. Scientists and managers must look at compensation, magnification and a variety of responses to a variety of influences. Managers must account for cumulative impacts on ocean ecosystems. Cumulative impacts have larger ramifications when a stock is overfished.

AUDIENCE, SESSION CHAIRS, AND RAPPORTEURS FROM THE DAIS. PHOTO: PFMC

PAPERS

Session 2
Advancing Ecosystem-Based Decision-Making

Topic 2
Forage Fish Management

A CASE FOR PRECAUTIONARY MANAGEMENT OF FORAGE FISH: PETER BAKER

A SCIENTIFIC PERSPECTIVE ON ECOSYSTEM RELATIONSHIPS OF FORAGE FISH: ISAAC C. KAPLAN

FORAGE FISH MANAGEMENT IN THE US: A COMMERCIAL FISHING PERSPECTIVE: RON LUKENS

A Case for Precautionary Management of Forage Fish

Peter Baker
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Abstract

As knowledge about marine ecosystems expands, our nation's fishery management infrastructure must evolve to keep pace. Recently, marine scientists have developed new understanding about one of the ocean's most important attributes: forage fish. Forage fish provide a vital link between small protein-rich plankton and top predators that make up our marine megafauna. Managing forage fish to sustain the productivity and resilience of marine ecosystems, and the health of top predators, is becoming increasingly important to modern fisheries management. As single-species, maximum sustainable yield (MSY)-based management has proven ineffective in managing forage fish, a paradigm shift must occur. Fishery management must move towards ecosystem-based fishery management with new strategies to manage forage fish acting as a sensible next step for that transition. As our knowledge evolves and fishery management follows, ideas such as incorporating forage fish as indicators of ecosystem health and the need to protect essential fish habitat will come to the forefront.

Forage Fish: Definition and Importance

Small, schooling fish that swim in ocean waters play an important role in our marine ecosystems. These "forage fish" are so-called because ocean predators, like larger fish, birds and marine mammals, rely on them as food. Recognizing the importance of forage fish for ecologically-sound fisheries management, a distinguished international group of 13 scientists formed the Lenfest Forage Fish Task Force (LFFTF) to review the impacts these species have on ecosystems. In 2012 they published a report that defined forage fish and made recommendations for how to manage them sustainably worldwide. For small fish species to meet the "forage fish" criteria, they must have several key characteristics. Forage fish:

- Transfer energy from the lower to higher levels of the food web by eating plankton, and then being eaten by larger predators;
- Are the most numerous fish by number of individuals, despite only a few forage fish species existing in any ecosystem;
- Are schooling fish that are small in size, mature early, live short lives and bear large numbers of offspring (Pikitch et al. 2012).

Many species of forage fish swim the nation's oceans, coastal waters, and estuaries. Some species are managed in Federal Fishery Management Plans (FMPs). Others are managed through interstate compacts such as the Atlantic States Marine Fisheries Commission (ASMFC). Many more species go completely unmanaged. Some examples of forage fish important to our marine ecosystems include:

- *Atlantic herring*—Atlantic herring is a keystone species in the Gulf of Maine ecosystem, supporting commercial fishing and serving as a major food source for many of the ecosystem's predators including codfish, striped bass, bluefin tuna, and endangered whales. Recent research reveals that predators can consume 300,000 tons of herring a year—roughly three times the amount caught by fishermen (Overholtz 2007). Given the major role herring play in the food web, managers need to take into account the needs of predators when setting fishing limits for herring.

- *Pacific sardines*—Pacific sardines support a valuable commercial fishery whose U.S. scope extends from southern California to the coast of Washington. They are a key forage species in the California Current Ecosystem. Pacific salmon stocks, albacore tuna, many groundfish species, seabirds such as brown pelicans, and marine mammals from harbor seals to whales depend on Pacific sardine as a major source of food. Ensuring sufficient abundance of Pacific sardine is therefore necessary for maintaining healthy populations of these important species at the top of the food web.
- *Atlantic menhaden*—Atlantic menhaden play an important role in fisheries and marine ecosystems from Maine to Florida. This valuable forage species is a food source for wildlife such as whales, dolphins, ospreys and eagles, as well as valuable Federally-managed fish species like tuna, cod, striped bass and tarpon. The Atlantic states recently took action to end overfishing of Atlantic menhaden, recognizing its importance to the diet of numerous valuable recreationally and commercially targeted species.

Ecological Importance

Forage fish play a pivotal role in food webs of many coastal and marine ecosystems. They form an essential link between primary and secondary producers (e.g., phytoplankton and zooplankton) and top predators (e.g., large fishes, marine mammals and birds). According to the research by the LFFTF, three-quarters of marine ecosystems worldwide have predators that are highly dependent on forage fish (Pitkitch et al. 2012). Scientists have estimated that total consumption of forage fish by the world's marine mammals can amount to 20 million tons each year (Kaschner et al. 2006). A single humpback whale can consume 1,000 pounds of forage a day (Witteveen et al. 2006). Numerous seabird species rely on abundant forage as well, requiring roughly 12 million tons annually. Recent research suggests that keeping one-third of the forage fish biomass in the water is necessary to sustain healthy breeding populations of seabirds (Cury et al. 2011).

In addition to their role as prey, forage fish provide other important ecological services. Most notably, researchers have discovered that forage fish can play a significant role in removing carbon dioxide from the ocean's surface by feeding on plankton and producing carbon-rich fecal pellets that sink to the ocean depths (Saba and Steinberg 2012). Migrating anadromous forage species, such as river herring and shad, also play a valuable role in transporting marine-derived nutrients to rivers and streams, and thus have significant impact on the productivity of freshwater systems (Hall et al. 2012). Forage fish are also important predators, feeding on planktonic organisms, including the eggs and larvae of other fish species. Studies have suggested that forage fish predation can have important top-down effects on phytoplankton and zooplankton populations, with implications for the wider food web (Cury et al. 2000). Given the important role forage fish play in marine ecosystems, fishery managers should be precautionary about setting catch limits for these species.

Historical Role

Forage fish species have always played an essential role in America's marine ecosystems, transferring energy from plankton to predators. Native Americans and early colonists depended on forage species such as river herring, shad, and menhaden as important protein sources in their diet, and fertilizer for crops (McKenzie 2010). Recreational fishing in coastal rivers and the oceans has been a national pastime for centuries. As the U.S. experienced the 19th century industrial revolution and the population expanded west, new forage fisheries like the Pacific sardine industry developed. This expansion provided thousands of jobs and served as the economic engine in many coastal communities like the famed "Cannery Row" in Monterey, California. By the 1960s, industrial fishing technologies had been introduced which increased the ability to catch and process previously unimaginable quantities of forage fish, creating higher profits and fewer jobs. Today, many forage fish populations are at historic lows or have collapsed, due in large part to overfishing. Since 1976, Federal management has focused on achieving conservation through single-species management with considerable success, but the system has failed to fully account for the value of forage fish left in the ocean. New ways of accounting for the supportive value of forage fish, like the recommendations of the LFFTF, should be implemented when setting catch levels.

Economic Role

Forage fish have continued to play a critical role in providing protein for humans. In 2011, the U.S. commercial fishing industry landed 9.9 billion pounds of seafood (NOAA 2012)[1]. Forage fish directly or indirectly provide much of the foundation for this important industry. Americans consume roughly 15 pounds of seafood per person annually and forage fish are essential prey for some of the most valuable food fish (NOAA 2012). For example, the majority of the Alaska walleye pollock diet is krill, along with other forage fish such as capelin and sandlance (NOAA 2011). Without these abundant prey sources, the largest fishery in the U.S. could collapse, which is a key reason why directed commercial fishing for krill and other forage species is prohibited in Federal waters off the Alaskan coast.[2] Forage fish also bring food to our tables indirectly as the primary source of bait in many of America's commercial and recreational fisheries. In the Northeast, American lobster and blue crab fisheries primarily use forage species such as herring and menhaden as bait. The domestic reduction industry lands menhaden in the Atlantic Ocean and Gulf of Mexico, which becomes protein for humans indirectly as feed for livestock and aquaculture.

The Task Force reported fluctuations in reliance on forage fish, with some ecosystems, especially areas of ocean upwelling, relying more heavily on forage fish abundance. However, in 75 percent of the ecosystems studied, there was at least one predator that depended on forage fish for over half of its diet, and in 29 percent of the cases there was a predator that was "extremely dependent," relying on forage fish for over 75 percent of its diet. This research creates a framework that managers can use for determining the importance of forage fish in the ecosystems they manage, and making wise choices that support all the species in the marine food web. Because of their importance as food for larger, higher-value fish, small forage fish are worth more in the water, rather than as direct commercial catch. The LFFTF studied 72 ecosystems and estimated that the value of direct landings of forage fish is $5.6 billion, whereas their "supportive value" to other commercial species is approximately double, at $11.3 billion.

Deficiencies in Current Forage Fish Management

Currently, many of the nation's forage fish are entirely unmanaged. In addition, many of the managed species face overexploitation because of several factors, including the reliance on single-species, MSY management, and static assumptions regarding natural mortality, among other factors. Moreover, economic analysis in fishery management plans too often relies only on the costs and benefits to directed forage fisheries (and their end markets, such as bait users) rather than evaluating the value of leaving forage fish in the ocean to provide ecosystem services and feed dependent predators.

The LFFTF found that "conventional management can be risky for forage fish because it does not adequately account for their wide population swings and high catchability. It also fails to capture the critical role of forage fish as food for marine mammals, seabirds, and commercially important fish such as tuna, salmon, and cod" (Pikitch et al. 2012).

1 The majority of this increase in catch was from Gulf of Mexico menhaden, a key forage fish, which increased by 407 million pounds (42 percent) in the Gulf states, see page ix. By weight, 79 percent of these domestic landings were consumed directly as human food, 3 percent were used as bait, and the remaining 18 percent were taken by the reduction industry, see Table: "Disposition of U.S. Domestic Landings, 2010 AND 2011," page 6.

2 See Final Environmental Assessment for Amendments 87/96 to the NPFMC Groundfish FMPs at http://tinyurl.com/lkhqunb.

Pacific Coast Councils: Examples of Effective Forage Fish Management

As ecosystem science has progressed and the implications for management have become clear, we have seen positive examples of ecosystem principles, like forage fish protection, being incorporated into existing management. For example, the North Pacific and Pacific regional Councils are leaders in protecting the forage base and the marine food web.

Specifically, the North Pacific Fishery Management Council (NPFMC) amended the Gulf of Alaska and Bering Sea/Aleutian Islands Groundfish FMPs in 1998 to preclude directed fishing on a suite of forage species.[3] According to National Marine Fisheries Service (NMFS), this was "necessary to conserve and manage the forage fish resource off Alaska…a critical food source for many marine mammal, seabird and fish species."[4] The NPFMC amended these FMPs in 2010 to update these actions, maintaining the prohibition on directed fishing and designating these forage species as ecosystem component species (ECS), consistent with the new National Standard 1 guidelines revised in response to the 2007 reauthorization of the Magnuson-Stevens Act (MSA)[5]. The NPFMC also created an Arctic FMP in 2009 whose primary purpose was to preclude new commercial fisheries in the Arctic Management Area, including for forage species, unless and until robust information was available and deemed sufficient to approve a new fishery.[6]

Meanwhile, the Pacific Fishery Management Council (PFMC) amended its Coastal Pelagic Species FMP to put in place a harvest prohibition on all species of krill.[7] The PFMC is also actively considering additional protections for all other unmanaged forage species, and in June 2012 adopted an objective of prohibiting new directed fisheries on unmanaged forage species.[8]

These examples of precautionary forage policy do not create winners and losers, nor do they have significant negative impacts on existing fisheries. In fact, proactive and precautionary management of the forage base can help increase both the productivity and sustainability of all fisheries. Conservation groups are not alone in this view. The NPFMC's ban on new fisheries for forage species is hailed in an industry-sponsored study as one of thirteen "best practices in ecosystem-based fishery management" (Warren 2007). The use of the ECS category by the NPFMC to advance an ecosystem-based approach to management through forage protection is of particular note. The NPFMC has applied the category to implement concrete measures to understand and protect the food web, recognized as one of the basic tenets of ecosystem-based fishery management (Christensen and Maclean 2011).[9] This approach should be undertaken by additional fishery management Councils.

Existing Legal and Regulatory Tools and Authority to Manage Forage Fish

Several MSA provisions provide authority for management of forage fish. The MSA requires every FMP to contain a number of specific provisions, all of which must be consistent with ten National Standards (NS) for conservation

3 See Final Rule implementing Amendments 36/39 to the NPFMC Groundfish FMPs at http://tinyurl.com/kbpjuxb. This action identified and protected over 20 important forage species in 9 scientific families by prohibiting directed fishing on those species.

4 50 CFR 679. See also June 2004 PFMC Meeting. Exhibit G.4.a Situation Summary.

5 See Final Environmental Assessment for Amendments 87/96 to the NPFMC Groundfish FMPs at http://tinyurl.com/lkhqunb.

6 See Final Rule implementing the Arctic FMP at http://tinyurl.com/km37bc9.

7 See 2009 Final Rule implementing the Amendment 12 to the CPS FMP at http://tinyurl.com/kxnl5c3.

8 See June 2012 PFMC Decisions Summary at http://tinyurl.com/cqrlxrg, page 4.

9 See Ecosystem-Based Fishery Management: a Report to Congress by the Ecosystem Principles Advisory Panel, available at http://tinyurl.com/mv4k3nd at pp. 29 and 33.

and management.[10] Importantly, NS 2 requires that all management measures be based on the best available scientific information.[11] The MSA also provides managers with discretion to implement additional measures that can be used to manage forage fish, including broad authority "to conserve target and non-target species and habitats, considering the variety of ecological factors affecting fishery populations; and . . . prescribe such other measures . . . necessary and appropriate for the conservation and management of the fishery."[12] While the MSA's required and discretionary provisions provide ample authority to manage forage species, and more broadly to engage in ecosystem-based management, codifying some of these provisions into requirements would create a strong framework for future management of forage fish. Several of the relevant provisions of the Act are briefly summarized below:

1. *Stocks in the Fishery*. The MSA requires that managers include any stock in need of conservation and management in an FMP.[13] In making this determination, Councils are required to look to factors such as the need for
   - rebuilding, restoring, or maintaining "any fishery resource and the marine environment,"
   - assuring among other things, a food supply and recreational benefits, and
   - avoiding long-term adverse effects on fishery resources and the marine environment.[14]
2. *NS 1: Preventing Overfishing*. The NS 1 requirements to achieve the dual goals of preventing overfishing while achieving optimum yield on a continuing basis have primacy over all other MSA requirements.[15] "Overfished" and "overfishing" are defined as "a rate or level of fishing mortality that jeopardizes the capacity of a fishery to produce the maximum sustainable yield on a continuing basis."[16] As fisheries managers typically recognize, the Act requires that excessive mortality of any forage stock must be reduced or maintained at levels necessary to prevent overfishing of that same stock of forage fish. However, the overfished/overfishing definition does not specify that the fishery experiencing an excessive rate or level of fishing mortality, and the fishery whose capacity to produce MSY is jeopardized, be the same fishery. Thus, the MSA provides the authority to manage the mortality of forage species at levels that do not jeopardize the capacity of dependent predator species to produce MSY.[17]
3. *NS 1: Achieving Optimum Yield (OY).* The MSA defines "optimum yield" as the amount of fish that "will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities, and taking into account the protection of marine ecosystems," and "is prescribed as such on the basis of the maximum sustainable yield from the fishery, as reduced by any relevant economic, social, or ecological factor."[18] The NS 1 guidelines reflect this statutory emphasis on ecosystem protection, specifying that "maintaining adequate forage for all components of the ecosystem" is a key consideration relevant to OY.[19]
4. *Annual Catch Limit (ACL) Requirements*. Setting ACLs requires establishment of a scientifically-robust acceptable biological catch (ABC) control rule.[20] An appropriate ABC control rule establishes an approach for setting catch levels that will vary as a function of where the stock is relative to an appropriate target biomass (target above Bmsy for forage fish) and accounts for scientific uncertainty.[21] NS 2 requires that ABC control rules be based on the best available science, and several recent studies address setting ABC control rules for forage fish, and call for new approaches (Pikitch et al. 2012, Smith et al. 2011, Cury et al. 2011,

10 16 U.S.C. §§ 1853(a), 1851(a).
11 16 U.S.C. § 1851(a)(2).
12 16 U.S.C. § 1853(b)(12)-(14).
13 16 U.S.C. § 1852(h)(1); 50 C.F.R. § 600.310(d), (h).
14 See 16 U.S.C. § 1802(5).
15 16 U.S.C. § 1851(a)(1); 50 C.F.R. § 600.310(l).
16 16 U.S.C. § 1802(34).
17 NMFS's essential fish habitat (EFH) guidelines support this interpretation of overfishing. These regulations specify that the loss of prey species may constitute an adverse effect on EFH and note that habitat loss or degradation can contribute to a species being identified as overfished. 50 C.F.R. §§ 600.810(a), 600.815(a)(1)(C), (a)(7).
18 16 U.S.C. § 1802(33).
19 50 C.F.R. § 600.310(e)(3)(iii)(C).
20 16 U.S.C. § 1852(g);50 C.F.R. § 600.310(b).
21 See e.g., 50 CFR § 600.310(c)(3), (f)(2)(ii)-(iii).

Tyrrell et al. 2011). Thus, setting ABC control rules for forage fish based on the best available science requires management consistent with the risks associated with forage fish populations' tendency to swing dramatically, their high catchability, and the critical role of forage fish as food for commercially valuable species, marine mammals, and seabirds.

5. *Essential Fish Habitat (EFH).* EFH includes "the waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity," and each FMP must "describe and identify [EFH] for the fishery . . ., minimize to the extent practicable adverse effects on such habitat caused by fishing, and identify other actions to encourage the conservation and enhancement of such habitat."[22] EFH regulations treat prey species as an integral component.[23]
6. *Minimizing Bycatch.* National Standard 9, and related provisions, require that conservation and management measures minimize bycatch to the extent practicable.[24] Forage species tend to swim in large schools and sometimes mix with other species of forage fish (e.g., river herring and Atlantic herring). They are thus susceptible to becoming bycatch, because fisheries targeting forage species generally use large mid-water trawl nets or purse seines capable of indiscriminately taking entire schools of fish.
7. *Maximizing Economic and Social Benefits*. National Standards 4 and 8 support managing forage species to maximize overall economic and social benefits to fishermen and fishing communities, consistent with the MSA's conservation provisions.[25] Conserving forage species can be crucial to these requirements because forage species provide the prey base that supports recreational and commercial fisheries.
8. *Non-Magnuson-Stevens Act Authority*. Additional authorities exist that can affect forage fish management.
   - *Interstate Fisheries Management*. Near-shore fisheries are typically managed in coordination by states through interstate compacts with varying levels of binding authority, and in some cases an overlay of Federal authority. For example, on the East Coast the ASMFC manages state fisheries pursuant to a compact and the Atlantic Coastal Fisheries Conservation and Management Act gives ASMFC plans legal force.[26] These authorities require "coastal fishery management plans" consistent with Magnuson-like standards designed to ensure that FMPs "promote the conservation of fish stocks throughout their ranges and are based on the best scientific information available."[27]
   - *Endangered Species Act (ESA)*. The ESA provides protection for endangered and threatened species.[28] Key authorities strictly limit the take of listed species, require designation of critical habitat and plans for their recovery, and impose consultation requirements on Federal agency actions affecting listed species.[29]

Improving Forage Fish Management as a Step Towards Ecosystem-Based Fishery Management

Currently, single-species management characterizes most fishery management strategies in the United States, including forage fish fisheries. Over the last several years, fishery management Councils and NOAA Fisheries have begun to discuss and plan for moving away from single-species management towards ecosystem-based fishery man-

22 16 U.S.C. §§ 1802(10), 1853(a)(7).
23 50 C.F.R. §§ 600.810(a), 600.815(a)(7).
24 16 U.S.C. §§ 1851(a)(9), 1853(a)(11).
25 16 U.S.C. §§ 1851(a)(4), (8).
26 16 U.S.C. §§ 5104 –5108.
27 See e.g., 16 U.S.C.. § 5104(a)(2)(A).
28 16 U.S.C. § 1531(b).
29 16 U.S.C. §§ 1538(a)(1)(B), 1533(a)(3)(A), 1533(f)), 1536(a)(2).

agement. Changing management strategies for the nation's forage fish to precautionary management can be a useful next step in this transition.

Precautionary Management

Because of the vital role forage fish play in marine ecosystems and the reliance of predators on healthy forage fish populations, a precautionary management strategy is advised. While many forage fish are currently unmanaged or managed for maximum sustainable yield, forage fish are often overexploited, negatively impacting predators and marine ecosystems in general. The LFFTF recommended specific precautionary catch levels to protect forage fish and their dependent predators. Management strategies that limited fishing rates (F) to half the conventional rate effectively headed off declines in dependent predator populations. Reducing the fishing on forage fish not only benefited predators but also reduced the risk of collapsing forage fish populations, albeit with some forgone commercial yield. This approach must be considered for future management of forage fish species.

Ecosystem-Based Fisheries Management

Just about everyone whose livelihood depends on going to sea in search of fish understands that the fish they depend on are part of an intricate system of predators, prey, and habitat—an ecosystem. When humans first began to fish the seas close to shore, their predation was readily absorbed by thriving marine ecosystems. All this changed as the abundance of people and the power of fishing technology exploded: people became such a powerful force that they unwittingly transformed the ecosystems they depended upon, leading to the disappearance of critical fish stocks, and other unfortunate consequences. Single species management of fishing has helped, but has proven inadequate to restore marine ecosystems because it fails to account for the interactions among species that are fundamental to the food webs. Basic dependencies among predators and their prey, for example, continue to be perilously ignored. Entire ecological regions such as the Northeast U.S. are being subjected to ecosystem overfishing (Murawski 2000).

Ecosystem-based fisheries management (EBFM) is a promising approach to fisheries management that is within reach, offering a solution to these problems, but it remains to be fully implemented in U.S. Federal waters. In simple terms, EBFM is managing fisheries within an ecological region "so as to coordinate, account for, and include all factors in a holistic, synthetic, integrated fashion" (Link 2010). These broad goals of EBFM can be achieved through a range of approaches from simple steps, to the use of multispecies or full ecosystem models. Implementing management plans that take into account the unique role that key forage species (such as Atlantic herring, menhaden, sardines, and krill and other zooplankton) play in the marine ecosystem is a common sense, first step along the path to EBFM. Fisheries management has failed in many places because it has not recognized the ecosystem and has not been sufficiently precautionary. Precautionary management of forage fisheries, and protections for these key species, has not yet been applied to directed fisheries, although it is crucial to the future of a healthy U.S. fishing industry.

Lenfest Forage Fish Task Force Recommendations

In reviewing various ecosystems, the LFFTF considered both the impact of fishing on the forage species themselves and the consequences of removing these fish from the ocean for the predators that depend on them as food. They discovered that conventional MSY management practices when applied to forage fish are often riskier than expected because these small schooling fish are particularly vulnerable to net capture and because these fishes typically undergo relatively wide population swings. They also discovered that harvest of forage fish puts their predators at risk of collapse.

Based upon an extensive analysis of ecosystems around the world, the LFFTF recommends managing forage fish so that the biomass is kept at levels substantially above those typically used as targets for other kinds of fish. In every case, they recommend a careful evaluation of the available information for a given forage species and its dependent predators, with specifics of guidance tailored accordingly. It is generally recommended that harvest control rules be adopted that stop fishing when population biomass falls below a threshold (e.g., corresponding to 40 percent of the biomass expected without fishing), and that strive to keep the biomass near 75 percent of B_0. Fishing mortality (F) should be held below half of the traditional F_{MSY}, or to half of the natural mortality rate if that is well-estimated and less than F_{MSY}. The Task Force also recommended that no new fisheries should be allowed to develop on forage stocks with limited information, a description that characterizes most currently unfished and unmanaged forage species.

In summary, the work of the Task Force shows that forage fish play a vital role supporting ecosystems and that the best available science demands a precautionary approach to managing these stocks (Gerrodette et al. 2002). In terms of developing new fisheries for as yet unexploited stocks of forage fish, caution is clearly warranted and the burden of proof must be on those proposing such fisheries to clearly establish that the proposed fisheries are ecologically-sound based on new scientific work on forage fishes. The U.S. should make precautionary management of its forage fishes a priority as a critical step toward EBFM, and fisheries management should move away from MSY management for these species.

Suggested Requirements Before New Forage Fish Fisheries are Conducted

Because of the important role forage fish play in marine ecosystems, new forage fish fisheries should be prohibited until a stock assessment has been conducted and required criteria for measuring when the stock is overfished and overfishing is occurring has been established. The stock assessment and stock status criteria must take into account:

- Ecosystem functions of the target forage fish.
- Historical, current, and future needs of predators that consume the target species.
- Variable abundance of the target species in response to fluctuating environmental conditions.

Fishing should be allowed only after an FMP is developed that:

- Establishes a management program that is consistent with the recommendations of the Lenfest Forage Fish Task Force, including the harvest control rule, precautionary mortality reference points, and a biomass target closer to the biomass with no fishing (B_0) than is typical in conventional management (i.e. $B>B_{MSY}$).
- Evaluates and quantifies the bycatch and habitat impacts of the fishery.
- Implements measures to monitor and reduce bycatch and habitat impacts in the fishery.
- Analyzes the environmental consequences of target species removals and the economic costs and benefits of direct harvest compared with leaving forage fish in the water.

Developing Federal Management Plans for Forage Fish Primarily Caught in Federal Waters

U. S. Federal fisheries management has a strong record of ending overfishing and in a number of cases rebuilding depleted fish stocks (NOAA 2012). However, many forage fish species that swim in the nation's Exclusive Economic Zone are currently unmanaged in Federal waters, and are also either unmanaged or poorly managed in state waters by interstate fishery management bodies. Efforts are underway to bring additional forage fish, such as river herring and shad on the East Coast, under Federal fishery management plans.[30] Improved coordination between interstate and Federal management is also required. Many additional species of forage fish would benefit from the requirements outlined in the MSA (e.g. ending overfishing, rebuilding fish stocks, minimizing bycatch, protecting habitat). This could be accomplished through joint management by Federal fishery management Councils, NMFS

30 See MAFMC, Scoping Document for Amendment 15 to the Atlantic Mackerel, Squid and Butterfish Fishery Management Plan, available at http://www.mafmc.org/fisheries/fmp/msb.

and interstate compacts like the Atlantic States Marine Fisheries Commission. Managing these forage fish by the standards of the MSA, and ultimately transitioning to EBFM, will result in a benefit to predators, the ecosystem, and the nation as a whole.

Conclusion

Forage fish play an important role in the nation's marine ecosystems and in the diets of top marine predators. For this reason, management of forage fish must be aligned with new ecosystem science and improved accordingly. The Lenfest Forage Fish Task Force report, which provides a set of robust recommendations to protect forage fish and move our nation's fishery management forward, should serve as the basis for sound management of our critically important forage species. Many more species of forage fish must be brought under precautionary, Federal management as the nation transitions from single-species to ecosystem-based fisheries management.

Key Recommendations

- Transition from single-species to ecosystem-based fisheries management.
- Ecological role of forage fish should be accounted for when setting catch limits.
- Economic value of forage fish should be expanded to include their supportive value to other commercial and recreational fisheries, and eco-tourism industries.
- Risk of wide population swings and high catchability of forage fish should be accounted for in fishery management plans.
- Stock assessments and FMPs should be developed before forage fisheries can be expanded or initiated to maintain their vital role in marine ecosystems.
- Protections afforded in the MSA should be given to forage fish caught in Federal and state waters, through improved coordination between fisheries management authorities.

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A Scientific Perspective on Ecosystem Relationships of Forage Fish

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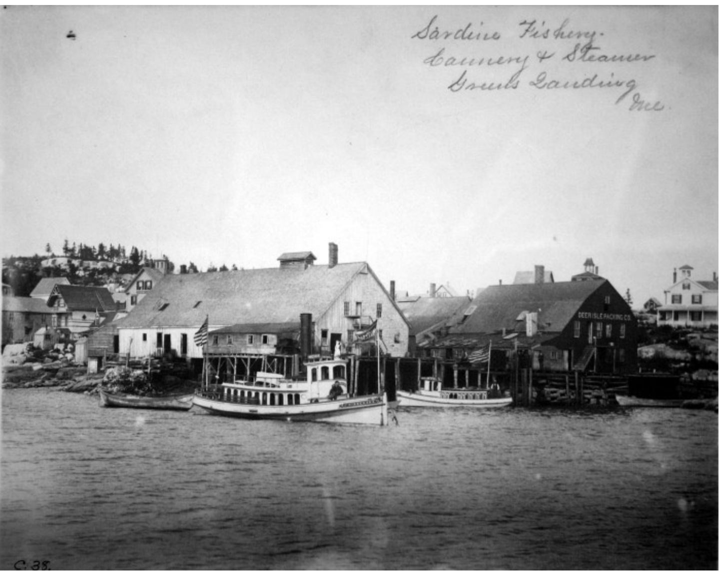
Abstract

Forage fish such as anchovy, sardines, herring, and menhaden are typically highly abundant plankton feeders, form dense schools, and play a key role in transferring production from phytoplankton and zooplankton to larger predators. On the global scale, harvests of forage fish total over 20 million metric tons annually and account for 25-30 percent of global fisheries landings. The key scientific challenges with respect to forage fish are understanding their high levels of population fluctuation, and understanding their supporting role—both ecologically and economically—in the fishery food web and ecosystem. Both characteristics make traditional fishery reference points (such as maximum sustainable yield) difficult to estimate. New approaches, largely based on global data analysis, economic analyses, and ecosystem modeling, can help to evaluate the trade-offs between forage fish yield, harvest of predatory fish, and persistence of protected predators and other marine species. Encouragingly, recent modeling work suggests that very simple harvest policies, quite similar to those already put in place by Regional Fishery Management Councils for many stocks, may be robust to climate-driven population fluctuations, and may minimize impacts of forage harvest on other fisheries and predators. The challenge at a regional level may be to identify, from a policy perspective, how to adjust harvest policies so that trade-offs are acceptable to stakeholders and the public.



Introduction

Definition of Forage Fish

On the global scale, harvest of forage fish such as anchovy, sardines, herring, menhaden, capelin, and mackerel total over 20 million metric tons annually and account for 25-30 percent of global fisheries landings (Figure 1). Forage species are typically highly abundant plankton feeders, form dense schools, and play a key role in transferring production from phytoplankton and zooplankton to larger predators (Smith et al. 2011). This definition excludes juveniles of species that mature to much larger sizes (e.g. tunas); it also excludes some smaller species (e.g. shortbelly rockfish, *Sebastes jordani*) that are known to be important prey items (Ainley et al. 1996, Lowry and Carretta 1999) but differ in other respects such as schooling behavior and life history. In the context of Regional Fishery Management Councils, a clear definition of "what is a forage fish" has been useful in the drafting of a Fishery Ecosystem Plan for the U.S. West Coast (Pacific Fishery Management Council 2011).

Here I focus mostly on forage *fish*, but the broader scientific literature on forage species includes invertebrates such as krill (*euphausiids*) and squid. The scientific literature on krill harvest and management in Antarctica offers examples of precautionary management and an awareness of the role of krill for predators such as whales, penguins, and fur seals (Constable et al. 2000). Euphausiid harvest has ranged from 104,000–215,000 metric tons annually during 2005–2010 (FAO 2010).

In this review, I first give some context by presenting data on U.S. forage fish landings. I then discuss the relationships between forage fish and their environment, in terms of oceanographic effects, population cycles, and the role that forage fish play in supporting predator populations. Finally, I discuss challenges and scientific evaluations of options for management of forage fish. Examples are taken from international studies as well as from U.S. fish stocks, with a bias towards the U.S. West Coast.

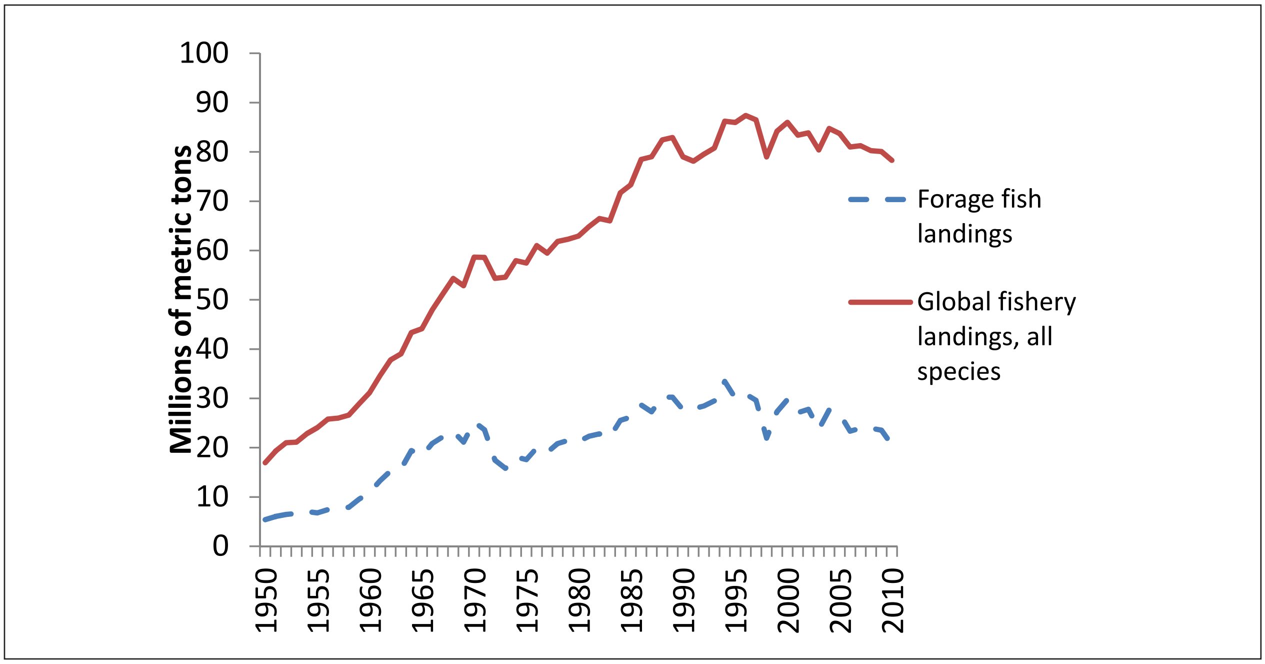


Figure 1. Global landings of forage fish and krill (FAO 2010); Forage fish here include the category "Herring, sardine, anchovy" as well as mackerels and capelin. Forage species were approximately 26%-32% of global landings for 2005-2010.

Discussion

Trends in U.S. Forage Fish Landings

U.S. landings of forage fish have been fairly stable at 715,000–1.5 million metric tons annually since 1950 (Figure 2), though there are important distinctions in trends for individual stocks. Landings for the period from 2005-2011 increased from 786,000 to 1.15 million metric tons; almost 70 percent of total landings are Atlantic and Gulf menhaden.

On the East Coast and Gulf of Mexico, alewife were harvested in the 1950s and 1960s but declined steeply after that (Figure 3). Aside from menhaden, landings are dominated by herring (with a peak of 101,000 metric tons in 2009), with increases in mackerel landings beginning in the 1980s. West Coast landings data (Figure 4) and abundance demonstrate cyclical patterns for anchovies and sardine (MacCall 1996). California market squid landings now exceed those of forage fish, and squid are also a major prey item for West Coast predators.

Figures 3 and 4 illustrate a key characteristic of forage species: they tend to have very large (more than tenfold) changes in population abundance that occur over short periods, often less than a decade. These population fluctuations are evidenced in both landings data and surveys of population abundance. When considering the impacts that these landings have on the harvested stocks (whether sardine, herring, menhaden, etc.), it is valuable to view these removals as a fishing mortality rate or exploitation rate. This exploitation rate can be compared between stocks or subspecies with similar productivity. For instance, Pacific sardine (*Sardinops sagax caerulea*) exploitation rates by the U.S., Mexico, and Canada are currently 0.145 (Hill et al. 2011), while the subspecies of Australian sardines (*S. sagax neopilchardus*) is currently lightly fished, with a fishing mortality rate of less than 0.03 yr^{-1}. Stocks of the South

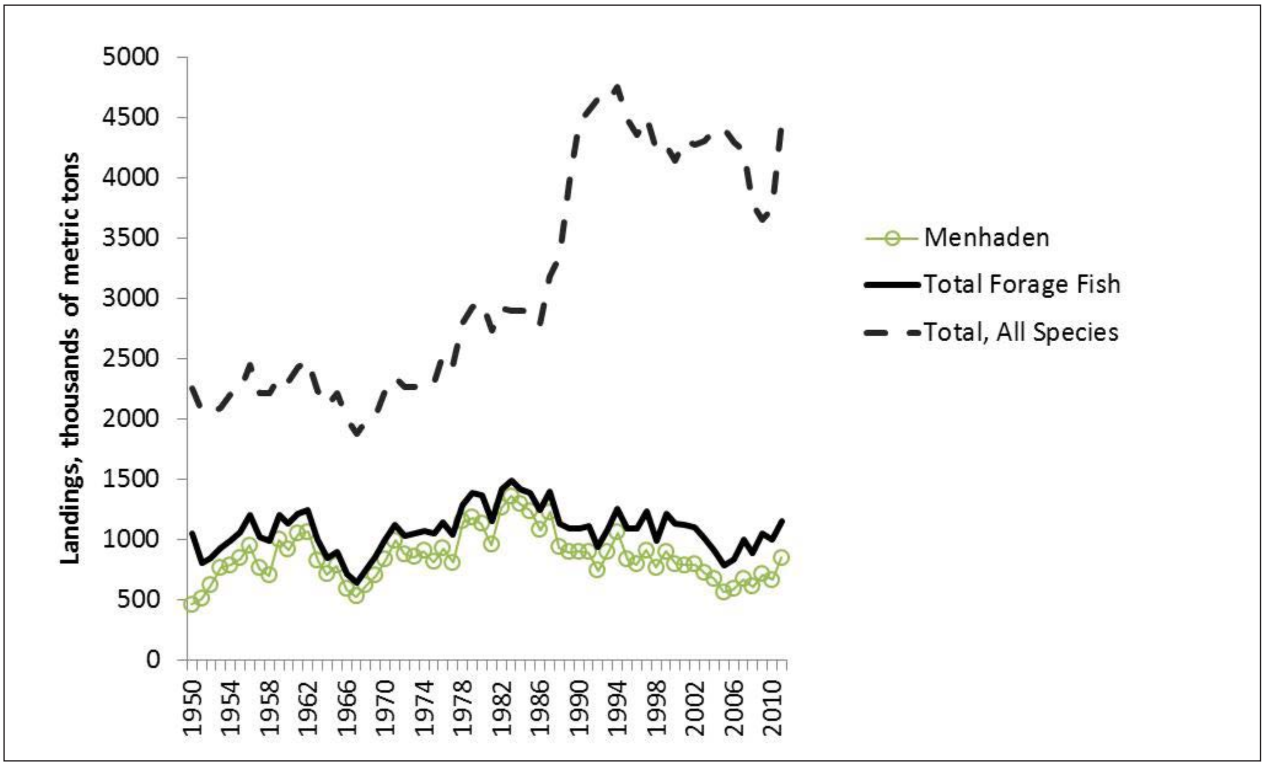


Figure 2. U.S. landings of menhaden, all forage species (including menhaden), and all species combined (NOAA ACL database 2012); Forage species here include alewife, anchovies, Atlantic herring, Pacific herring, jack mackerel, Atlantic mackerel, chub mackerel, menhaden, Pacific sardine, California market squid, and longfin squid.

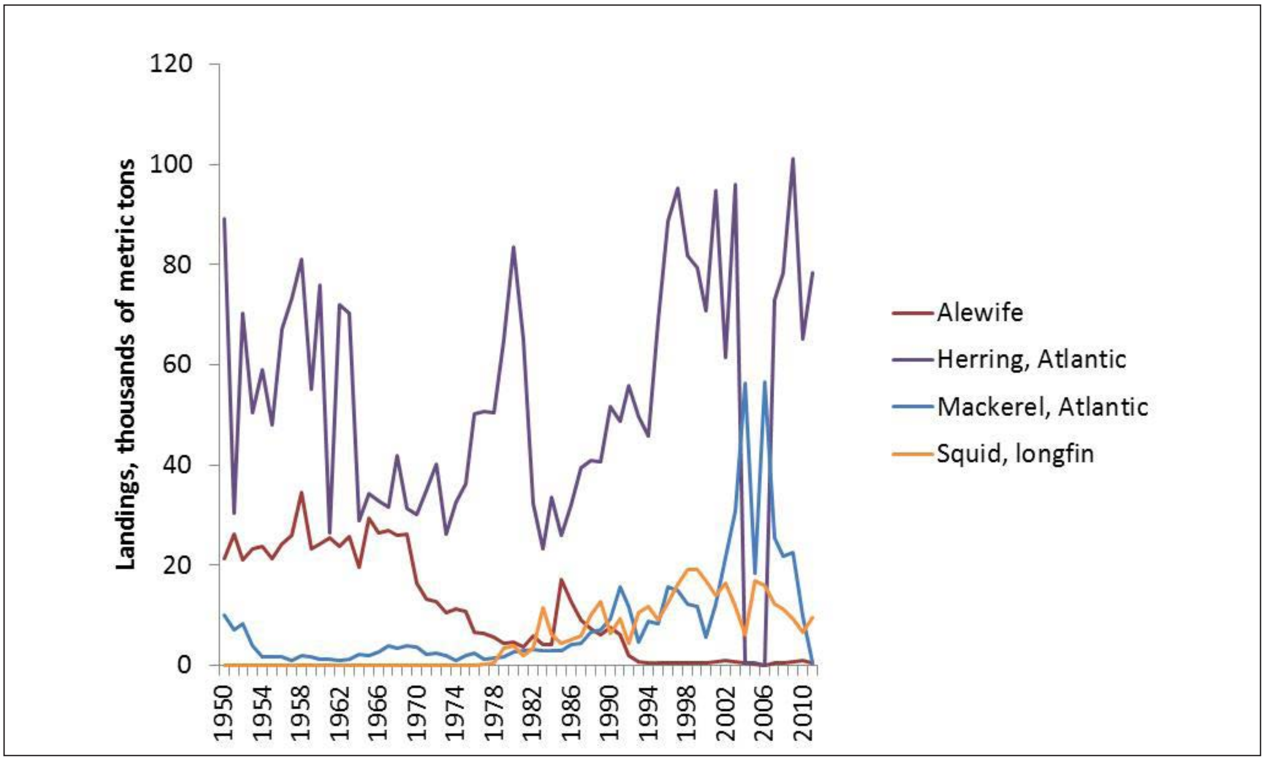


Figure 3. U.S. landings of forage species (excluding menhaden) along the Atlantic and Gulf of Mexico coasts (NOAA ACL database 2012). Minor forage species with annual landings <50 metric tons not shown.

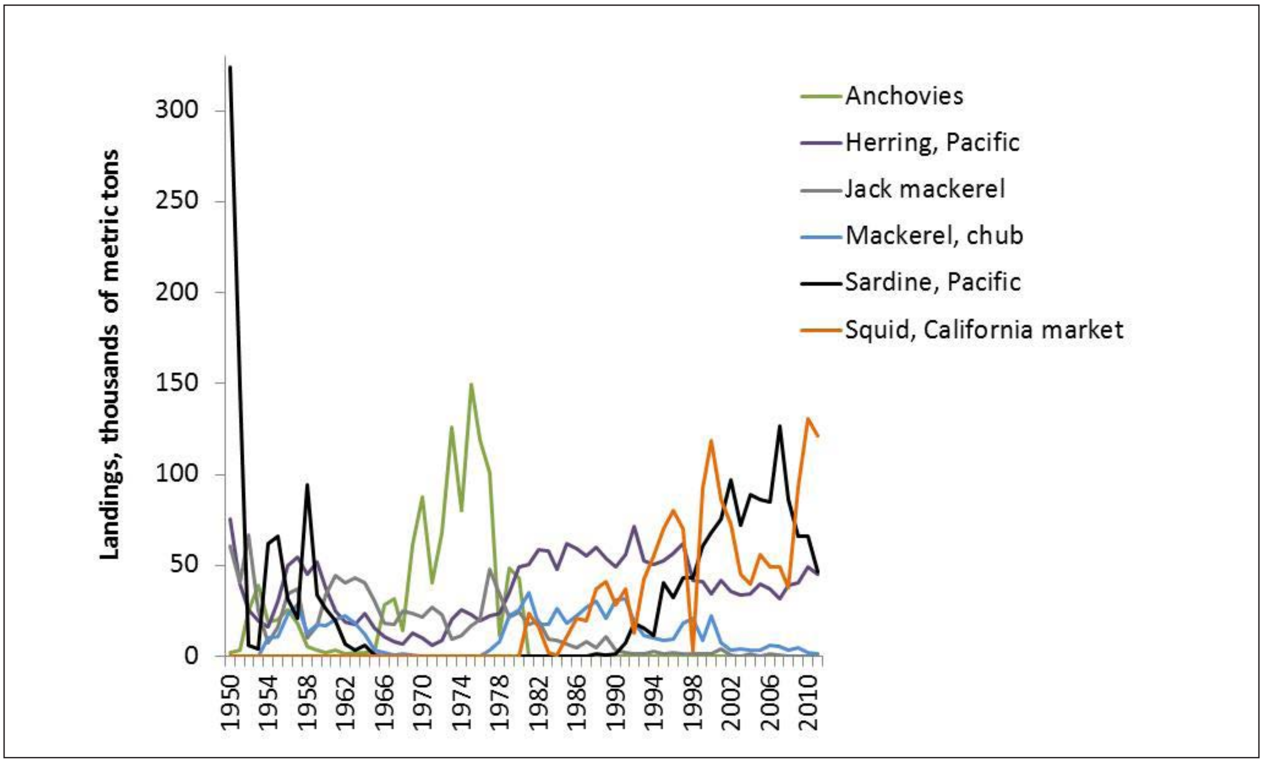


Figure 4. U.S. landings of forage species in West Coast and Alaskan waters (NOAA ACL database 2012). Minor forage species with annual landings <50 metric tons not shown.

African and Namibian subspecies (*S. sagax*) have fishing mortalities closer to 0.3 yr^{-1}; and the North/Central Peruvian stock (*S. sagax*) is currently harvested at approximately 0.18 yr^{-1} (Barange et al. 2009).

On a very crude level, the landings data illustrate the tons of prey (forage) removed from the systems, and no longer available to predators. The implications of such population fluctuations and predator demands are discussed below.

Population Dynamics and Role of Forage Fish in the Food Web

POPULATION FLUCTUATIONS

Forage fish differ from other stocks due to their population fluctuations and to their ecological role in the food web. Fishery landings, scientific surveys, and on-the-water experience point to the strong decadal-scale cycles in many forage fish stocks. Such cycles occur for fishery landings throughout the world (Alheit et al. 2009). European catch records indicate strong fluctuations in catch, and likely abundance, of herring and sardines over ten centuries (Alheit and Hagen 1997). On the U.S. West Coast, Baumgartner et al.(1992) have identified strong cycles of abundance in patterns of fish scales deposited in the sediment over the last 1700 years. It is notable that these fluctuations were present long before modern fishing began; this does not mean that fishing lacks effect, but that it occurs in the context of somewhat unstable productivity for these stocks. For sardine and anchovy, previous authors have suggested that there was a global synchrony to fluctuations of each species, and that the two species cycled asynchronously (out of phase). However, new evidence and interpretation suggests that these cycles are determined by processes at the scale of single oceans, rather than by global drivers, with no consistent inverse correlation between sardine and anchovy abundance (Field et al. 2009, MacCall 2009a).

Though environmental or climate effects are often assumed to drive these cycles, disentangling the exact mechanism is not always straightforward. In Chesapeake Bay, Kimmel and colleagues (2009) found that years with low precipitation and low river discharge coincided with higher abundance of juvenile menhaden. These authors proposed that entry of menhaden larvae from the ocean into the Chesapeake may be facilitated during dry years. For sardine and anchovy stocks, the exact mechanism for population fluctuations has been debated for nearly forty years. One theory by MacCall (2009b) noted that anchovies are smaller, and are therefore restricted to areas closer to shore, and so their productivity declines when nearshore upwelling and nutrients decline during periods of weak currents. In a comparable study, van der Lingen and colleagues (2006) proposed that warm water conditions associated with weak currents favor a food chain with smaller plankton that are primary prey for sardine; during stronger current flows and colder conditions, larger plankton species become more abundant, as does their predator, anchovy.

Just as bankers may be more interested in forecasts of what the stock market will do, rather than why it will do it, natural resource managers and the fishing industry may be satisfied with straightforward measures that predict trends in forage fish populations. However, even identifying these simple proxies can be challenging. For instance, Jacobson and MacCall (1995) found that Pacific sardine recruitment increased with sea surface temperature. In an analysis of the continuing time series, McClatchie et al. (2010) found that the relationship no longer held; an even more recent study with improved statistical analyses (Lindegren and Checkley 2012) suggests that the relationship remains valid. Such scientific debate is not merely an academic exercise, as the Pacific Fishery Management Council has in the past adjusted harvests following a rule that includes temperature (Hill et al. 2008).

Role as Prey

Predator diets, whether observed in a laboratory or at a filleting table, often indicate that small pelagic fish are important as prey. For example, on the West Coast (Figure 5), seabirds, salmon, and albacore tuna diets suggest reliance on forage fish such as sardine, anchovy, herring, and smelt for more than 50 percent of their diets (Dufault et al. 2009). In systems such as the Benguela Current in the South Atlantic off Africa, an upwelling region similar to the U.S. West Coast, a small number of forage species play critical roles in transferring primary and plankton production to top predators (Cury 2000). In a global review that utilized 72 ecosystem models to handle the "book keeping" of predator diets, Pikitch et al. (2012b) found that half of all predator groups relied on forage fish for more than 10 percent of their diets, and 16 percent of predators relied on forage fish for more than 50 percent of their diets.

Below, I discuss the evidence that reduced abundance of forage species can impact predator abundance, particularly predators that can't easily switch from forage fish to some other prey species. The extent to which predators decline when forage fish are depleted is relevant to potential impacts on harvested predator stocks, and species of conservation concern such as marine mammals and birds. Finally, I discuss fishery management responses that may address this concern.

Food Web Impacts of Fishing Forage Fish

The move toward ecosystem-based management of marine resources (Pikitch et al. 2004, McLeod and Leslie 2009) has encouraged a broader perspective regarding the impacts of fishing. Fishing on small pelagic fish is understood to potentially impact a suite of non-harvested species, particularly predators. Recent advances in scientific capacity, in particular global analysis of long-term data sets and development of ecosystem models, can begin to quantify expected food web responses.

Though it is difficult to predict complex food web responses from observations of a single location or system, global analyses by large groups of scientists have offered key insights. A team of scientists studied 14 species of seabird in seven different marine ecosystems (Cury et al. 2011) and suggested that seabird breeding success declines when prey abundances are less than about 1/3 maximum. (Prey included forage fish but also a broader set of species such as krill and walleye pollock.) The authors suggest that this may be a rule of thumb for ecosystem-based management of forage stocks.

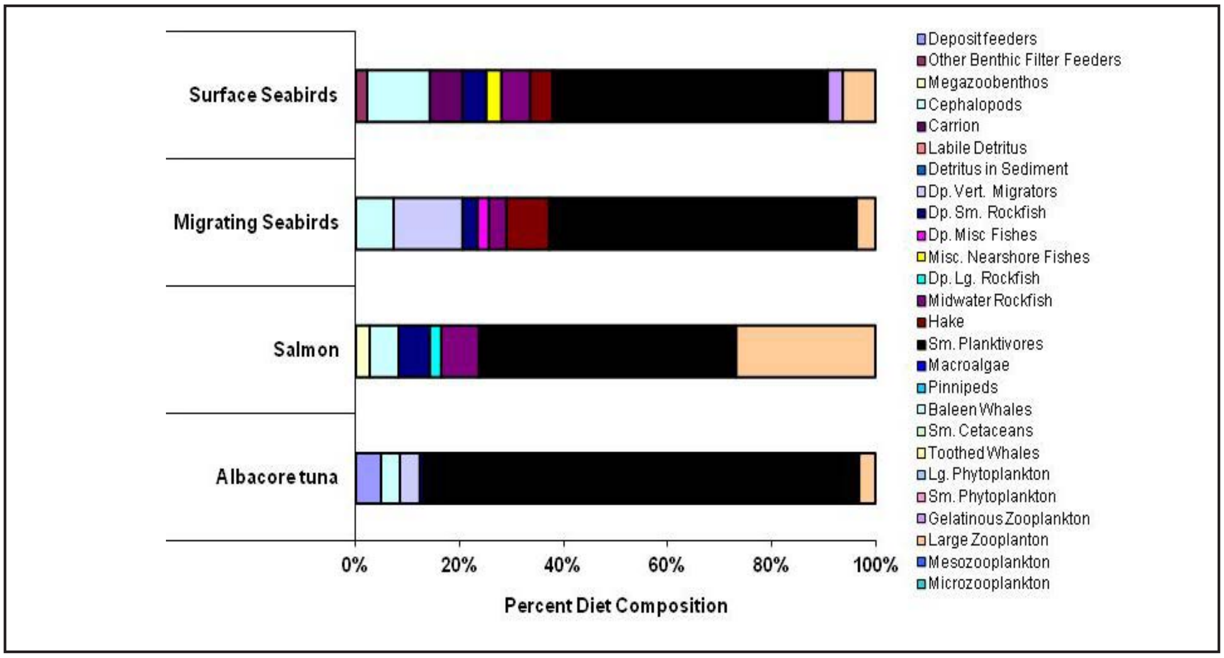


Figure 5. Diet composition of four groups of predators in the California Current, U.S. West Coast. Black portions of bars are small planktivores, a forage group that includes sardine, anchovy, smelt, and herring. From Dufault et al. 2009.

Ecosystem models (Rose et al. 2010, Fulton 2010) are a new type of analysis that has developed rapidly as computer speed increased in the last decades. Such models typically simulate and predict oceanographic conditions, multiple species of predators and prey, and fishing. In most models, predator diets fluctuate as different prey items change in their abundance or availability. Several ecosystem modeling frameworks operate on a map-based framework, while others ignore space (much like a traditional stock assessment). These models are almost always intended as strategic tools—essentially "flight simulators" to test ideas about how the ecosystem works, how fisheries might respond, and what implications stem from management actions. Ecosystem models are not tactical tools that would be used for example to precisely set quotas.

In an ecosystem modeling study, Smith et al. (2011) found that across five global regions, harvest of forage groups had large impacts—positive and negative—on many other species. This was particularly true for forage groups that comprised large portions of an ecosystem's biomass, or that were highly connected in the food web (e.g. had many predator/prey links). The study included forage fish, but also key prey groups such as myctophids (lanternfish) and krill. Biomass changes of more than +/- 40% were observed throughout the food webs, including fishery target species. Impacts on seabirds and marine mammals were often negative. The authors found substantial impacts on the food web when forage stocks were fished down to levels (typically 60 percent of unfished abundance) that gave maximum sustainable yield. Reducing catches so that forage species were fished less intensely (to 75 percent of unfished abundance), reduced these food web impacts but led to only 20 percent reductions in yield. Consistent with Smith et al, Kaplan et al. (2013) found that harvest of forage fish and krill had large impacts in two ecosystem models that simulated the California Current food web. Depleting krill to 40 percent of unfished levels altered the abundance of 13–30 percent of the other functional groups by more than 20 percent. Depleting forage fish to 40 percent altered the abundance of 20–50 percent of the other functional groups by more than 20 percent.

The focus of the ecosystem modeling studies above was primarily to characterize the magnitude of impacts, and to identify broad groups (such as all birds or mammals) that might be most susceptible to forage fish depletion. Another recent study (Pikitch et al. 2012a) identified specific characteristics of predators that predict this susceptibility. Drawing from ten ecosystem models in a global database, Pikitch and colleagues (2012a) developed statistical relationships that predict the likelihood of a particular predator declining, given the amount of targeted forage species in its diet, and the forage species' depletion level. For instance, for a predator with half of its diet comprised of a forage species, the forage species would need to be maintained above 57 percent of unfished levels for a decline of more than 50 percent for that predator to be unlikely or very unlikely. The results could serve as guidelines for systems or species that lack the detailed ecosystem modelling analyses of Smith et al. (2011).

In summary, modeling results and some observational studies suggest that predators, and the food web in general, are affected by depletion of forage groups. Predators will often decline when forage fish are depleted, though predators' ability to switch diets may lead these declines to be less severe than would be predicted by diet compositions alone. Finally, some species that are prey or competitors of forage fish may increase in abundance when forage fish are removed.

Ecosystem models, including those discussed above, are always incomplete cartoons of the true world. One large gap is modelers' inability to represent local depletion of forage fish around bird and mammal colonies, rookeries, and haulouts. Local depletion of forage stocks, and negative impacts on critical life stages such as seabird fledgelings (Ainley et al. 2009, Hipfner 2009), may explain differences between the coast-wide view taken by much of the modeling, and site-specific observations such as those by Cury and colleagues (2011) of seabird reproduction. A final consideration is that most ecosystem models do not reproduce the dynamic fluctuations that are typical of forage fish populations. Further use of ecosystem models to evaluate harvest policies will require either that such fluctuations are directly forced on the models, or that detailed feeding mechanisms (such as those described above for sardine and anchovy) are included to lead the models to reproduce these cycles.

The Case for Balanced Exploitation

Though there has been an increasing demand for conservation of forage fish, balanced exploitation—harvest of forage species as well as higher trophic level species—may reduce negative ecological effects. Zhou and colleagues (2010) argued that fishery managers should attempt to spread fishing mortality more evenly across species, sizes, and sexes, in an effort to minimize impacts on biodiversity, ecosystem function, and ecosystem and fishery productivity. Such balanced exploitation would establish minimum abundances for each target population, above which fishing would be allowed at a rate proportional to the productivity of the stock (Zhou et al. 2010). This concept of proportional mortality implies that fast-growing and early-reproducing species, including most forage fish, could be fished more heavily than longer-lived species. A broader set of forage species would be harvested, though harvests would not necessarily increase on current target forage stocks. Garcia and colleagues (2012) tested the concept of balanced exploitation using 36 multi-species ecosystem models that represented 30 systems around the world. They found that harvest policies that encouraged fishing across a broad range of species and sizes led to higher yields, fewer extinctions, and higher abundances.

For many parts of the U.S., balanced exploitation would be a paradigm shift in management—a shift toward exploitation and assessment of a broader 'basket' of forage species; high exploitation rates for productive forage fish groups; less emphasis on bycatch reduction; and development of markets for large volumes of species that are traditionally discarded and not targeted. Fishery Councils and other resource managers, whose management actions are often currently triggered by single-species reference points (in other words, if a species is above or below some threshold abundance), would likely be guided more by community and ecosystem metrics related to biodiversity, size of fish, and likelihood of extinction or reduction of biodiversity. Though these are not the currencies of most U.S. fisheries management, metrics of fish size and diversity are now calculated by NOAA from existing fisheries and survey data (Ecosystem Assessment Program 2009, Levin and Schwing 2011), and likelihood of extinction is central to management of some species such as salmon (Legault 2005). In summary, true balanced exploitation may not be practical or legal under U.S. law, but the concept may help us understand and monitor potential ecological effects of "less balanced" fisheries policies.

Economic Value of Forage Fish

Due to the role of forage fish in supporting the abundance of other species, recent analyses have begun to calculate not only the landed (dockside) value of forage fish, but also their contribution as "inputs" to the production of tunas, cod, pollock, and other predatory fish.

Pikitch et al. (2012b) used a global set of ecosystem models to quantify the direct contribution of forage fish to harvest value ($) and the indirect contribution when forage fish are preyed upon by higher-trophic level fishery target species. As an example, an indirect contribution of forage fish to tuna might be calculated as $8 million if forage fish comprised 80 percent of tuna diets, and the tuna fishery had a landed value of $10 million. Overall, Pikitch and colleagues estimated that forage fish contribute a total of about U.S. $16.9 billion to global fisheries values annually, with $5.6 billion in direct catch and roughly twice as much ($11.3 billion) in indirect supporting value for commercially targeted predatory species. Fishery Councils that are charged with managing recreational fisheries might also consider the supporting role of forage fish for recreational anglers, which were not included in the global analysis of Pikitch and coauthors.

On the U.S. West Coast, Hanneson et al.(2009) and Hanneson and Herrick (2010) also developed bio-economic models for forage fish and their predators, and identified situations (such as dockside prices for both prey and predators) for which higher or lower harvest of forage fish would be economically optimal. For instance, under base assumptions, they found that if sardine predators (ranging from tunas to seabirds) have an average value of $0.12 per kg, sardine are worth more as forage than as harvest, while if sardine predators are not valued at all, optimal sardine harvest rate is high, $0.45yr^{-1}$. Analyses such as these will be essential tools if fishery managers are to consider economics as they evaluate tradeoffs between harvest needs of different sectors, and between harvest of forage fish and energetic needs of predators.

Target Reference Points

Predatory fish such as groundfish are often managed on the basis of reference points that can reduce biomass to below 50 percent of unfished levels (Clark 2002). However, several studies have found that lower fishing rates—meaning lower harvests—may be more appropriate for forage species, based on single-species (not ecosystem) considerations. These guidelines for harvest rates are useful in considering options for management approaches (see below).

A species' natural mortality rate (due to factors such as predation, disease, and old age) can serve as a useful management guidepost that can be estimated from available data (Pauly 1980) and can be related to harvest rates. Caddy and Csirke (1983) reviewed global data and suggested that small pelagic fish species may only be able to sustain fishing mortality that is considerably less than their very high natural mortality (e.g. predation rates). Similarly, Patterson (1992) and Mertz and Myers (1998) suggest that small and medium sized pelagic groups might have optimal fishing rates that are only 50-60 percent of the natural mortality rate, lower than for larger predatory fish. Such fishing mortality rates typically will lead to biomass levels substantially above 50 percent of unfished levels.

Note that these target fishing mortality rates from previous studies did not include specific relationships between a set of predators and prey. Given the new studies such as the food web and ecosystem modeling discussed above, decision makers may now wish to consider whether target rates and reference points should explicitly take food web impacts into account. Combining results from stock assessments, food web modeling, and economic analyses could allow decision makers and stakeholders to weigh trade-offs between conservation, harvest of small pelagic fish, and other fishery and economic goals.

Management Approaches for Forage Fish

The fluctuating population dynamics of small pelagic fish, and their role as forage, may require a management approach different from that used for other stocks. However, a number of examples offer avenues to tackling these challenges and addressing these ecosystem considerations.

In the U.S. and in other countries, reference points based on maximum sustainable yield (MSY) and unfished biomass ($B_{unfished}$) are central to management decisions and goals (*Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006* 2007, European Commission 2010). From a scientific perspective, it is difficult to provide advice regarding MSY for forage fish: MSY and unfished biomass are moving targets, due to shifting climate, recruitment, and stock productivity. One potential response would be to develop fishery management strategies that explicitly adjust fishing mortality rates in response to climate, as has been proposed by MacCall (2002) and King and McFarlane (2006). However, statistical estimation of these productivity shifts and fluctuating reference points is difficult in a stock assessment context (A'mar et al. 2009, Haltuch et al. 2011). Climate variability affects marine ecosystems. The mechanisms relating low-frequency environmental fluctuations (regime shifts, and these difficulties may outweigh the theoretical benefits.

Simpler management approaches may be necessary to address the impacts of fluctuating populations without attempting to statistically estimate fluctuating management reference points. Threshold control rules (Figure 6) are one management approach that is robust to these fluctuations. Threshold control rules allow no fishing below a minimum stock abundance, with the fishing mortality rate increasing gradually up to a maximum as abundance increases. Such a threshold control rule is in place for Pacific sardines (Pacific Fishery Management Council 2006), and was implemented 35 years ago for anchovy (Pacific Fishery Management Council 1978). For a Japanese sardine stock, Hurtado-Ferro and colleagues (2010) compare performance of a simple threshold control rule with a slightly more elaborate threshold rule that reduces maximum fishing mortality rate when environmental conditions are poor. In this simulated case, the more elaborate rule performed slightly better than a simple threshold rule, particularly in terms of avoiding heavy depletion of the stock. However, overall these two threshold rules performed similarly, and substantially better than a policy with a fixed fishing mortality rate and no minimum biomass threshold.

Threshold control rules may also be a strategy to address ecosystem impacts by "setting aside" a minimum forage base for predators. Pikitch et al. (2012a) applied ecosystem models for ten different marine regions, and scored harvest control rules in terms of impacts on dependent predators, as well as fishery yields. Their results led to the recommendation that fishery managers implement threshold control rules that set aside a minimum of 30 percent of each forage stock as unfished, and limit fishing mortality rates to less than three-quarters of F_{MSY} (fishing mortality that results in maximum sustainable yield). In cases where less information is available about a forage stock, Pikitch et al (2012a) recommended maximum fishing mortality rates of half of F_{MSY} and measures to keep biomass above 80 percent of unfished levels. This target of 80 percent is comparable to the 75 percent reference point identified by Smith and colleagues (2011) as a target that would greatly reduce impacts on predators, while lowering fishery yields by only ~20 percent.

Threshold control rules that accommodate predator needs will often imply forage fishery yields below what might be calculated as optimal by single-species stock assessments. Economic and social costs of reduced harvests would need to be weighed by local decision makers, for instance at the Regional Fishery Management Council level. The trade-offs are not just between forage fish harvest and protected predators such as birds and mammals. As mentioned above, there are also economic costs in terms of yield of predatory fish (tunas, salmon, etc.), and other metrics related to biodiversity and community metrics such as size of fish. Current harvest rates on forage fish vary widely by species and region; in some cases exploitation rates are already very low. In those cases, scoping exercises or scenario planning (Alcamo 2008, Ash et al. 2010) can be used to identify potential increases in market demand or harvests in the future, and to focus management efforts.

Conclusions

Of the trigger questions posed on the topic of forage fish, I have addressed three here from the scientific perspective (while several others fall more in the policy realm):

- Do current characteristics of forage fish warrant a departure from the current management approaches, characterized by some as a traditional single-species approach?

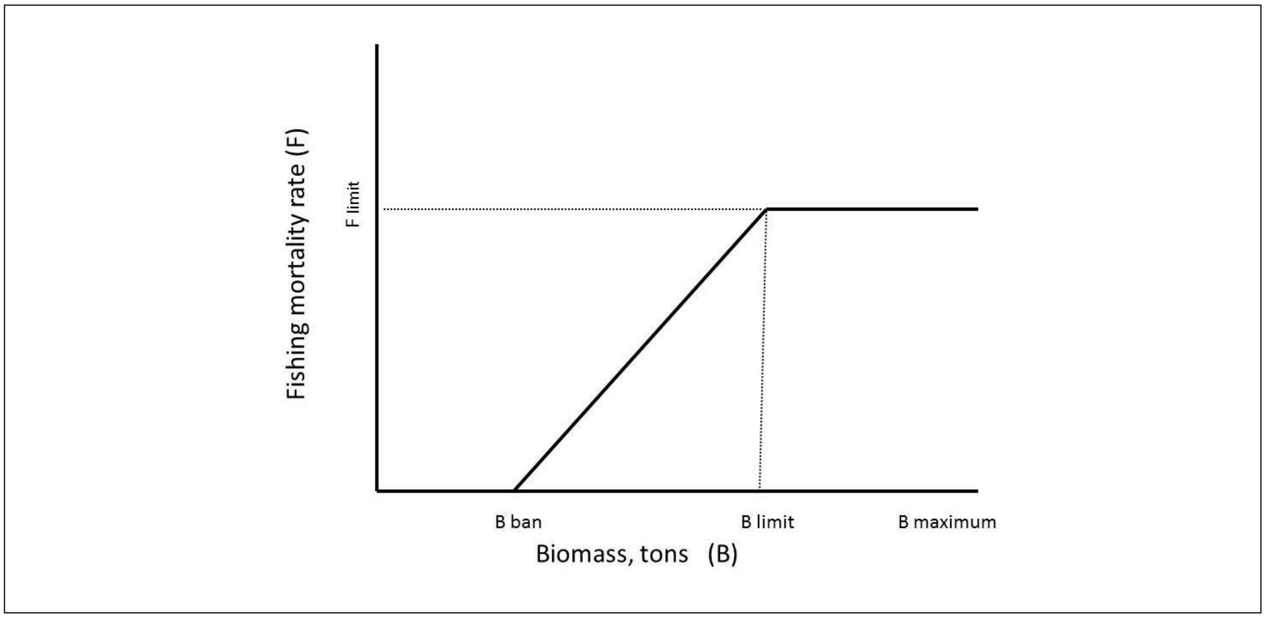


Figure 6. Example of hypothetical threshold harvest control rule, which adjusts fishing mortality in response to changing biomass of the stock. F limit is the maximum allowable fishing mortality rate; B ban is the biomass below which fishing is not allowed; B limit is the biomass above which fishing can operate at the maximum rate (F limit); B maximum is a maximum observed or estimated unfished stock biomass.

The key scientific challenges with respect to forage fish are understanding their high levels of population fluctuation, and understanding their role—both ecologically and economically—in the fishery, the food web, and the ecosystem. Both characteristics make traditional fishery reference points difficult to estimate, despite the centrality of reference points such as MSY in U.S. fishery policy.

- Where on the trophic scale should we be harvesting and managing species? As societal targets change, is there a need to redefine optimum yield and what the Regional Fishery Management Councils should be managing for?

Analyses discussed here related to balanced exploitation suggest that ecological effects of fishing may be minimized if fishing is spread more evenly across species, sizes, and sexes. This would involve harvesting a broader set of forage species, but not necessarily increasing harvests on current target forage stocks. Such an approach of balanced exploitation would face practical challenges related to marketing, assessment, and bycatch. Balanced exploitation may not be practical or legal under U.S. law, but this research topic may help us understand and monitor potential ecological effects of "less balanced" fisheries policies.

Modeling and field studies suggest trade-offs between harvest of forage fish, versus harvest of larger fish and conservation of predators such as marine mammals and birds. Approaches identified here (global data analyses, economic approaches, and ecosystem modeling) can identify these trade-offs; generally the scientific literature suggests that harvest of forage species at their single-species optimum leads to declines in protected species and other harvested stocks.

- How should management reconcile ecosystem services valuation and the economic value of forage fisheries? What are some of the trade-offs?

New approaches presented above, largely based on global data analysis, economic approaches, and ecosystem modeling, can help to evaluate the trade-offs between forage fish yield, harvest of predatory fish, and persistence of protected predators and other marine species. Several of the analyses suggest rules of thumb for predicting impacts of forage species harvest on predators; others offer examples of detailed ecosystem modeling that, where available, can provide predictions tailored for particular regions and species.

Encouragingly, recent modeling work suggests that managing with very simple threshold harvest control rules (Figure 6), quite similar to those already put in place by Regional Fishery Management Councils for many stocks, may

be robust to climate-driven population fluctuations, and may minimize impacts of forage harvest on other fisheries and predators. The challenge at a regional level may be to identify, from a policy perspective, where to set the reference points (B_{limit}, F_{limit}, B_{ban} in Figure 6) so that trade-offs are acceptable to stakeholders and the public. Coupled with spatial management that restricts fishing near sensitive breeding areas for marine mammals and birds, appropriate control rules may provide a balance between the competing demands on forage fish.

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Forage Fish Management in the United States: A Commercial Fishing Perspective

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Abstract

Ecosystem-based management is a term very familiar to fisheries scientists and managers, as well as environmental groups and the fishing public. Actual understanding of exactly what ecosystem management is likely varies among all the groups identified. What is clear to most is that ecosystems are very complex, causing management of those systems to be quite complex as well. For some species, Atlantic menhaden for example, ecosystem approaches to management are more realistic through the use of multi-species modeling. While simpler than full ecosystem management, multi-species modeling is still complex and is very data intense, requiring extensive predator/prey data. Because of the regional variability of species, species interactions, and environmental conditions, among other factors, management of coastal and marine species is largely conducted through Federal Regional Fishery Management Councils and interstate fisheries commissions on a "fishery" (generally single-species) basis. Likewise, so-called "forage" species should be managed through these existing regional management systems under the well-tested fisheries management framework enshrined in the Magnuson-Stevens Act (MSA) and mirrored by the commissions, incorporating knowledge gleaned through improved understanding of ecosystem and species interactions. The fact that forage species represent a food source for other species simply means that extra layer of complexity must be considered when conducting the science and designing a management approach. As it is important to understand what eats forage species, it equally important to understand what forage species eat. There could, in fact, be situations in which forage species consume egg, larval, or juvenile forms of other, economically important species, exemplified by the impact of North Sea herring on eggs of plaice and cod (Daan et. al 1985).

The following recommendations are presented:

Recommendation 1: If a management entity is planning to engage in ecosystem approaches to management, provisions to collect the appropriate type and amount of data should be ensured.

Recommendation 2: Any process to establish a goal or goals (a desired ecosystem state) for ecosystem-based management must be fair and balanced, involving affected user groups, and must consider scientific, economic, and sociological factors, as well as the legal framework. For example, if a process to manage Atlantic menhaden using ecosystem-based management strategies allows anti-commercial fishing groups to dominate, the outcome for the directed commercial fishery would likely be negative. In addition to scientific factors, issues such as jobs, economic well-being, cultural history, and historic participation and dependence on a fishery must play a prominent role in the decision-making process.

Recommendation 3: Management of forage species should be accomplished at the regional, not national, level. Policies and management approaches affecting both forage and predator species will be most effective if achieved under the existing management structures.

Recommendation 4: It is not necessary to change the Magnuson-Stevens Act or the Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA) to achieve effective management of a group of fish categorized as forage. They will, however, require the same due diligence that is required of effective management of other species: a full understanding of and data on 1) life history characteristics, 2) predator/prey and other species interactions, 3) fishery scope in space and time, and 4) fishery practices, among other factors I may have missed.

Recommendation 5: Full implementation of ecosystem-based management may, however, require legal changes, particularly to allow one fishery to be managed for the benefit of another. True ecosystem-based management also should allow for reducing the size of certain predator stocks (by, for example, temporary "overfishing") for the benefit of forage and other non-forage stocks alike, if doing so would to improve ecosystem dynamics and increase economic yields. As such, the goals of ecosystem-based management should be defined in broad terms that recognize the need to maintain a healthy marine ecosystem, strong commercial and recreational fisheries, and vibrant fishing communities by considering species interactions while maximizing the benefits marine resources provide. It must also be accompanied by a legal framework that supports this approach.

Recommendation 6: Further, more expansive research should be conducted to determine the possible effects of climate and weather on the status of fish populations under management, specifically forage species.

Recommendation 7: It is important to understand the food sources that are required of forage species for at least two specific reasons. First, if food could be a limiting factor in the overall success of a population, it is important factor to help explain possible declines in fish health or abundance. Second, species such as Atlantic menhaden that are filter feeders could, and may, consume meroplankton, including eggs and larvae of other species. Very little is known about the possibility of this occurring and what the potential impacts may be on species of economic importance.

Introduction

One of the most talked about concepts in natural resource management over the last ten to fifteen years is ecosystem-based management. It is a concept that sounds and feels right. Most scientists can readily see the allure. We know that all things in nature are connected. There is no meaningfully distinction between state and Federal waters or separating watersheds from the estuaries they feed, and yet we draw jurisdictional lines. We know that phenomena such as rainfall, large storm events, and shifts in temperature all affect the natural system individually and in combination, and yet we are limited to managing only activities that we can affect, which usually comes down to fishing activities. We push and shove at improving coastal water quality, but human-driven economic development activities typically win over attempts at control. These are but a few of the many and complex issues related to the ecosystem. Can humans manage ecosystems? Perhaps the future will hold real ecosystem management, but for now we are experimenting with ecosystem-based management or ecosystem approaches to management.

Ecosystem-Based Management and Multi-Species Management

Recognizing that humans are not capable of managing natural, large-scale, environmental phenomena, we have begun to focus on those things that we think we can affect. Ecosystem-based management, at least for Atlantic menhaden, has emerged in the form of multi-species management. This session is dedicated to examining issues related to managing forage fish; not simply managing the extraction of forage fish, but also managing forage fish as a food base for predators. The harvest of forage fish needs to be in the context of the relative importance of the species in question to the predators upon which they rely. Of specific interest to the commercial fishing industry is *How do we account for predation mortality on forage fish while successfully managing for direct harvest?*

Forage can be either a noun or a verb, either a source of food or the act of looking for food. It is a fact that just about everything in the coastal and ocean environments is forage at one time or another in their life cycles. It is worth pointing out that the MSA does not include or define "forage fish" as a specific category of fish, so it behooves us to come to some understanding of what species we are categorizing as such. There is a general agreement about the characteristics of forage fish, and it is clear that Atlantic and Gulf menhaden, species with which I am most familiar, meet “forage fish” characteristics. The identification and definition of “forage fish” for management purposes should be left to the Regional Fishery Management Councils and Interstate Marine Fisheries Commissions to determine in the context of species currently under their management or as future species to manage. This is partly because variability among forage fish is high. For example, Pacific sardine, Atlantic herring, and Atlantic menhaden all exhibit different life histories and predator/prey relationships. Attempting to address forage fish at the national level will not allow the flexibility to account for such variability. Addressing forage fish through the development of a National Standard under the MSA would most likely limit managers’ ability to confront issues specific to forage species, their ecosystems, and their predators. While it is true that forage fish present a challenge to current single-species management approaches, it is not necessary to create a different management structure to confront that challenge.

Continuing this theme, the Atlantic States Marine Fisheries Commission’s (ASMFC) Atlantic Menhaden Technical Committee has used a model known as the Multispecies Virtual Population Analysis (MSVPA-X) to model predator and prey populations dynamics and estimate natural mortality for Atlantic menhaden. This is an example of ecosystem-based modeling in the form of multi-species modeling. The MSVPA-X currently includes the following predators and estimates of their predation pressure on Atlantic menhaden: striped bass, bluefish, and weakfish. These species are used, because there is an available predator/prey database for each, and these three species constitute the majority of predation mortality on Atlantic menhaden in the Chesapeake Bay. Coast-wide, resurgent spiny dogfish populations are likely another major source of predation. While the MSVPA-X could be used to support multi-species management, its use in this case doesn’t really represent multi-species management. It is currently used as a tool to assist single-species management of Atlantic menhaden using the output of three single-species assessments to provide better estimates of time- and age-varying estimates of natural mortality for the menhaden assessment. It is, however, a step in the right direction. While this approach appears to result in positive benefits to the Atlantic menhaden stock assessments, alternative approaches may be needed to address other forage species and their predators. This fact exemplifies why such management decisions should be made at the regional level.

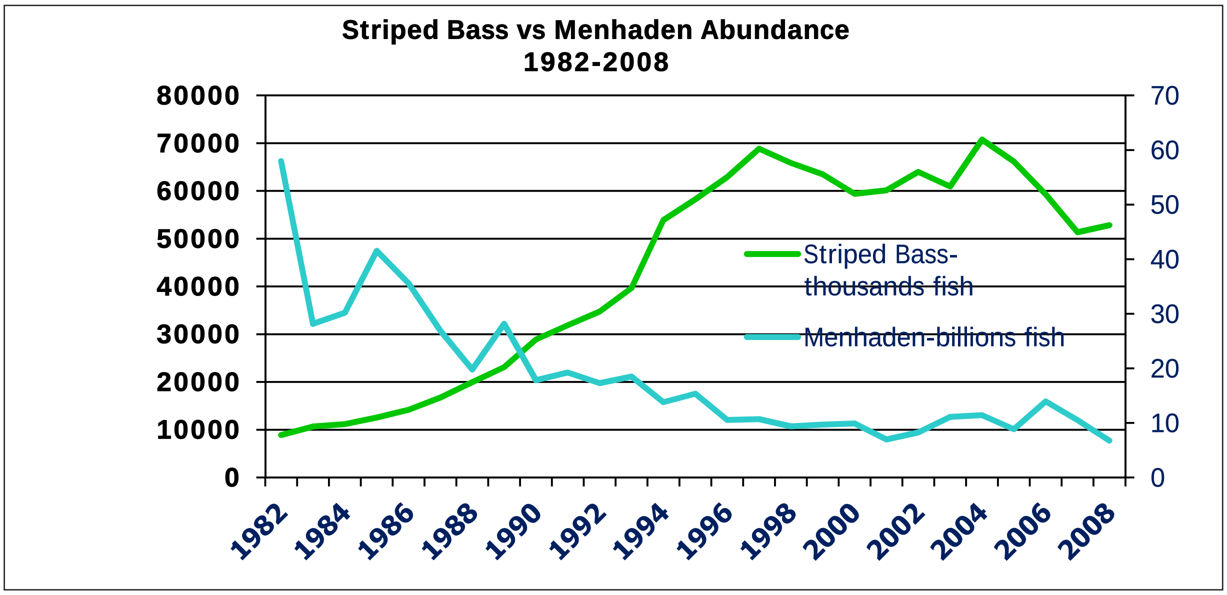
The Technical Committee is currently considering additional species, like dogfish, to include in future stock assessments. This approach seems reasonable, as it includes the use of reliable data on actual predation mortality over time. It is an approach that adheres to the tenets of the MSA and the ACFCMA by using the best available science. The multi-species approach requires that fisheries scientists and managers do their due diligence by conducting a defensible analysis of the species involved in the predator/prey relationship. Not all species are associated with long-term predator/prey data sets, and therefore, some would present unique challenges for management. However, for those species for which data are available, appropriate scientific scrutiny should be required in developing management strategies for harvest. Lumping “forage fish” into a single management category and establishing across-the-board management standards does not allow for flexibility to develop scientific or management strategies to address specific regional needs.

Management of Forage Species

In managing marine species, regardless of specific management goals, it is important to understand their life history characteristics. Such life history characteristics include life span, growth, genetics, sex ratios, food habits, environmental preferences and tolerances to name a few. Forage fish exhibit large shifts in abundance, even without fishing pressure, typically influenced by environmental conditions impacting predator and prey populations and their recruitment success. This is certainly true with menhaden, as recognized by NOAA Fisheries, stating that “menhaden recruitment appears to be independent of fishing mortality and spawning stock biomass, indicating environmental factors may be the defining factor in the production of good year classes” and the ASMFC which concluded in its 2010 stock assessment (ASMFC 2011) that fluctuations in menhaden abundance may be “almost entirely driven by non-fishery sources."

This particular life history characteristic poses real challenges to developing a management strategy that may span climate regimes that can sometimes prevail for 20 to 30 years. In the case of Atlantic menhaden, new science examining the role of climate in recruitment of coastal species has shown that some climate regimes enhance recruitment success for some species, while diminishing recruitment success for others. In other words, certain species wax while others wane under certain environmental conditions. A shift in climate regime can trigger the opposite effect (Wood and Austin 2009).

Striped bass is often seen by many as a species that requires large schools of menhaden in their diet for their survival. Many believe that there are currently too few menhaden available to striped bass, a situation that has resulted in striped bass exhibiting poor condition and sometimes showing lesions attributed to nutritional stress. According to Wood and Austin (2010), striped bass and Atlantic menhaden are typical of species types whose recruitment success is affected by climate—climatic conditions favoring striped bass cause menhaden to languish and *vice versa*. The chart shown below uses data from ASMFC stock assessments for both striped bass and Atlantic menhaden. The figure represents total abundance of Atlantic menhaden in billions of fish and striped bass in thousands of fish.

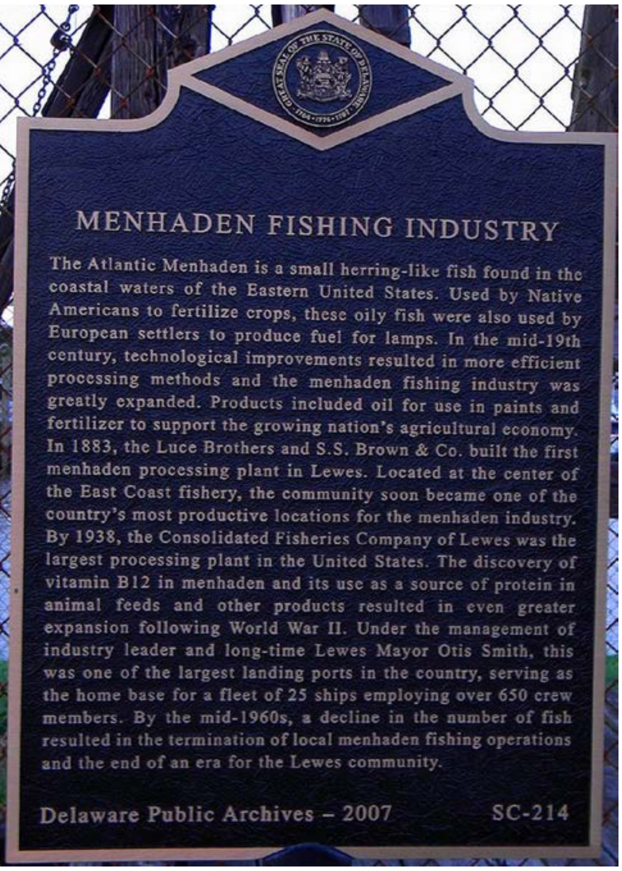


The two species are negatively associated. Beyond climatic conditions favoring predator over prey, or the other way around, another element of this inverse relationship is a factor common to all such relationships, be it striped bass and menhaden or rabbits and foxes. In a perfectly natural system unaffected by humans, population booms of predators will increase pressure on prey, driving down their abundance. As food becomes a limiting factor, predator species decline and lessen pressure on prey, allowing those species to rebuild (Zwolinskia and Demerb 2012). These direct impacts are exacerbated and confounded by a myriad of other factors, just a few of which include conditions favoring recruitment, food supplies for prey populations, disease outbreaks in dense populations, relative abundance of various prey species, and all the other competitors in the ecosystem. Further, many pelagic stocks each of which may meet any reasonable definition of forage actually compete with each other in the same ecosystem and are seldom, if ever, at peak biomass at the same time (Springer and Speckman 1997). There is more than a bit of hubris in thinking we can micromanage an ecosystem and enforce a balance among interrelated species through human action. In the end, ecosystem management comes down to the choices we make as humans to decide what a specific ecosystem should look like. What it *will* look like is up to nature.

This illustrates the need to manage species in their own contexts. If scientists, managers, and the public believed that simply cutting harvest of Atlantic menhaden would immediately result in more and healthier striped bass, they all would be sorely disappointed. In fact, a natural experiment has been conducted over the past twenty-plus years. Menhaden harvests coast-wide declined 34 percent based on average harvests for the period 1955 through 1989 versus 1990 through 2011. Absolute removals in the Chesapeake Bay have also declined significantly (about 31 percent), particularly after the institution of a cap on removals by the reduction fishery in 2006.

This significant reduction in harvest did not lead to an increased menhaden population. In part, recruitment may have been, on average, slightly lower in the latter decade compared to the 1990s. That recruitment has not increased in the face of significantly reduced pressure on spawners underscores the lack of a spawner-recruit relationship in the stock and the importance of environmental conditions on success (ASMFC 2009). Further, the remarkable stability in the menhaden spawning stock over the past twenty to twenty-five years, even as harvest has dramatically decreased, suggests that increased predator populations, particularly striped bass and dogfish, have been taking their share as forage. One of the results of the most recent menhaden stock assessment is a notable recent increase in natural mortality, particularly on the older age classes. That the stock has not declined, suggests that there are ample menhaden to meet the needs for predation (Crecco 2010) and the directed fishery.

This is an observation, not a definitive scientific result. However, it would suggest that the menhaden example over this period would make an excellent case study for further investigation of the predator/prey relationship. I would note, however, that if we want to ensure that predators have food, those fish will be removed from the population. We cannot judge the success of our management programs simply on the basis of the number of prey species left in the water. Cutting directed harvest in order to leave more forage in the water for predation should result in a quantifiable increase in the abundance or condition of predator species which are believed to be dependent upon the species in question. In addition, cutting directed harvest in order to leave more fish in the water in order to increase biomass of the forage species should result in an increase in recruitment and, ultimately, an increase in biomass. Certainly, management actions should be evaluated to determine if the desired result is achieved. If forage fish population levels are high, it is more likely an indication of depressed predator stocks than a healthy marine ecosystem.



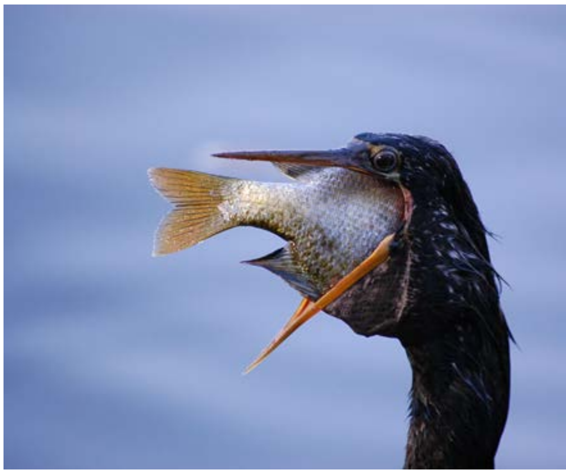
In this regard, if we want to move towards true ecosystem-based management, we need to understand what these prey species are eating. We know that when species like deer proliferate, they will over-graze and eventually cause shortages and population decline. It should not be merely assumed that similar issues do not arise in the marine context. This is particularly true for piscivores like herring, which are considered "forage fish" (Daan *et al.* 1985). They prey on eggs of plaice and cod. It makes no sense to ignore this element of the equation.

Even the ecosystem impacts of a species like menhaden, which subsist primarily on planktonic life, should be accounted for in ecosystem-based management. As juveniles and adults, menhaden are filter feeders, an energy-intensive method of food intake (as young-of-year, menhaden have teeth and feed like any other fish). Menhaden thus search out high-energy zones, areas of high concentration of zooplankton and the phytoplankton upon which they prey. Menhaden, whose gillrakers expand with age, target increasingly larger food sources. Swimming in schools of millions, menhaden can efficiently sweep an estuary of a large percentage of its planktonic composition (Durbin & Durbin 1998).

The question no one has yet investigated, however, is whether menhaden in primary nurseries for other fish, like the Chesapeake Bay, also consume "meroplankton," or temporary plankton. That is, eggs and larvae. There is no evidence to suggest that menhaden actively avoid these sources of what would be an important source of protein. From a purely practical perspective, it is nearly impossible to imagine that large schools of menhaden would not be a large source of predation on these early life stages.

To raise the question is not to answer it. It is fascinating to imagine menhaden preying on striped bass. More fundamentally, however, given the pure efficiency of such a large component of our ecosystem—that is, all species we can agree fit in the category of "forage"—it would be counterproductive to remain willfully blind to the role on recruitment and population of other stocks that is attributable to their predation. Certainly, any system of management that ignores these ecological processes cannot call itself ecosystem-based.

As a final note, moving toward ecosystem-based management that includes the objective of establishing catch levels to preserve the health of the ecosystem and setting catch levels in forage fisheries to benefit predator stocks may require a change in law. It does not take a legal expert to understand that the MSA's goal of achieving the level of biomass that produces maximum sustainable yield for all stocks of fish at the same time in perpetuity is ecologically impossible. Nor is it clear that the law's requirement to achieve optimum yield from each fishery allows for such trade-offs between fisheries. More broadly, we should recognize principles of ecosystem-based management should not solely encompass the concept of maintaining forage stocks for the maximum health of all predator species. It must also recognize that there are times when it is prudent, both from a management perspective and the law's goal of achieving the maximum benefit from our marine resources, to "prune" predator stocks to help enhance the health of stocks on which they prey—whether such stocks are "forage fish" or simply piscivores lower down the food chain. Spiny dogfish are the best current example, as this low value species' abundance and voraciousness is credibly thought to be having an adverse impact on more valuable fisheries. However, being able to utilize this as tool in the ecosystem-based management toolbox may require "overfishing" as it is currently defined—and prohibited—by law. This is but one of the many challenges in the move toward ecosystem-based management.



Conclusions and Recommendations

Managing ecosystems is a worthy goal. It is, however, not without a considerable amount of costs, both monetary and otherwise. Generally speaking, fisheries management is engaging in ecosystem approaches to management, attempting to incorporate certain components of ecosystem management into the assessment process. An example of this is the use of the MSVPA-X to account for predation mortality within the Atlantic menhaden management process. While this is a positive step, it leaves a long road ahead to achieve real ecosystem management that will account for climate conditions, localized weather conditions, spatial changes, water quality issues, among others.

Conclusion 1: Ecosystem approaches to fisheries management will require the use of mathematical models which will require a great deal of data.

Recommendation 1: If a management entity is planning to engage in ecosystem approaches to management, provisions to collect the appropriate type and amount of data should be ensured.

Conclusion 2: Ecosystem-based management can be viewed as an attempt to maximize the use of ecosystem parameters along with fisheries data to achieve a desired ecosystem state. In order to be successful, such a process will require the involvement of affected user groups to assist in determining what the desired ecosystem state is.

Recommendation 2: Any process to establish a goal or goals (a desired ecosystem state) for ecosystem-based management must be fair and balanced, involving affected user groups, and must consider scientific, economic, and sociological factors. For example, if a process to manage Atlantic menhaden using ecosystem-based management strategies allows anti-commercial fishing groups to dominate, the outcome for the directed commercial fishery would likely be negative. In addition to scientific factors, issues such as jobs, economic well-being, and cultural history must play a prominent role in the decision-making process.

Conclusion 3: Regional Fishery Management Councils and Interstate Marine Fisheries Commissions exist and provide an important service in fisheries management because they recognize that fisheries populations, including forage species, vary significantly regionally. Problems that plague one region may not be a problem in another region.

Recommendation 3: Management of forage species should be accomplished at the regional, not national, level. Policies and management approaches affecting both forage and predator species will be most effective if achieved under the existing management structures.

Recommendation 4: It is not necessary to change the MSA or the ACFCMA to achieve effective management of a group of fish categorized as forage. They will, however, require the same due diligence that is required of effective management of other species: a full understanding of and data on 1) life history characteristics, 2) predator/prey and other species interactions, 3) fishery scope in space and time, and 4) fishery practices, among other factors I may

have missed.

Conclusion 4: Recommendation 4 speaks only to improved management under the current legal framework. The move toward ecosystem-based management that includes providing for the health of the marine ecosystem as a whole while also maintaining the MSA and other fisheries laws goals of maximizing economic and recreational benefits from our Nation's fisheries likely will require a change in law. Such changes should give managers discretion to make decisions to manage resources in a manner consistent with these objectives, including allowing fishing predator stocks down (as well as building forage stocks up) when justified biologically and economically.

Recommendation 5: Define the goals of ecosystem-based management in broad terms that recognize the need to maintain a healthy marine ecosystem, strong commercial and recreational fisheries, and vibrant fishing communities by considering species interactions while maximizing the benefits marine resources provide. Develop a legal framework that supports this approach.

Conclusion 5: It is clear that some species, a good example being Atlantic menhaden, are affected by large-scale, long term climate factors, such as El Niño and the North Atlantic Oscillation, among others. It is believed that such factors may significantly affect recruitment success for Atlantic menhaden and striped bass.

Recommendation 6: Further, more expansive research should be conducted to determine the possible effects of climate and weather on the status of fish populations under management, specifically forage species.

Conclusion 6: Very little investigation has been done into the issue of what forage species are eating.

Recommendation 7: It is important to understand the food sources that are required of forage species for at least two specific reasons. First, if food could be a limiting factor in the overall success of a population, it is important factor to help explain possible declines in fish health or abundance. Second, species such as Atlantic menhaden that are filter feeders could, and may, consume meroplankton, which is eggs and larvae of other species. Very little is known about the possibility of this occurring and what the potential impacts may be on species of economic importance.

There is a lot of work left to be done before moving in this direction. Hopefully the next generation of marine biologists will take up the challenge of investigating these unresolved issues.

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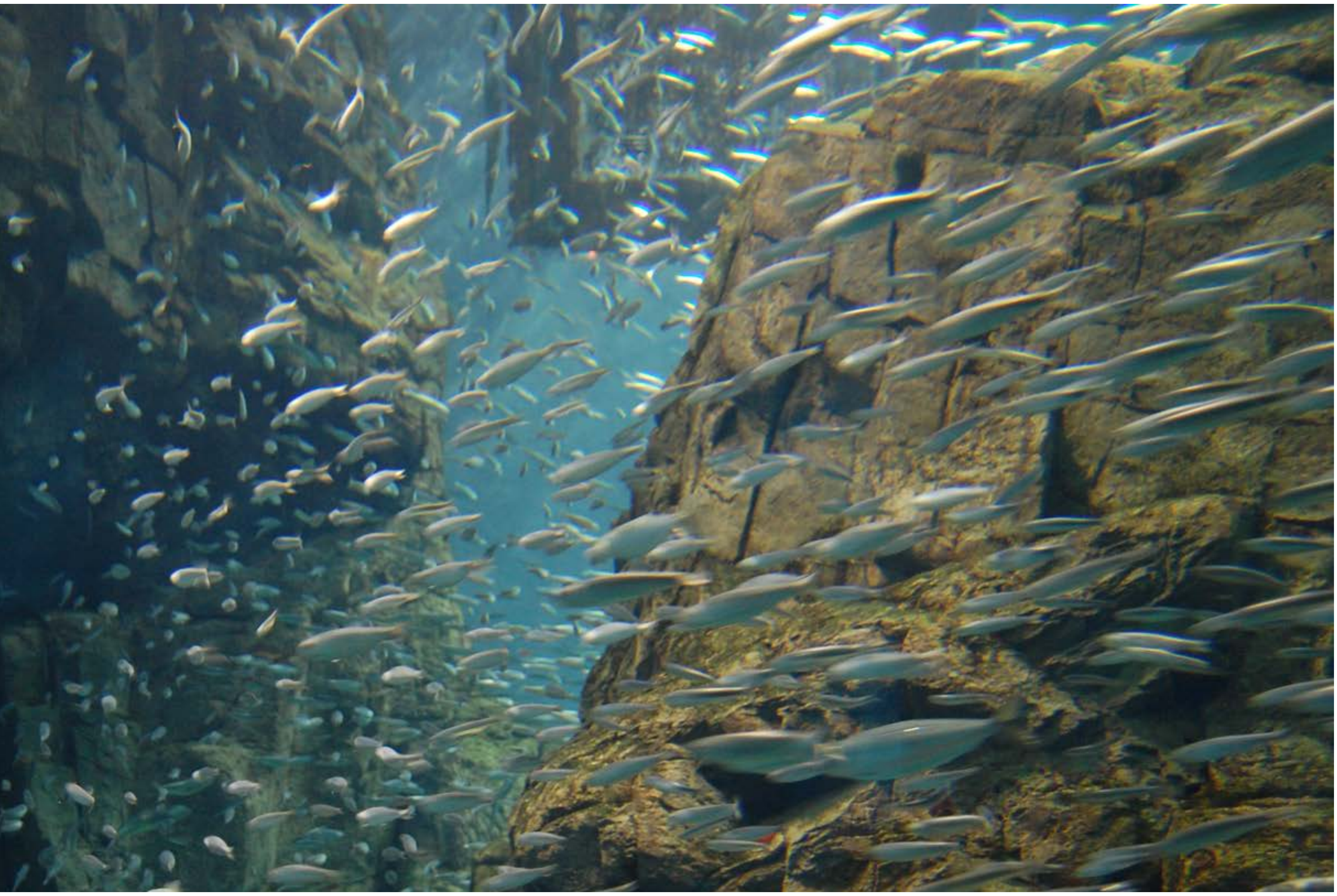
SARDINES. PHOTO: TKOSAKA, FLICKR CREATIVE COMMONS.

DISCUSSION SUMMARY AND FINDINGS
Session 2 Topic 2

Forage Fish Management

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Discussion Summary: Forage Fish Management

The following findings emerged during the discussions under Session 2, Topic 1: Forage Fish Management.

Proposed Legislative Changes: Stay the Course or a New National Standard for Forage Fish?

No Changes to the Magnuson-Stevens Act are Necessary to Sustainably Manage Forage Fish

One of the main questions of this session was, "Do we have the tools to effectively and sustainably manage forage fish?" Most participants agreed that there are many tools available to effectively manage forage fish under existing laws, regulations, and authorities.

Establish a New National Standard to Ensure Adequate Forage to Support Vibrant Fisheries, Wildlife, Communities, and Ecosystems

Some participants countered that simply having access to the tools is not sufficient if management authorities are not willing to use them. This led to a finding that the Magnuson-Stevens Act (MSA) should be amended to include a new National Standard that establishes a mandate to ensure an adequate forage base to support vibrant fisheries, wildlife, communities, and ecosystems.

Several other legislative ideas emerged during the discussions:

- Moving toward ecosystem-based management of forage species and reliance on more complex ecosystem models may require a change to MSA.
- Define forage species in MSA.
- Transfer current forage species provisions in National Standard 1 guidelines into MSA requirements.

Best Practices for Management

Maintain a Regional Approach by Defining and Identifying Forage Species at the Regional Level

Many panelists and members of the audience showed general support for using the existing management structures at the Regional Fishery Management Councils and marine fisheries commissions to manage forage fish. The regions should define "forage" based on the unique ecosystem and the complex species interactions in each area. The responsible management authorities should identify specific forage species for their region.

Use Meta-Analysis and Global Studies to Provide Rules of Thumb as a Starting Point in Discussions for Forage Fish Management or as a Guide in Data-Poor Situations

Global meta-analysis can be used to aggregate data across regions and species to gain insight into how predator populations may respond to forage fish populations. For example:

- Sea bird breeding success responds to the level of prey abundance, therefore prey abundance should be maintained above 1/3 of unfished biomass to support sea bird populations.
- Harvesting forage species at maximum sustainable yield (MSY) can have large impacts on other parts of the ecosystem, suggesting that comparatively small reductions in catch below MSY can lead to big benefits for other species in the ecosystem.
- Ecosystem models can also provide insight on the critical forage fish biomass needed. If predators have a 25-50 percent diet dependency on the prey and managers want a 75 percent confidence of success, then forage biomass should remain above 57 percent of unfished levels to avoid a 50 percent decline in dependent predators.

The results of these studies provide meaningful guides to forage fish management (for more information and references see paper by Isaac Kaplan). The results of these studies also provide a scientific starting place for managing data-poor species. Based on these and other studies, participants offered the following rules of thumb for managing forage species:

- Maintain prey abundance above one-third of unfished biomass
- Maintain 30 percent of each forage stock as unfished set-aside
- Establish fishing cutoff values at no less than 40 percent of unfished biomass
- Specify a limit biomass threshold greater than or equal to the long-term average biomass that produce MSY, below which a forage fishery is considered to be overfished
- Limit $F<3/4\ F_{msy}$
- Maintain fishing mortality below half of the traditional F_{msy} or to half of the natural mortality rate
- When less information is available $F_{max}=1/2F_{msy}$ and $B>80\%$
- Use natural mortality as a guidepost for management

It was also noted that while global analysis is a helpful guidance, the use of regionally-specific data and studies is preferred when available.

Use Threshold Harvest Control Rules to Manage Forage Fish

Many fisheries already use harvest control rules in management and many of the participants supported their expanded use for forage fish. Threshold harvest control rules establish a framework for management based on the abundance of the population. When the biomass of a stock is abundant, the fishing mortality rate is permitted to increase up to a limit; however, as the biomass declines, fishing mortality is reduced. When biomass falls below a certain level, fishing is no longer permitted. The targets and limits of the harvest control rule describe the management response that will be followed based on the stock status. Threshold harvest control rules minimize impacts on other fisheries and predators, are robust to climate-driven population fluctuations, and force frank discussions of acceptable tradeoffs.

While harvest control rules focus attention on establishing harvest limits from directed fisheries, the consideration

of bycatch is another important source of mortality that must be considered when controlling the catch of forage fish. For example, managers may set incidental take limits on all forage species caught as non-target species (e.g.. Alaska groundfish bycatch caps).

Develop Ecologically Based Reference Points

Forage species inherently display wide population fluctuations that can swing dramatically each year and are often sensitive to changes in climate. They also exhibit schooling behavior that lead to high catch rates. As scientists and managers develop biological reference points, it is important to account for the risk of high population swings and catchability, as well as consider a broad range of ecosystem services provided by forage species when setting targets and limits.

Conduct Economic Valuation

The session included an extensive discussion on the topic of economic valuation. There was a cautious interest in including more economic valuation in management decisions on forage fish. Many questions arose on what economic data was appropriate or being used, along with the methodologies used to derive economic valuation information. Some economic studies suggest that forage fish may be more valuable left in the water as prey to predator populations that demand a high price at the dock. Another study found that the optimal fishing mortality rate for sardines depends on how much we value their predators (tuna, seabirds, mammals). While no agreement arose on these topics, there were several aspects of economic valuation that emerged:

- Consider the value of leaving forage fish in the water,
- Consider the value to fishing communities (both direct harvest and indirect through bait), and
- Include the supportive value as prey to other fisheries, as well as activities such as eco-tourism (i.e. whale-watching or sea lions).

Clearly there is a need for additional research as well as methods for weighing the complex tradeoffs and information relating to the economic value of forage fish.

Account for Ecosystem and Predator Needs by Requiring Explicit Consideration of the Impact of Forage Species on the Ecosystem and Fishing Communities

Forage fish play an important role in maintaining healthy and resilient marine ecosystems. Scientific tools exist through ecosystem modeling and integrated ecosystem assessments to consider and account for the role of forage fish in their environment. Forage fish management should account for the dynamic needs of predator populations, the availability of alternate prey and ecosystem services when conducting stock assessments, establishing optimum yield, and setting annual catch limits.

Evaluate Tradeoffs

New scientific and management tools are now available to help evaluate tradeoffs in fishery management decisions. Global data analysis allows datasets from around the world, across regions and species, to be aggregated and evaluated to determine general trends that can be used as "rules of thumb" for managers. Ecosystem models can evaluate the implications of forage fish harvest levels on predators and other ecosystem services. Integrated ecosystem assessments can evaluate the role of climate on forage fish populations, among other things. Economic valuation can identify the various and complex benefits of forage fish to the ecosystem, fisheries, and fishing communities. By using these existing tools (and developing new tools), managers should move beyond a single-species approach by defining and explicitly considering the tradeoffs across species and interests when making management decisions for forage fish. There was recognition that we cannot maximize all species at all times in management, making it important to consider tradeoffs and establish priorities.

Evaluate and Address Localized Depletion

Localized depletion occurs when forage fish (or prey) become depleted in specific areas or during specific times. It can be the result of excessive fishery removals, but also the result of climate and other environmental factors. It is believed that localized depletion is problematic because there is insufficient prey to meet the foraging demands of predatory populations during critical times or life history stages. Some participants felt that localized depletion can in turn affect communities, for example, if the opening of a fishing season depends on the arrival of prey to bring the target species inshore. Others felt there is inadequate scientific proof on where and whether localized depletion takes place, therefore additional research is needed to validate its occurrence. Spatial management and gear modifications were suggested as tools for addressing localized depletion. In addition, diet studies could be used to identify hot spots for pulse feeding, allowing for adaptive or dynamic management to avoid localized depletion.

Prohibit New Fisheries on Forage Species Until Scientific and Management Evaluations are Conducted

Some panelists raised concerns about new fisheries developing on forage species. There are fears that the rising demand for fish meal and oil for aquaculture or terrestrial animal feed, or other markets, may result in the initiation of new fisheries for species low on the food chain. The current process makes it cumbersome to add species to management plans, yet relatively easy for a fishery to begin. New tools are needed to prevent fisheries from developing on unmanaged species. In order to provide protection to forage species and marine ecosystem, no new fisheries should be initiated or expanded until a stock assessment is conducted and a management plan is developed and approved. Another tool suggested to address new fisheries was to create a list of managed species that included all forage fish stocks.

Implement Real-Time Data Collection to Inform Adaptive Management

The wide population fluctuations typical of forage species make it challenging to consider tradeoffs between stability and opportunity in the management of directed fisheries. For example, on the West Coast, precautionary measures protect forage stocks in low abundance years, but also limit the fishery from taking advantage of high abundance years. A new system of scientific capacity to assess population abundance on an annual basis should be paired with adaptive management that provides the regulatory flexibility to implement management measures in real-time. This new system would allow the fishery to sustainably access higher catches, while still protecting the stocks and ecosystem when abundance is low by ratcheting down catch rates when stocks are in decline. This is an opportunity to increase reliance on the industry to collect data and conduct cooperative research. It was also suggested that this could be funded through fishery revenues.

Require Scientists to Provide Managers with an Index of Key Forage Species Composition and Abundance in Each Region

The forage base is an important indicator for understanding the dynamics of predatory populations and the health and productivity of the marine ecosystem. Currently, managers will look at stock assessments for managed forage species, but they do not have insight into the overall health of the combined forage base that supports higher trophic levels. Scientists should look at all the fishery indices available to define the forage base, evaluate the composition, and report to managers on annual trends in each region.

Improve Inter-Jurisdictional Coordination on Forage Fish Management

Recognizing that a great deal of coordination and cooperation already happens between state and Federal partners, there was general awareness and agreement that improvements are both possible and necessary. In some cases, state agencies or inter-state commissions provide the lead management authority for forage species, while a Regional

Fishery Management Council has the lead authority for its predators. In other cases, two management authorities share responsibility for the management of the same species. And even within management authorities, improved coordination is possible between fishery management plans for predator and prey stocks. In addition, issues such as at-sea bycatch, or river passage and water quality highlight the importance of coordination between state and Federal managers. In addition to improved domestic coordination, additional attention can be focused on international coordination. For example, require National Marine Fisheries Service (NMFS) to pursue international agreement on catch allocations and give NMFS mandate to impose trade sanctions on countries that refuse to engage in an international agreement of straddling stocks (i.e. Pacific sardine). As fishery management moves toward more integrated ecosystem approaches, management must also respond with more integration and coordination across jurisdictions and management plans.

Invest in Science: Advance Scientific Tools and Conduct New Research

The science behind forage fish and ecosystems has developed rapidly over the past decade. Managers now have more tools and greater access to data and information than ever before. A lot is known about the science behind forage fish, their role in the ecosystem, and the important historical and economic role forage fisheries play in our country.

On the other hand, we need to collect more and better data. Many suggestions were offered on how to improve or expand the science and research for forage fish:

- Conduct more expansive research to determine the effect of climate and weather on the status of forage fish populations.
- Investigate the role of habitat in supporting forage fish stocks.
- Collect new data on life history characteristics needed to inform stock assessments.
- Conduct new research on the diet of forage fish and how their consumption impacts other species.
- Conduct assessments on predator needs and alternative prey to include in harvest control rule formulas.
- Study the impacts of higher abundance of forage species on the ecosystem.
- Collect better fishery-independent data for forage species.
- Develop better spatial models to address localized depletion and competition.
- Evaluate the effectiveness and utility of closed areas to protect and maintain healthy forage fish populations.

The discussion recognized that current fiscal limitations make it necessary to prioritize research needs. Congress and the Administration need to make an investment in science—advancing the scientific models and hiring or training staff—as fishery management transitions from single-species to ecosystem-based management.

Moving Toward Ecosystem-Based Fishery Management

Transition from Single-Species to Ecosystem-Based Fishery Management

Within the broader discussion of ecosystem-based decision-making, there were intersections between the three topics of climate, forage, and habitat in each session, including the forage fish session. For example, one participant asked, "Is there more that we can do to improve forage fish stocks besides restricting fishing?" Participants noted the importance of protecting habitat as a possible means to improve productivity without associated reductions on fishing catches. There was also recognition of the strong influence that climate change exerts on forage fish and ecosystem health and productivity. Participants recognized that fishery management must move toward understand the linkages across these topics and focus management efforts on integrated ecosystem considerations.

Establish an Ecosystem Scientific and Statistical Committee at the Council or Commission Level

In addition to new basic science on forage fish species, there is a greater need to integrate across multi-species and ecosystem considerations. Some Regional Fishery Management Councils have established Ecosystem Scientific and Statistical Committees (SSCs) that have the expertise and mandate to evaluate ecosystem considerations and provide management advice. An Ecosystem SSC is a place to engage scientists across disciplines and jurisdictions to evaluate new ecosystem science and inform management. Some participants recommended the establishment of Ecosystem SSCs as a best practice to assist in forage fish management as well as other ecosystem-related issues.

Build Capacity to Use New Management Tools and Advance Ecosystem-Based Decision-Making

With the new tools and scientific assessments available, additional staff training will be necessary. New tools and methods offer great promise in expanding our capacity to incorporate new and important data sets into management decisions. It's important that staff and managers understand the capabilities, limitations and appropriate applications of new tools. In addition, conduct fully-integrated management strategy evaluation linking single-species fishery models with multi-species and ecosystems models. The fishery management system must build capacity to advance ecosystem-based decision-making.

While a wide range of views and opinions were offered during the session, all were in agreement that all stakeholder groups want healthy, sustainable forage fish populations.

SCIENCE ACTIVITY: STUDYING ECOSYSTEMS. PHOTO: JUDY BAXTER, FLICKR CREATIVE COMMONS.

PAPERS

Session 2
Advancing Ecosystem-Based Decision-Making

Topic 3
Integrating Habitat Considerations

Should Habitat Conservation Become a New National Standard for Fishery Management Plans?

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Abstract

The coastal and marine environment off the U.S., as well as elsewhere around the globe, is continuing to experience change brought about by a combination of human intervention and climate. We cannot afford to have loss of fish and shellfish habitat take a back seat as the U.S. ocean policy and analogous policies of other coastal nations play out. Habitat conservation to support fisheries resources needs to be a prime objective in coastal and marine spatial planning (CMSP). Already an essential part of fisheries management, perhaps the most effective way to keep habitat conservation in the forefront as CMSP develops is to make it a National Standard under the Magnuson-Stevens Act. Establishing a National Standard for habitat conservation would elevate the importance of identifying essential fish habitat (EFH), focus habitat-related research and monitoring, facilitate operational improvements to the Federal process involved with habitat conservation, and help the Regional Fishery Management Councils refine their habitat conservation objectives for fisheries management.

Introduction

The coastal and marine environment off the U.S., as well as elsewhere around the globe, is continuing to experience change brought about by a combination of human intervention and climate. Human intervention, triggered by the need for new sources of renewable energy and additional sources of protein, is leading to an increasing demand for tidal- and wind-based power systems, unrelenting fishing pressure on wild fisheries stocks, and expansion of offshore aquaculture operations. All these competing demands, many of which are destructive to habitats that support fisheries resources, are being placed on marine ecosystems that are already stressed by climate change. Climate change in the coastal and marine environments is causing ocean warming, which is leading to shifts in distributions of marine biota, lowering of ocean pH, sea level rise, and loss of polar ice caps, among other things.

We cannot afford to have loss of fish and shellfish habitat take a back seat as the U.S. ocean policy and analogous policies of other coastal nations play out. Habitat conservation to support fisheries resources needs to be a prime objective in CMSP. Already an essential part of fisheries management, perhaps the most effective way to keep habitat conservation in the forefront as CMSP develops is to make it a National Standard under the Magnuson-Stevens Act.

Habitat Conservation and the Magnuson-Stevens Act

The current incarnation of the Magnuson-Stevens Fishery Conservation and Management Act ("the Act," PL 94-265) contains several provisions related to conservation of habitats supporting fishery resources. Fishery management plans are required to identify and describe essential habitat for managed species, minimize adverse effects of fishing practices on habitat (to the extent practicable), and identify other actions that could be taken to conserve habitat. Also, Regional Fishery Management Councils are encouraged to comment on Federally licensed and permitted projects that may adversely impact habitat of their managed fisheries stocks.

The Act and its associated guidelines, however, still fall short in terms of promoting habitat conservation. For example, NOAA Fisheries does not have regulatory authority over actions that may adversely affect EFH. The Act also does not require periodic monitoring to ensure that EFH is maintaining the functions necessary to support the well being of fisheries resources. Furthermore, there is a tenuous link between habitat conservation and ecosystems-based fisheries management (EBFM); the Act encourages the Regional Fishery Management Councils to pursue EBFM, but these provisions are fishery-focused and offer no clear guidance as to how changes to local habitats supporting fisheries resources are to be considered in the broader ecosystem context. Finally, the Act does not offer guidance as to how habitat conservation should be integrated into CMSP, essentially leaving it up to the individual regional Councils to figure out how to get the habitat conservation foot into the slowly opening CMSP door.

NOAA Fisheries' Habitat Blueprint

Although the Act falls short of providing NOAA Fisheries, and through it the Regional Fishery Management Councils, with the tools necessary to conserve habitat supporting fisheries resources, NOAA has recently developed a habitat blueprint to address habitat conservation on a much broader scale. The purpose of the Habitat Blueprint is to provide "... a forward looking framework for NOAA to think and act strategically across programs and with partner organizations to address the growing challenge of coastal and marine **habitat loss and degradation**," integrating habitat conservation requirements "... for fish, threatened and endangered species, marine mammals, and other natural resources within the coastal zone" (http://www.habitat.noaa.gov/habitatblueprint/). The approach taken in the Habitat Blueprint is three-fold: (1) establish NOAA habitat focus areas for long-term habitat science and conservation; (2) implement a systematic and strategic approach to habitat science to inform effective decision-making; and (3) strengthen policy and legislation to enhance our ability to achieve meaningful habitat conservation. The remainder of this paper will focus on the third approach, strengthening policy and legislation, as it relates to the Act.

A Modest Proposal

Currently, the Act requires that fishery management plans developed by the regional Councils and ultimately approved by the Secretary of Commerce must adhere to ten National Standards.

To strengthen the habitat conservation requirements of the Act, I propose adding a new, eleventh National Standard:

> **Minimize adverse impacts on essential fish habitat to the extent practicable.**

The implications of this proposed text are far-reaching. Depending on how the associated guidelines are written, it could give the Secretary of Commerce regulatory authority (i.e., veto power) over Federally licensed or permitted projects that may adversely affect EFH. This veto power would be akin to the veto power currently held by the Administrator of the Environmental Protection Agency over Federal projects that could adversely affect water or air quality. The guidelines could also require identification and monitoring of activities that could potentially negatively (or positively) impact EFH. Finally, NOAA Fisheries and the Regional Councils would be able to move from their current consultative role to a role that is more active and cooperative, perhaps even pre-emptive, as they work in closer cooperation with other regulatory agencies.

Is establishment of such a National Standard for habitat conservation justified? Absolutely. Once approved by the Secretary of Commerce, fishery management plans, plan amendments, and framework actions are considered public policy. My experience has been that public policy carries a lot of weight in Federally-approved actions and associated judicial rulings. Furthermore, rebuilding fishery stocks and maintaining them at sustainable levels involves much more than addressing overfishing; habitats must be capable of supporting the renewed production of fishery stocks, especially if those stocks are at or near their historically highest levels of abundance. Finally, strengthening the habitat conservation provisions of the Act would provide a greater guarantee that objectives of fishery management plans can actually be achieved.

Establishing a National Standard for habitat conservation would elevate the importance of identifying EFH, focus habitat-related research and monitoring, facilitate operational improvements to the Federal process involved with habitat conservation, including closer coordination between and among regulatory and resource conservation agencies, and help the Regional Councils refine their habitat conservation objectives for fisheries management. Also, the National Standard would give the Secretary of Commerce more clout in reviewing offshore projects that are Federally licensed or permitted. A habitat conservation National Standard would also facilitate integrating habitat-level assessments into ecosystem-based fishery management and, on a broader scale, further facilitate CMSP by having a clear set of objectives that help define essential ecosystem services in support of fisheries management.

On the negative side, adding a new National Standard would very likely increase the probability of litigation, as managers try to address (and balance) the new standard with the ten existing ones. Meeting the guidelines that will be established for the new standard may lead to additional delays in approvals of fishery management plans and plan amendments. A stronger and broader base of scientific support will also be required, which may be difficult in the current era of shrinking budgets for state and Federal agencies.

Implications for Science

Almost any investigation into the relationship between organisms and their environment could be considered habitat research. A mission-oriented agency, such as NOAA Fisheries, however, cannot afford to conduct research for research's sake. Priorities need to be set in order to assure that research undertaken by agency scientists is responsive to the informational needs of its stakeholders, including the Regional Fishery Management Councils. Establishment of a National Standard for habitat conservation under the aegis of the Act would enable NOAA Fisheries and its funding partners to focus habitat-related science on efforts that will help the Regional Fishery Management Councils identify real or potential threats to habitat supporting fisheries resources, and develop means to prevent or mitigate their impacts.

The question is: will the current cadre of agency scientists and their academic partners be capable of addressing the questions about habitat conservation that are being asked, and will be asked, by fishery resource managers attempting to comply with the new National Standard? To do so, more emphasis will be needed on habitat monitoring and assessment. NOAA Fisheries already has a plan in place to steer habitat research in this direction. The Habitat Assessment Improvement Plan is intended to:

- "Assist [NOAA] in developing the habitat science necessary to meet the mandates of the [Act] and the economic, social, and environmental needs of the nation;
- Improve our ability to identify EFH and habitat areas of particular concern;
- Provide information needed to assess impacts to EFH;
- Reduce habitat-related uncertainty in stock assessments;
- Facilitate a greater number of "Marine Fisheries Stock Assessment Improvement Plan" Tier 3 stock assessments, including those that explicitly incorporate ecosystem considerations and spatial analyses;

- Contribute to assessments of ecosystem services (i.e., the things people need and care about that are provided by marine systems); and
- Contribute to ecosystem-based fishery management, integrated ecosystem assessments, and coastal and marine spatial planning." (NMFS 2010)

In addition to using the Habitat Assessment Improvement Plan to plot a course of action to meet the informational needs of fishery resource managers, additional research will be needed to solidify the linkage between habitat-related impacts on fisheries resources at the local level and ecosystem-based fisheries management at the regional level; i.e., assessment of habitat-related impacts should not be treated in isolation.

Summary

Expanding the use of oceans for renewable energy and aquaculture, along with increasing pressure on the marine environment brought about by human population growth and climate change, are prominent challenges to conservation of habitats that support production of marine fisheries resources. Current legislation governing fisheries resources management needs to adapt to these challenges. Establishing habitat conservation as a National Standard under the Act seems to be a logical next step in the execution of NOAA Fisheries' Habitat Blueprint, and the agency's Habitat Assessment Improvement Plan has already laid the groundwork for implementation of the standard. Some might argue that the Act already contains provisions to conserve habitat in a manner consistent with the Habitat Blueprint and Habitat Assessment Improvement Plan, and that additional legislative action is not necessary. In any event, it is a debate worth having.

Reference Cited

National Marine Fisheries Service. 2010. Marine fisheries habitat assessment improvement plan. Report of the National Marine Fisheries Service Habitat Assessment Improvement Plan Team. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-F/SPO-108. 115 p.

Integrating Habitat: A Necessary Part of the Equation

C. M. "Rip" Cunningham Jr.
Chair, New England Fishery Management Council

Introduction

Nobody thinks twice about constructing a suitable and solid foundation when a new building goes in the ground, but in managing the natural world, the foundation is often overlooked. It seems fairly basic that without suitable habitat, all effort to sustainably manage any resource is futile. Whether the living resource is terrestrial or marine makes little difference. Habitat forms the foundation on which everything else is built. For the marine environment, habitat forms the basis for the trophic pyramid, with high numbers of prey species at the bottom and the apex predators at the top. To quote Captain Thomas Brown, a nineteenth century naturalist, "Nature does nothing in vain:" a short quote with far-reaching implications. The natural world is more than a puzzle; it is more like a multidimensional chess game.

Given the importance of habitat in the natural world, why has it taken so long to incorporate it more prominently in the fishery management process? Is it simply because habitat is not easily visible below the surface of the ocean? Not likely, since for hundreds of years, fishermen have used that very subsurface structure to pinpoint concentrations of fish. Or is it more likely to be the product of a longstanding distrust of fisheries regulators by independent-minded fishermen? (The author's use of that term is gender neutral.)

As resource managers look to the future, incorporation of habitat into the entire marine ecosystem management process is necessary to ensure a sustainable outcome. This paper focuses on the incorporation of habitat considerations into the fishery management process, but it has implications in the broader scheme of coastal and marine spatial planning as well.

Background

The 1996 re-authorization of the Magnuson-Stevens Fishery Conservation and Management Act (MSA), which came to be known as the Sustainable Fisheries Act, strengthened the importance of habitat protection for healthy fisheries and enhanced the ability of the National Marine Fisheries Service (NMFS) and the Regional Fishery Management Councils (Councils) to conserve and protect marine habitat through the Fishery Management Plan process as outlined in MSA 305 (b). The guidelines called this habitat "essential fish habitat" (EFH) and defined it broadly to include "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity." This is a very broad definition and one that may have been and continue to be part of the user group's concerns.

For the New England Fishery Management Council (referred to here as the New England Council or Council), the process started in 2003, prior to my appointment as a member. At this point, the Omnibus Essential Fish Habitat Amendment will not be completed and implemented until 2014, after my term limit deadline in 2013. Other Councils have completed this task in a fraction of this time, but in New England we have always felt that we are different! The Habitat Committee for the Council was one of my first committee assignments. Like most new Council members it took a while to get one's arms around the process as well as the subject matter. Most of my time in a leadership position with the Council has been focused on groundfish issues. However, as the Chair for the last two years, I have been trying to push the habitat process along without trying to overly influence the outcome. There are many points of view and political forces at play in the Council process. My philosophy is to try to help navigate through the issues, not try to dictate the eventual outcome.

To implement fish habitat protection, the MSA guidelines initially required that the Councils, along with input from NMFS, amend all of its fishery management plans (FMPs) to include habitat considerations by October of 1998. The Councils were required to:

- Describe and identify EFH for the species managed by the Council,
- Minimize to the extent practicable adverse effects on EFH caused by fishing, and
- Identify other actions to encourage the conservation and enhancement of EFH.

Also, according the Interim Final Rule (*Federal Register* Vol. 62 No. 244, December 19, 1997), the Councils were required to search out EFH that was judged to be particularly important to the long-term productivity of populations of one or more managed species or determined to be vulnerable to degradation. These areas should be designated as habitat areas of particular concern (HAPCs). The interim final rule insinuated that HAPC designation would require some higher level of conservation. For some in the fishing industry this raised another red flag.

The guideline also required a five-year review and update of the EFH Amendment, which in the case of some Councils, the New England Council in particular, became a complete review of the original amendment and a finer-scale look at EFH and HAPCs. The guidelines under Sec 305 (b) also specified the process for Councils to comment on and make recommendations to the Secretary of Commerce concerning any activity that may impact EFH. In the parlance of fisheries management and marine spatial planning, Councils were given an indirect consultation authority that allowed them to comment on any project that would or could impact EFH or HAPCs. On its face, this is a good thing. The problem is a lack of requirement for those receiving the comments to take any action.

New England Council Habitat Process

In October of 1998, the Council met its requirements under the MSA by submitting the Omnibus Essential Fish Habitat Amendment 1. This amendment incorporated the Northeast Multispecies FMP, Sea Scallop FMP, Atlantic Salmon FMP, Monkfish FMP, and components of the Herring FMP, which was a work in progress.

The purpose of this Amendment was to identify, protect, conserve, and enhance habitat. To support the Council's Habitat Policy, the objectives for the EFH Amendment were:

1. To the maximum extent possible, identify and describe all EFH for those species of finfish and mollusks managed by the Council.
2. To identify all major threats (fishing and non-fishing related) to EFH of those species managed by the Council.
3. To identify existing and potential mechanisms to protect, conserve and enhance the EFH of those species managed by the Council, to the extent practicable.

As outlined by the Interim Final Rule (*Federal Register* Vol.62 No. 244, December 19,1997), there were certain requirements that had to be met by NMFS and also by the Councils:

NMFS had to:

- Develop guidelines, by regulation, to assist the Councils in the description and identification of EFH in FMPs (including adverse impacts on EFH) and consideration of actions to ensure conservation and enhancement of EFH by April 11, 1997 (Sec 305(b)(1)(A))
- Develop schedules for amending FMPs for EFH, and for future periodic review of EFH amendment (Sec 305(b)(1)(A))
- Provide each Council with recommendations and information regarding EFH for each fishery under the Council's authority (Sec 305(b)(1)(B))
- Review programs administered by the Dept. of Commerce and ensure that relevant programs further the conservation and enhancement of EFH (Sec 305(b)(1)(C))
- Consult with Federal agencies regarding any activity, or proposed activity, authorized, funded or undertaken by the agency that may adversely affect EFH (Sec 305(b)(2))
- Coordinate with and provide information to other Federal agencies to further the conservation and enhancement of EFH (Sec 305(b)(1)(D))
- Recommend conservation measures for any action undertaken by any state or Federal agency that may adversely affect EFH (Sec 305(b)(4)(A))

The Councils were required/authorized to:

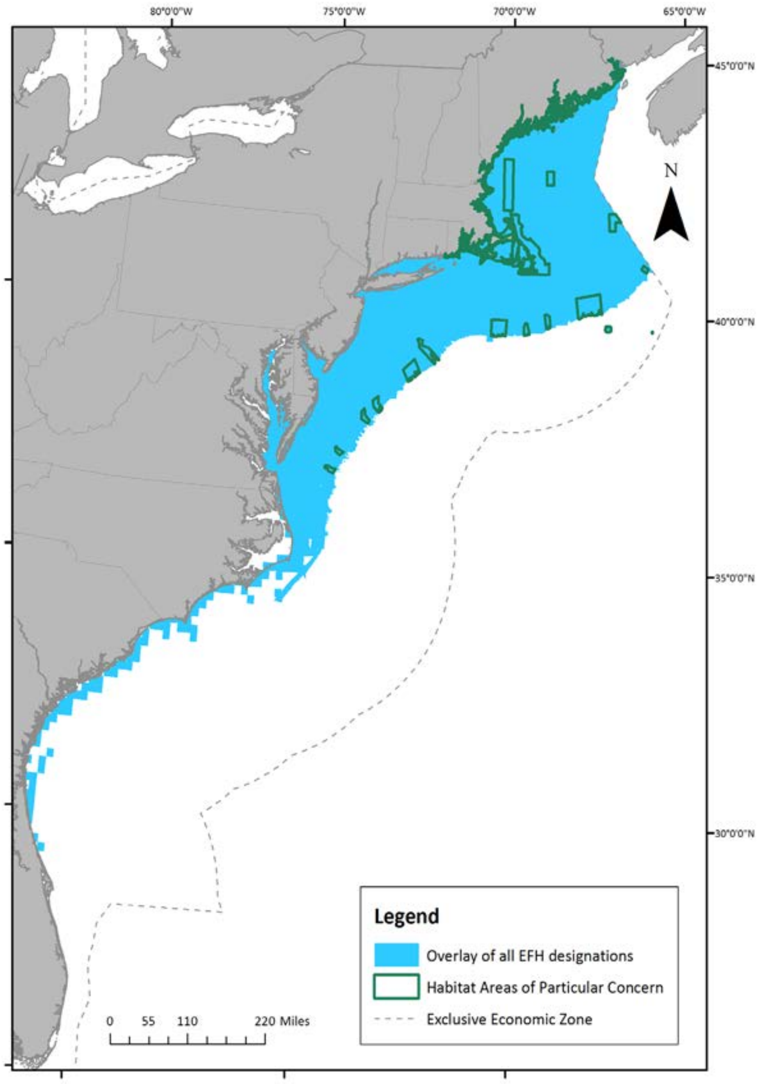
- Submit FMP amendments to the Secretary to implement the EFH and other new FMP requirements by October 11, 1998
- Describe and identify EFH for the fisheries based on the guidelines established by NMFS, minimize to the extent practicable adverse effects on such habitat caused by fishing, and identify other actions to encourage the conservation and enhancement of EFH (Sec 303)
- Comment on and make recommendations to NMFS and any Federal or state agency concerning any activity, or proposed activity, authorized, funded, or undertaken by any Federal or state agency that may adversely affect the habitat, including EFH or a fishery under its authority (Sec 305(b)(3)(A))
- Comment on and make recommendations to NMFS and any Federal or state agency concerning any activity that is likely to substantially affect the habitat, including EFH, of an anadromous fishery (sec 305(b)(3)(B)).

While the New England Council met all of its requirements, most of the EFH designations were very broad. In most cases, this included just about all of the areas showing at least moderate abundances of the species and the required life stage (egg, larvae, juvenile, adult and/or spawning adult) over a long time series of survey data. In effect this tended to water down (pun intended) the impact of the EFH designation. The Council designated only one small offshore area for the next level of habitat designation, as a HAPC. This was an area on Georges Bank that was considered important to juvenile cod. At the same time, some rivers along the Maine coast were designated as HAPC for Atlantic salmon.

In 2003, the Council started the process of reviewing and updating its EFH and HAPC designations and associated measures to minimize habitat impacts with an Omnibus EFH Amendment (2). The focus of this amendment was to refine the EFH designations to make them be those areas that had a higher level of importance to the individual species (Level 3 and 4) and to add a series of HAPC designations. As outlined in the Amendment, the purpose is to address additional measures that are necessary in order to:

1. To meet NMFS's published guidelines for implementation of the MSA's EFH provisions to review and revise EFH components of FMPs at least once every five years.

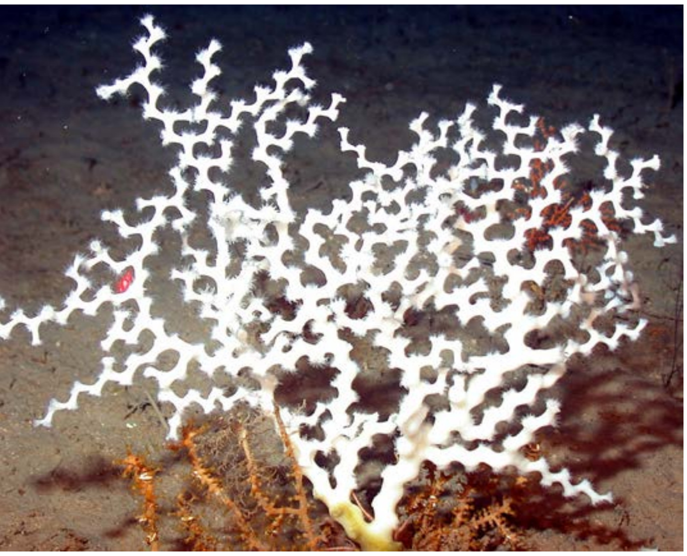
2. To develop a comprehensive EFH management plan that will successfully minimize adverse effects of fishing on EFH through actions that will apply to all Council-managed FMPs.



This figure shows an overlay of all the Omnibus EFH Amendment 2 proposed EFH designations for species managed by the New England Council. The proposed and existing HAPCs are outlined in green and include various areas on the shelf in addition to specific canyons and seamounts. (From Draft DEIS for Omnibus EFH Amendment 2.)

It has taken longer than several of the required five-year review cycles to fully complete the Omnibus EFH Amendment 2. Some might argue that since the Council completed and accepted the work on EFH and HAPC designation midway through the process, that it met its obligation under the five-year review requirement. Others would agree, but say that the Council did not submit this update for implementation until the entire process was complete. As stated earlier, my first term on the Council began with membership on the Habitat Committee. My nine-year tenure will end without that Amendment being completed. While this is incredibly slow progress, there are reasons how this slow progress has unfolded. Some of the problems should have been anticipated, while others could not have been. However, it is hard to know how much adverse effects minimization is needed, and also what "practicable" means. It seems as though practicable will be determined at the level of protections that will raise both the environmental non-governmental organizations and the industry to the same level of unhappiness about the amendment, but that's not exactly an objective criteria. It has been challenging for the Habitat Plan Development Team to provide advice about how much is enough in terms of habitat protection.

Much of the early committee work struggled with the designation of HAPCs because designation criteria and evaluation metrics were not well-defined. At the same time, some participants in the commercial fisheries that could be impacted began to get concerned that this process was merely a backdoor attempt to designate marine reserve closures to fishing. This concern was deepened by the second effort to pass Oceans 21 legislation in 2007, previously debated by Congress in 2005. This bill was a comprehensive attempt to put in place a coordinated and extensive plan to manage all the varied and sometimes contradictory uses of our oceans and marine resources. The bill did not pass, and those who fought against it demonized it as simply a way to zone the oceans to restrict fishing activities through marine reserves. This merely poured gasoline on the fire of concern about HAPCs and made the progress of the Omnibus EFH Amendment creep along. Part of this slow progress may also have been due to a lack of narrowly focused objectives for HAPCs. I cannot overstate the industry's (both commercial and recreational users) distrust of "government." This is a major reason why this process has dragged out so long and probably one that could have been mitigated with better planning.



Also, the 2007 Reauthorization of MSA gave the Councils specific authority to manage deep-sea corals. While the New England Council waited to see what the guidelines from NMFS would be, there was debate as to whether this should be part of the Omnibus EFH Amendment or a separate action. This also slowed down the process. Preliminary guidelines were sent to the Council in May 2010 and ultimately deep-sea corals were split out into a separate Council action in September 2012.

As the amendment progressed, the Council began to work on the adverse impacts aspect of the action. What became clear was the lack of a metric by which to measure these actual and potential impacts, yet under the MSA Councils are required to minimize the adverse effects of fishing on EFH. The Omnibus EFH Amendment 2 attempts to optimize the minimization of adverse effects on EFH across FMPs. To accomplish this, the Habitat Plan Development Team developed the Swept Area Seabed Impact (SASI) model. SASI was developed to estimate the magnitude, location and duration of adverse effects across gear types and FMPs. While this model had the potential to substantially improve the estimation of impacts, it was a new model that took time to develop and peer review. This caused another three-year delay in the amendment's progress.

SASI was not the only output from the Habitat Plan Development Team. As part of the whole SASI process the Plan Development Team developed a five component approach:

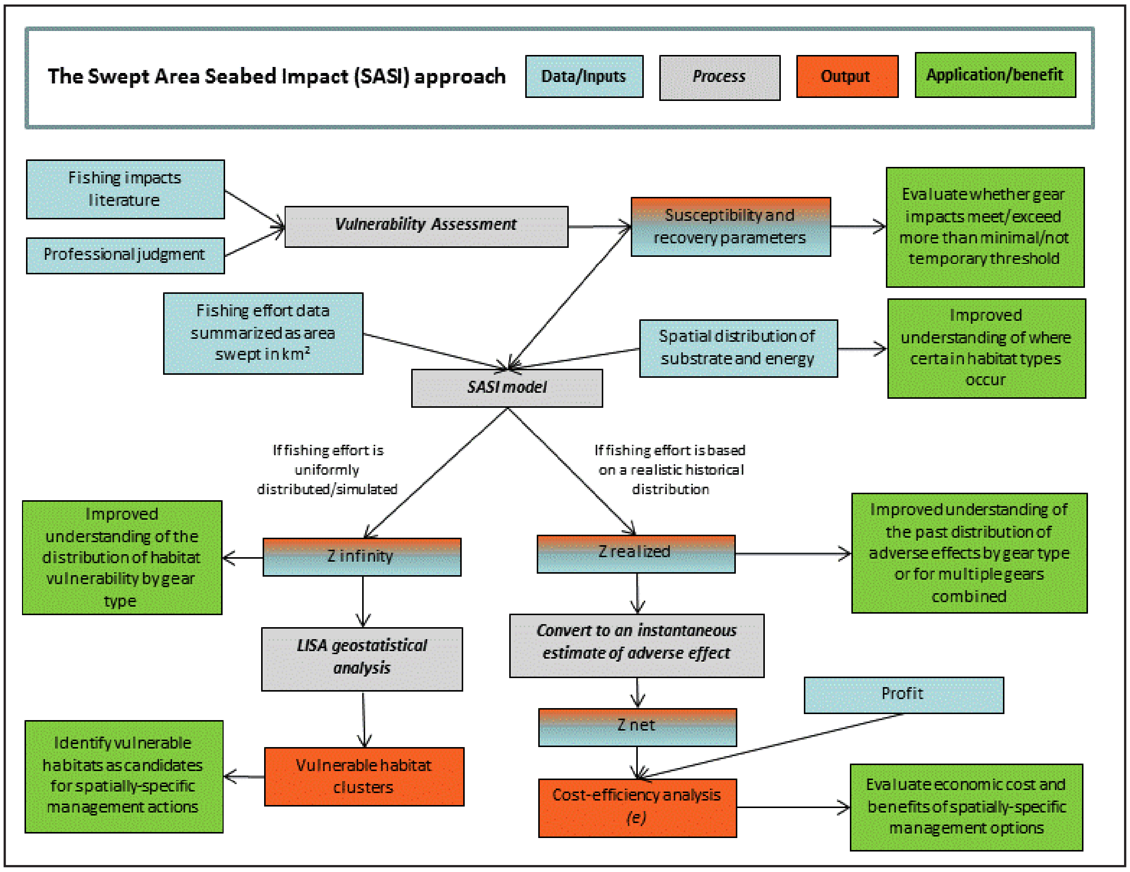
1. Vulnerability Assessment—a comprehensive review of the scientific literature on gear effects and a framework for generating susceptibility and recovery parameters for the SASI model.

2. SASI model—a geo-referenced analytical tool to estimate the adverse effects (Z) of fishing on seabed structure.

3. Local Indicators of Spatial Association analysis—a geostatistical approach to translate the broad array of highly vulnerable structural habitats identified in the Z analysis into smaller clusters that could serve as the foundation for habitat management area design.

4. Cost-efficiency analysis—to evaluate the costs (i.e. adverse effects to EFH) and benefits (profits) of various management alternatives.

5. Area Closure analysis—to estimate the potential magnitude of adverse effects generated by fishing under various area closing/open scenarios and to estimate the expected costs and benefits of implementing such scenarios.



For the New England Council, there were other issues that have also formed roadblocks to getting the EFH Omnibus Amendment completed. The first was a desire and need to coordinate this action with a re-assessment of the value associated with the groundfish mortality closures, which overlap spatially with existing habitat closures. If some areas were to be opened and others closed, it makes great sense to look at all the closed areas comprehensively. With this in mind, the final analysis and Council action has been further delayed to allow the Groundfish Plan Development Team, the Closed Area Technical Team and the Groundfish Committee time to evaluate all the groundfish mortality and spawning closures and suggest revisions as needed. One of the emerging complications has been a lack of data on egg and larval distribution and origination, as well as a lack of scientific data directly linking habitat and spawning success. The latest research by Vert-pre et al. (2013) indicates that spawning success is impacted by a number of variables. Unfortunately, as that process was partially underway, team members were pulled away to work on major groundfish problems with Gulf of Maine and Georges Bank cod and Georges Bank Yellowtail flounder.

The desired end game is the illusive, but comprehensive, analysis of all Council habitat and groundfish closed areas. Unfortunately the "groundfish disaster" caused the Council to want to find mitigation measures within some of the existing closures outside of this comprehensive plan. This continued to pull technical expertise away from any coordinated plan. It also meant that what was envisioned, as a coordinated and comprehensive analysis would become a piecemeal attack on closed areas that could have long-term detrimental impacts. At the same time as the groundfish industry was pushing for opening closed areas, the scallop industry was pushing to get other areas open for access to high concentrations of scallops which would result in lower interaction with yellowtail flounder. If that was not enough, the Mid-Atlantic Fishery Management Council was pushing to get part of Georges Bank reopened to dredging for ocean quahogs. It was akin to the Wild West of fisheries with a potential for unknown harm to habitat.

As this is written, the final chapters have not played out. The current timeline has the Council approving Omnibus EFH Amendment alternatives related to habitat and groundfish management in June. Selection of final alternatives is planned for September or November. Public hearings will take place during the summer. The Council will approve the EFH Omnibus Amendment 2 as soon after September as possible with implementation in 2014.

Strategic Plan

As part of the Omnibus EFH Amendment process, the Council crafted a strategic plan to outline how it will fulfill the mandates of MSA as they pertain to the EFH. This includes the five-year review process. It covers the implementation of the consultation process that gives the Council the authority to comment on any non-fishing activities that have the potential to impact EFH or HAPCs.

While I am not one for creating more rules, there has to be a better process for Council comments on non-fishing impacts. For the most part, Council comments get added to the file of public input and that is usually the end of the process. If Council comments are supposed to protect EFH and HAPCs, there needs to be a more formal process as to how comments are incorporated into the non-fishing impact review. The Council tends to defer to NOAA Fisheries Northeast Regional Office Habitat Conservation Division on these issues because it is simply too time consuming. Also, the Council and its staff do not have the expertise to consult on all manners of non-fishing impacts. Maybe the answer involves the Council prioritizing non-fishing impacts of greatest concern and focusing Council comments on those issues?

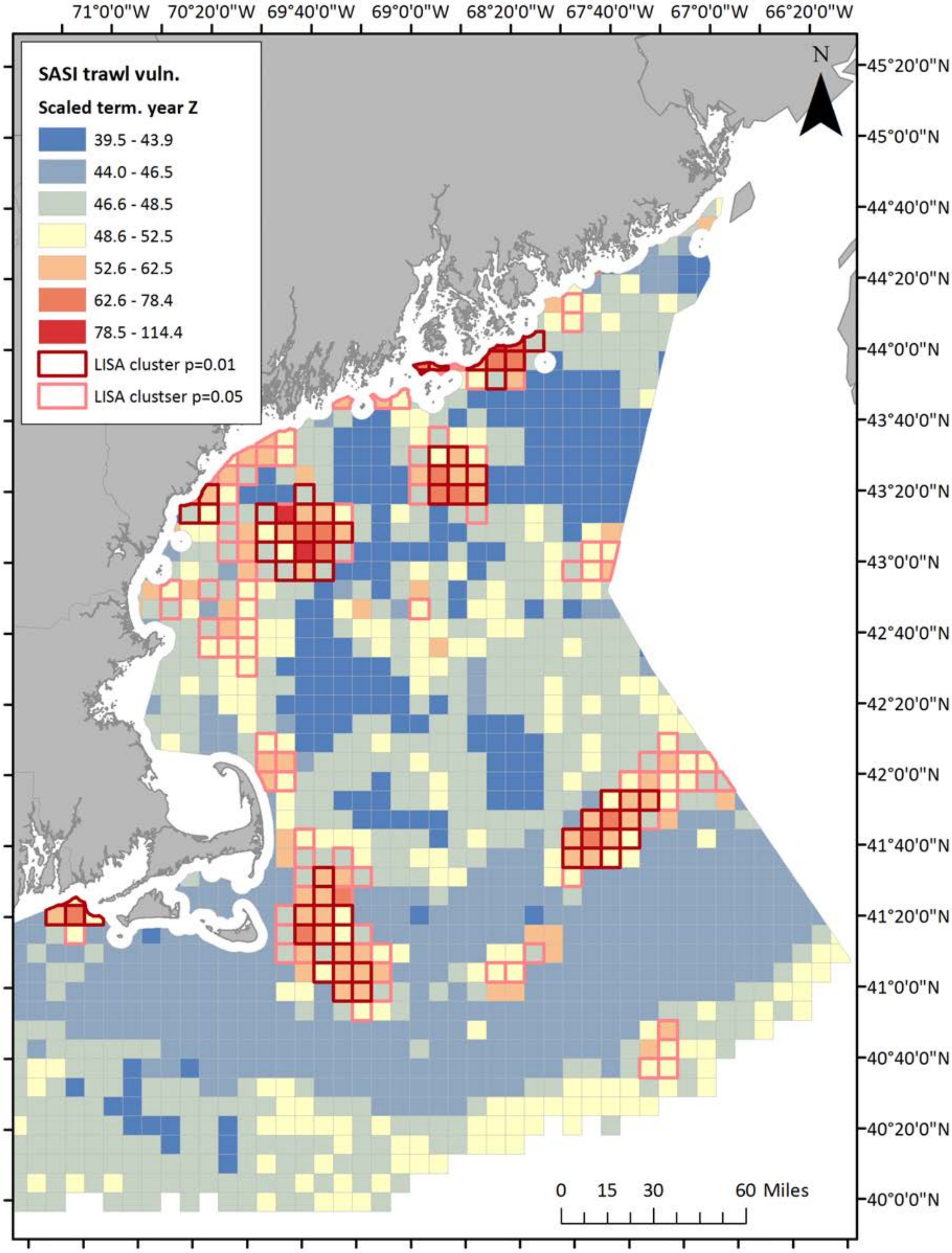
The goal of the Strategic Plan was to "improve the quality and increase the productivity of New England's fishery resources through implementation of the habitat management program." The goal is to be reached through a set of objectives that have largely been incorporated into, or are the basis of, Omnibus EFH Amendment 2.

Challenges and Tradeoffs

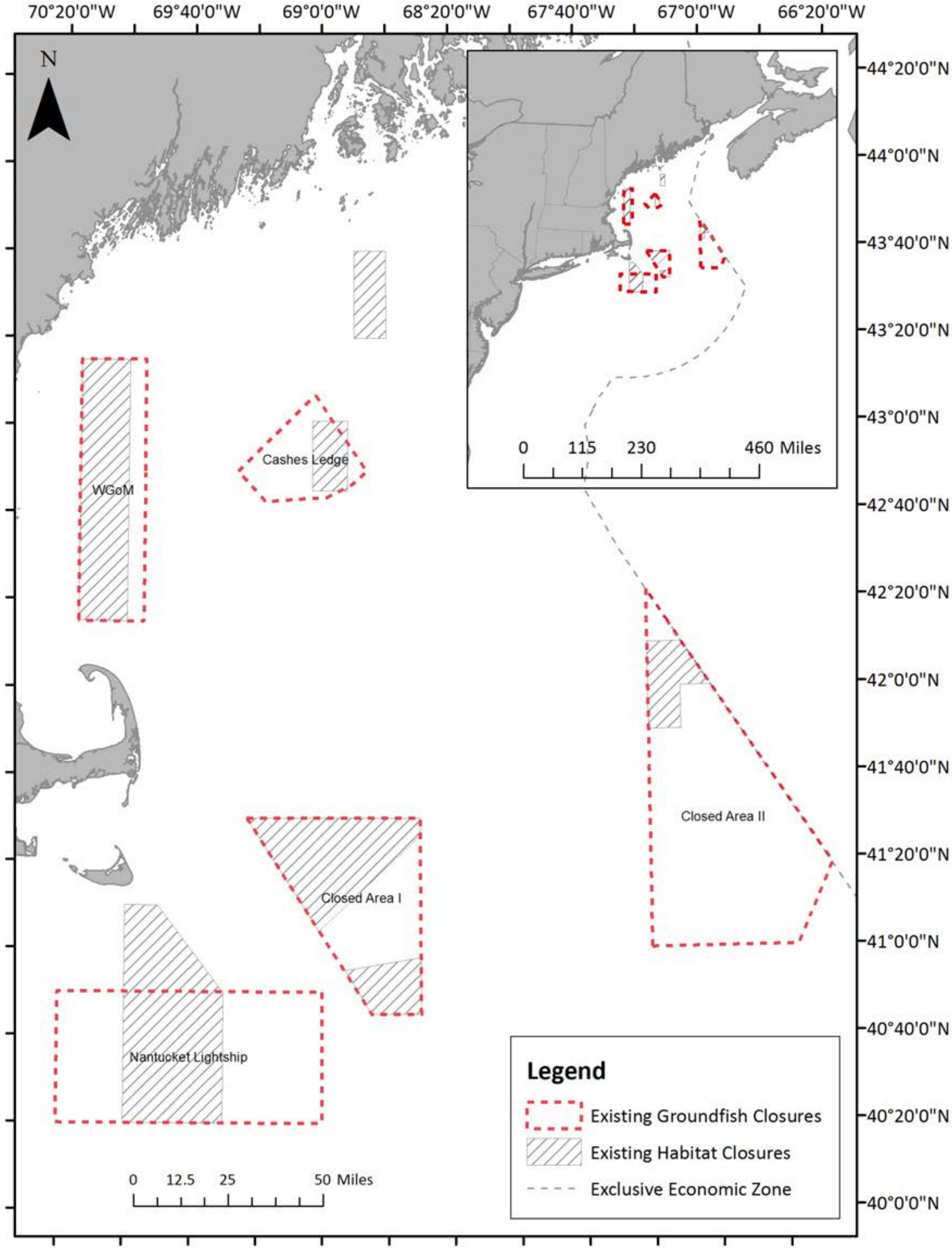
This process has been a lesson in balancing short-term needs of the fishing industry with the long-term viability of the resources. Managers tend to be very good at responding to public pressure, but not very good at being visionary. The concept of opening up some of these closed areas to access healthy fish stocks sounds reasonable. It sounds even more reasonable given the public outcry that the closed areas did not have any beneficial effect. Some would argue that if they had been beneficial then the stocks would be in better shape. That begs the question that without them would stocks have been in worse shape? In any case opening them without proper analysis undoes 20 years of sacrifice without any real understanding of what the benefits might have been.

If there are no more major potholes in the road, this amendment will have taken 11 years to complete. What are the takeaways from this process? First, be very clear in goal setting, so the public understands what the desired outcome is. When designating EFH, be clear as to what this means to the broad range of user groups. The same is true with designating HAPCs. Stakeholders should know what to expect for protective restrictions being placed on these areas. Stakeholders should also know what the benefits are for managing habitat as part of the process of managing fish. It should be noted that it is hard to know precisely what these benefits are, and that it's hard to know how much habitat protection may be necessary to achieve them. There is still a lot unknown about fish and their habitat needs/associations, and what is known could be changing in the face of environmental regime shifts.

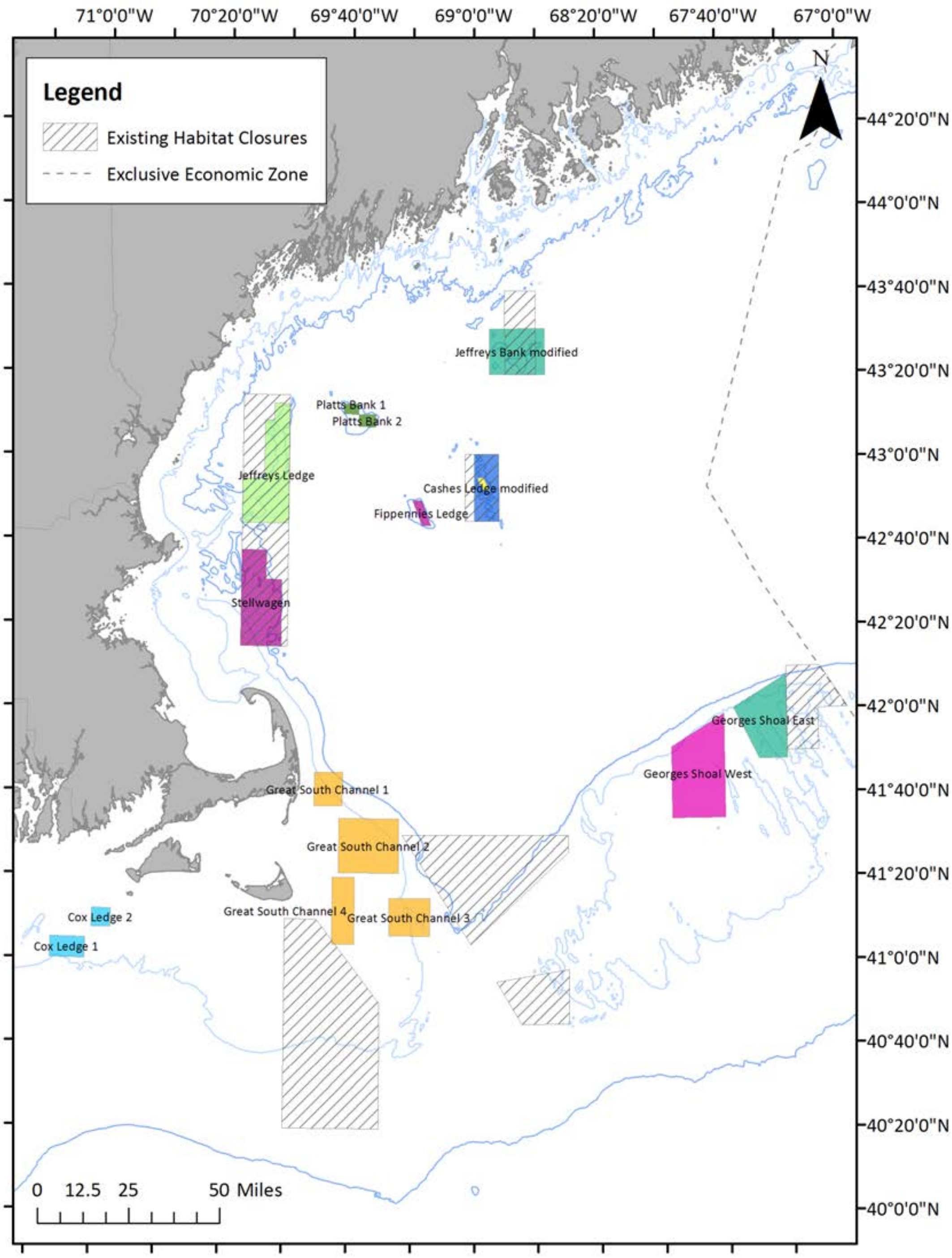
With this in mind, there may need to be more reference to and emphasis on habitat in MSA. While not exactly absent, habitat is only mentioned in one section of the Act, Section 305(b). While I am not sure that there needs to be a National Standard 11 dealing with habitat, having a more prominent inclusion of habitat in the Act would point out the importance of habitat to the overall process.



This figure shows estimated habitat vulnerability to otter trawl gear in the Gulf of Maine/Georges Bank region. Clusters of high values at two probability thresholds are shown in pink and red outlines. These outlined cells represent locations that have high vulnerability scores and are near other cells with high vulnerability scores, and were used by the Council's Habitat Plan Development Team and Oversight Committee as a foundation for habitat management area development. (From Draft Environmental Impact Statement (EIS) for Omnibus EFH Amendment 2.)

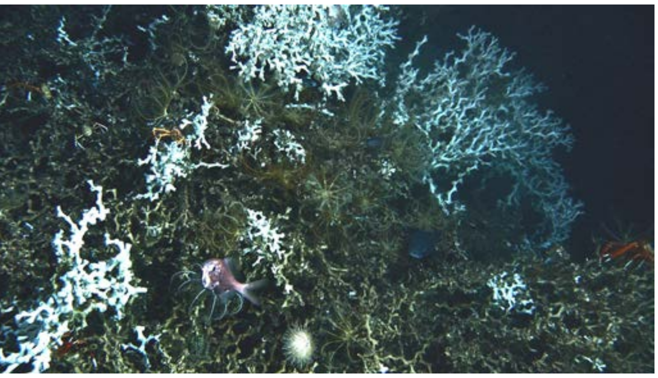


This figure shows the current habitat and groundfish management areas. The groundfish areas were closed to many types of gear capable of catching groundfish starting in the mid-1990s, and the habitat areas were closed to mobile bottom tending gear in 2004. (From Draft Environmental Impact Statement for Omnibus EFH Amendment 2.)



This figure shows the range of draft habitat management areas proposed in Omnibus EFH Amendment 2 as of January 2013. (From Draft Environmental Impact Statement for Omnibus EFH Amendment 2.)

The National Environmental Policy Act analysis for actions that include habitat and habitat impacts needs to compare current costs, if any, with the long-term benefits of habitat protection. In the "perfect" world this is sometimes hard to analyze, but it becomes even harder when the environmental regime is changing at the rate it appears to be in the Northeast. The fishing industry in New England has heard the "current pain for future gain" scenario before and has grown extremely leery of that elusive promise.



Conclusion

An elephant is best eaten one bite at a time. To the extent possible, divide a huge task into manageable chunks. The New England Council took on a large task with this EFH Omnibus Amendment 2 and then continued to make it bigger. It is better in my mind to accomplish smaller tranches. Certainly, it is easier for managers and stakeholders to focus their efforts. Setting clear and understandable goals and objectives upfront give stakeholders a better sense of transparency. In the Council's defense, it had been advised that severing updated EFH designations from the adverse impacts minimization measures was not a good idea, so the ability to simplify was limited. The Council certainly could have ignored the deep-water coral issues and would have saved a lot of time developing canyon and seamount HAPC proposals in 2006 and designing coral management alternatives in 2010-2011. In hindsight, the path may be clearer.

Going back to the opening statement, habitat is the foundation on which all resource management should be built. Without consideration of this important element, successful management and sustainable fisheries will be much harder to achieve. The sooner all the stakeholders realize this, the better the end product of the management process will be.

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Integrating Habitat in Ecosystem-Based Fishery Management

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Abstract

Healthy freshwater, coastal and marine habitats are essential to fisheries and coastal communities, and to the ecosystem functions on which both depend. Since the 1996 Sustainable Fisheries Act, Regional Fishery Management Councils in partnership with the National Oceanic and Atmospheric Administration (NOAA) Fisheries Service have made progress on addressing adverse impacts of fishing and non-fishing activities on habitat. Yet too often, habitat issues have not been integrated into mainline fisheries management. Many coastal habitats are still at risk, with adverse impacts to fisheries that are poorly understood and masked by overfishing. Our success in addressing overfishing provides an opportunity for a greater focus on habitat, better integrating habitat issues into ecosystem-based fisheries management and better integrating marine fisheries into an ecosystem approach to ocean management. We propose several practical steps toward this goal: 1) Identifying and delineating priority habitats and their vulnerabilities; 2) Setting habitat conservation objectives; 3) Integrating habitat conservation explicitly into other aspects of fisheries management; and 4) Expanding partnerships and building alliances to conserve habitat. NOAA's Habitat Blueprint (2012) provides a roadmap to focusing Federal resources and achieving these steps.

Introduction

Healthy habitats sustain resilient and thriving marine and coastal resources, communities, and economies. It is appropriate that habitat conservation is a major topic in the Managing our Nation's Fisheries 3 conference, as the ecosystem functions, goods and services provided by conserving and restoring riverine, coastal and deepwater habitat play a critical role in sustaining fisheries and recovering protected species. Therefore it is imperative that we incorporate habitat conservation into any effort at ecosystem-based management.

The goal of ecosystem-based management is to sustain diverse, productive, resilient coastal and marine ecosystems and the services they provide, thereby promoting the long-term health, security, and well-being of our nation (National Ocean Council 2012). To reach this goal, we must ensure that the ecosystem services provided by protecting and restoring riverine, coastal and deepwater habitat are more clearly defined, demonstrated, and valued. The National Oceanic and Atmospheric Administration (NOAA) has established a Habitat Blueprint that gets to the heart of ecosystem approaches to management. The Blueprint provides a focusing mechanism to leverage NOAA and other funding sources on issues critical to accomplishing our habitat conservation mission.

In this paper, we briefly sketch out the progress that the Regional Fishery Management Councils (Councils) and the National Marine Fisheries Service (NOAA Fisheries) have made in addressing the two major components of the habitat challenge in the context of fisheries: (1) fishing impacts to habitats—affecting the goods and services these habitats provide to society; and (2) non-fishing impacts to habitats upon which fisheries productivity depends. We then propose some practical steps that we in the fisheries community can take to further advance the integration of habitat considerations into ecosystem-based management. NOAA's Habitat Blueprint provides the forward-looking framework for achieving these steps. It is designed to help NOAA think and act strategically across programs and with partner organizations to increase the effectiveness of our efforts to improve habitat conditions for coastal and marine life, including fisheries species, thereby providing economic, cultural, and environmental benefits to our society.

Progress to Date

In 1996, the Sustainable Fisheries Act added the essential fish habitat (EFH) provisions to the Magnuson-Stevens Fishery Conservation and Management Act (MSA). These provisions require NOAA Fisheries and Councils to identify and describe EFH and minimize, to the extent practicable, the adverse effects on such habitat caused by fishing. The provisions were added in recognition that degradation of fish habitat threatened many of our nation's fisheries stocks and that habitat conservation should be used as a tool to achieve sustainable fisheries. Since 1996, NOAA Fisheries and the Councils have made significant strides in identifying, protecting, and restoring fisheries habitat, including identifying EFH for multiple life stages of more than 1,000 species of Federally-managed fishes and designating over one hundred habitat areas of particular concern (HAPCs). The regular five-year reviews of EFH and HAPC designations that have begun to be implemented by the Councils are serving a key role in moving toward adaptive management that uses the best available scientific information.

Fishing Impacts

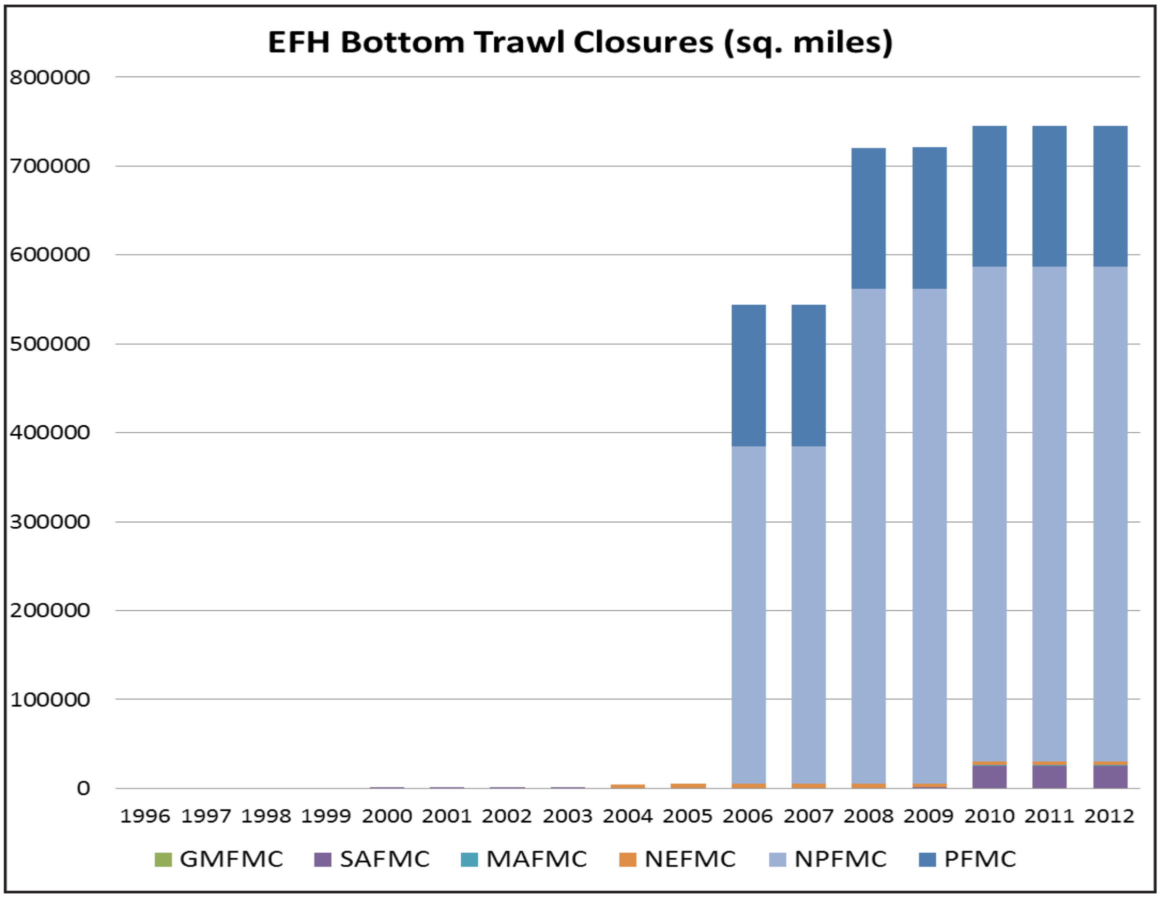
Beginning around 2005, the Councils used their MSA EFH authorities to develop region-wide approaches to habitat conservation on a scale commensurate with ecosystem management. These actions have made the United States a world leader in protecting vulnerable benthic habitats from the adverse impacts of certain fishing gears. Key approaches were pioneered by the North Pacific and Pacific Fishery Management Councils and became effective in 2006, ten years after the EFH legislation. These actions relied primarily on closing areas to bottom trawling—the fishing activity deemed the most likely to damage benthic habitats (Fig. 1).

Topographic features such as ridge systems (e.g., Bowers Ridge and Mendocino Ridge), portions of undersea canyons (e.g., Monterey Canyon), and banks (e.g., Heceta Bank) were protected from bottom trawling. Such habitats are often associated with hard substrata known to be colonized by corals, sponges, and other fauna. Certain habitats deemed particularly vulnerable, such as deep-sea coral "gardens" in the Aleutian Islands and seamounts in the Gulf of Alaska and off the West Coast, received a higher level of protection and were closed to all bottom-contact gear (bottom trawls, pots, and bottom-set longlines and gillnets).

A particularly innovative aspect of the measures recommended by both Councils was to apply a precautionary management approach prohibiting the use of bottom trawl fishing gear in deeper areas where such gear had not yet been heavily used, while allowing historically-fished areas to remain open to such fishing. This approach to "freeze the footprint" of bottom trawling was designed to allow existing fisheries to thrive, while preventing expansion into unsurveyed areas that might contain deepwater corals, sponges, and other vulnerable hard-bottom habitats. This approach was exemplified by the Aleutian Islands Habitat Conservation Area, which covered nearly 370,000 square miles and represents the largest single effort to conserve relatively undisturbed bottom habitats in U.S. waters.

Such ecosystem-scale habitat measures, blending targeted protection with a precautionary approach, have since been applied by the North Pacific Council in the Bering Sea and by the South Atlantic Council in protecting snapper-grouper habitats and over 24,000 square miles of deep-water Coral Habitat Areas of Particular Concern. A similar approach is being considered by the Mid-Atlantic and New England Councils.

Figure 1. Marine benthic EFH areas protected from impacts of bottom-trawl fishing gear. The figure shows the cumulative area in square miles protected by NOAA Fisheries and the Fishery Management Councils since the 1996 Sustainable Fisheries Act. (Note: The Western Pacific Fishery Management Council protected the entire exclusive economic zone under its jurisdiction from trawling and certain other bottom-contact fishing gears in the early 1980s, prior to the EFH amendments. Bottom-trawling does not occur in the Caribbean Council region. In addition to these EFH-specific closures, there are additional closures in place to reduce gear conflicts and other purposes, which also benefit habitat conservation.)



Non-Fishing Impacts

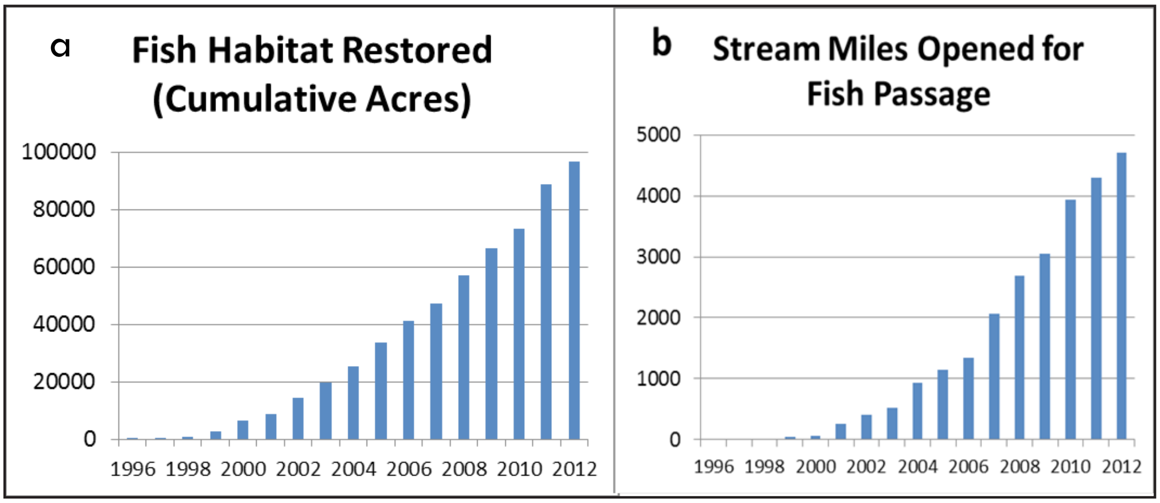
Addressing the fishing impacts to EFH in Federal waters is fully under the authority of NOAA Fisheries and the Councils. In contrast, the primary responsibility for protecting and restoring EFH degraded or destroyed by non-fishing threats most often lies with other agencies, often multiple agencies at the state and Federal level. Nearshore, estuarine, and riverine habitats are also subject to a greater number and variety of impacts than are offshore habitats, adding complexity to the decision-making process and making conservation progress more difficult to measure.

Despite these constraints, we are convinced that NOAA's efforts have had a significant impact on improving habitat for fisheries species. Endangered Species Act and EFH consultations with other Federal agencies are an important tool to address non-fishing impacts. In 2012, NOAA Fisheries was able to reduce or avert impacts to 364,000 acres of habitat through its EFH consultation authority. In many cases, through reviewing permit processes and hydro-power licensing, consultations have resulted in revisions to originally-proposed actions that have reduced, averted or mitigated negative impacts to habitats. For example, NOAA Fisheries has used the EFH consultation process to influence plans for proposed open-loop liquefied natural gas facilities in some of the most biologically productive areas in the Gulf of Mexico marine ecosystem. These open-loop facilities draw in large volumes of seawater to regassify the liquid natural gas, potentially putting at risk commercially and recreationally valuable fish like snapper and red drum, as well as the organisms on which they feed. NOAA's consultations and the engagement of the fisheries and environmental communities have resulted in the redesign of several facilities to closed-loop systems to avoid entrainment and impingement of marine organisms. In another example, based on advice from NOAA Fisheries and the

New England Fishery Management Council, in 2010 the U.S. Army Corps of Engineers denied a permit requested by the Commonwealth of Massachusetts to use 500,000 cubic yards of sand and gravel from a 103-acre offshore site in Massachusetts Bay for erosion control on Winthrop Beach. The material would have been removed from an area of the Bay designated as EFH for 26 Federally-managed species, including valuable Atlantic cod. NOAA advised the Corps on alternative sources of material that would avoid the negative impacts of the proposed project and helped to support cod recovery efforts in Massachusetts.

NOAA also conducts habitat restoration targeted at improving habitat for fisheries species. On the restoration front, NOAA has restored nearly 100,000 acres of coastal, marine and Great lakes habitat since 1996 (Fig. 2a). This includes 69,000 acres of habitat through 2,300 community-based restoration projects and 8,000 acres of coastal wetlands in Louisiana. Through our work, more than 200 dams and other barriers have been removed since 1998, opening up more than 4,000 stream miles for fish passage (Fig. 2b).

Figure 2. *Fish habitat restored through NOAA Fisheries-led activities since the 1996 Sustainable Fisheries Act. (a) Cumulative area in acres of coastal, marine and Great lakes habitat restored. (b) Cumulative miles of streams opened for fish passage.*



Unfinished Work and New Challenges

Despite this progress, habitats essential for healthy fisheries are still at risk. Estuaries support fish and shellfish species that comprised approximately 46% by weight and 68% by value of the U.S. commercial catch landed nationwide from 2000 through 2004 and approximately 80% of the U.S. recreational landings over the same period (Lellis-Dibble et al. 2008). Yet 53% of the estuaries (by area) in the lower 48 states are considered at high or very high risk of current habitat degradation (National Fish Habitat Board 2010). Between 2004 and 2009, marine and estuarine intertidal wetlands declined by an estimated 84,100 acres (Dahl 2011), and the loss rate of intertidal salt marshes increased to three times the previous loss rate between 1998 and 2004. Freshwater wetlands in coastal watersheds provide important habitat for anadromous marine fish such as herring and salmon, and contribute to the overall health of the estuaries lower in the coastal watersheds. Yet despite an overall increase in wetlands nationally between 1998 and 2004, there was a net loss of wetlands in coastal watersheds adjacent to the Atlantic Ocean and Gulf of Mexico of more than 385,000 acres, or more than 60,000 acres per year (Stedman and Dahl 2008). The primary causes of these habitat trends range from development in upland watersheds, polluted run-off and other effects of urbanization and agriculture affecting estuaries, and coastal storms, land subsidence, and sea-level rise impacting intertidal wetlands.

Up until now, the extent to which these coastal habitat trends have affected recreational and commercial fisheries has likely been masked by overfishing. Our historic success in ending overfishing may open a window on understanding the linkages between habitat and fisheries productivity. In a review of NOAA Fisheries rebuilding plans, Milazzo (2012) found that effective, lasting and well enforced controls of fishing mortality resulted in evidence of stock recovery in two-thirds of the rebuilding plans for which we have adequate data on fishing mortality and biomass levels. However, certain stocks appear to respond poorly and/or belatedly to rebuilding measures. These include certain demersal species (Atlantic cod), many rockfish stocks, diadromous species (such as salmon), stocks in the snapper-grouper and reef fish complexes, and deep-sea species. Many of these species are known to be tightly associated with particular habitats. For these species, controlling catch and fishing effort alone is not enough, and rebuilding plans need to address other factors such as habitat that may be bottlenecks to recovery. The nation's success in addressing overfishing should allow us to better identify stocks whose recovery depends on restoring and protecting habitat.

Steps Toward Integrating Habitat into Ecosystem-Based Management

So where do we go from here? It seems to us that there are several practical steps that offer an opportunity to make progress. The following suggestions build on recommendations from policy groups such as the U.S. Commission on Ocean Policy (2004) and the Ecosystem Principles Advisory Panel (1999), as well as a NOAA Habitat Blueprint Symposium we sponsored at the 142nd Annual Meeting of the American Fisheries Society in August 2012.

Identify and Delineate Priority Habitats and their Vulnerability to Fishing and Non-Fishing Impacts

NOAA and the Councils have made progress in identifying EFH, sometimes based on limited habitat data, but we have been less successful in prioritizing among habitats. If every habitat is "essential" then no habitat will get the attention needed for successful conservation. For example, our EFH consultations on non-fishing habitat impacts have been extensive (more than 4,000 per year), but often not focused on priorities most likely to achieve measurable benefits for achieving sustainable fisheries. Likewise, small and dispersed habitat protection or restoration activities will likely fail to achieve large-scale, measureable results. Focus becomes increasingly critical in a time of diminishing financial resources.

From the fisheries management standpoint, we must be explicit in the identification of those habitats where we can achieve measurable benefits that will support priority fish stocks. This effort will benefit from improved scientific information linking specific habitat improvements to fishery productivity. NOAA Fisheries has developed a Marine Fisheries Habitat Assessment Improvement Plan (NMFS 2010) that defines the agency's role in pursuing habitat science and establishes a framework to coordinate habitat research, monitoring, and assessments in support of our fishery management responsibilities. Among other goals, it is explicitly designed to reduce habitat-related uncertainty in stock assessments, support assessments of ecosystem services, and contribute to ecosystem-based fishery management and integrated ecosystem assessments. The plan deals with managed stocks and stock complexes within fishery management plans, with particular focus on the 230 stocks in the Fish Stock Sustainability Index. NOAA Fisheries has also initiated a regional process to further prioritize needed habitat assessments. The process results in two prioritized lists; the first identifies specific stock assessments that are most likely to benefit from improved habitat assessments and the second identifies stocks for which habitat assessments will most advance EFH identification and conservation. The pilot process was implemented in California in 2012 (NMFS 2012), identifying a number of priority stocks in both categories. The majority of these stocks were anadromous salmon (e.g., Chinook and coho stocks) and rockfish (e.g., bocaccio, canary rockfish, and cowcod) stocks, and there was a nearly complete agreement between the priorities for stock assessment and those for other habitat science. A similar process will be conducted in the other regions to help NOAA focus its habitat research.

However, these information gaps should not prevent us from dealing with habitat conservation problems. Fishery stakeholders agreed on this point almost ten years ago at the first Managing Our Nation's Fisheries conference (Kurland 2004). We still need to identify and act on our management priorities now, while we work to improve our science base. We also need to broaden our approach from species-by-species, to identifying habitats that benefit multiple species and those that provide additional ecosystem services that we value. In 2005, the U.S. Commission on Ocean Policy recommended that NOAA Fisheries change the designation of EFH from a species-by-species to a multispecies approach and, ultimately, to an ecosystem-based approach that includes consideration of ecologically valuable species that are not necessarily commercially important. While there is a growing body of science-based analytical methods that could support such designations, we suggest that there is already scientific and societal consensus on the importance of certain habitat types based on their contributions as fish habitat, biodiversity and ecosystem services. These include tropical coral reefs, coastal wetlands, seagrass and kelp beds, and deep-sea coral communities. This would be a practical place to start focusing our attention and, as we discuss below, will facilitate building alliances beyond the fisheries management community.

Set Habitat Conservation Objectives

Successful management depends upon translating concepts into specific objectives and measurable targets. In single-species fisheries management, these targets have generally been target stock sizes that will avoid overfishing. Success in ending overfishing has benefited from a focus on overfished stocks; clear targets established through mandates and regulations (e.g., National Standards, determinations of maximum sustainable yield/optimum yield, allowable catch levels, accountability measures, etc.); and the ability to measure progress (i.e., through stock assessments).

In a similar manner, a key aspect of an ecosystem approach to management is developing indices of ecosystem health as targets for management (Ecosystem Principles Advisory Panel 1999). A number of authors have identified the difficulties in setting performance measures for a small selection of fisheries ecosystem metrics, however nearly all approaches identify the centrality of habitat. While in most cases, the extent and quantity of habitat that is needed to contribute to increased productivity of a particular fisheries stock, or to a "healthy ecosystem" cannot be determined exactly, suspected tipping points may be inferred, and prudent managers will set targets that are likely to avoid degradation.

Table 1. Selected examples of existing quantitative habitat conservation targets. (Source: NMFS 2013)

Program	Goal	Target	Reference
Chesapeake Bay Program	Restored oyster populations in priority tributaries	50-100% of restorable bottom in tributary restored.	http://www.chesapeakebay.net/
		15 to 50 oysters/m2 covering at least 30% of the reef area	
San Francisco Bay Sub-tidal Habitat Goals Project	Conserve ecosystem services provided by eelgrass beds	Protect eelgrass habitat through no net loss to existing beds (3,700 acres in 2009).	http://www.sfbaysubtidal.org/
		Increase native eelgrass within 8,000 acres of suitable intertidal/subtidal habitat	
Puget Sound Partnership	Wild Chinook salmon population recovery	10% of bluff-backed beaches with high sediment supply or priority nearshore habitat facing development pressure are protected	http://www.psp.wa.gov/

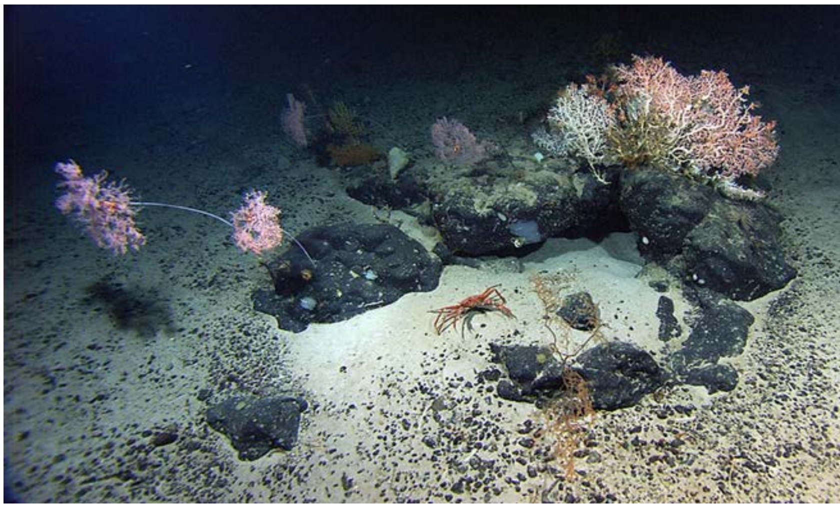
There are examples from existing habitat programs that are successfully using habitat objectives or indicators to identify habitat priorities and set management goals through their planning processes (Table 1). A variety of approaches have been used to set habitat objectives for both freshwater and marine fish species. There is a role for both qualitative and quantitative objectives and targets, and both can serve to measure progress and influence decisions about investing resources to affect a desired outcome for fisheries (NMFS 2013). However, we should strive to develop quantitative targets and measure progress to reach these targets.

Setting habitat objectives and targets that can enhance fisheries management requires understanding the ways in which habitat bottlenecks can constrain fish productivity, for example dams impacting access by diadromous fishes to spawning areas. It also requires the ability to delineate priority habitats and clearly identify their vulnerability to fishing and non-fishing impacts. While it remains a challenge to parse out specific effects of multiple human activities, particularly in nearshore and freshwater areas, there are methods that can be employed to systematically identify and prioritize the human activities that are the strongest drivers of ecosystem change (e.g., Altman et al. 2011). In most cases habitat objectives will measure the extent and quality of the habitat. As improved habitat assessments begin to yield habitat-dependent fishery productivity rates for priority habitat-dependent stocks, we will come closer to a being able to provide information to stock assessments using the same units.

Integrate Habitat Conservation Explicitly into Other Aspects of Fisheries Management

Habitat conservation efforts still remain relatively separated from traditional fisheries management approaches. We need to identify and build upon the synergies between fisheries habitat objectives and other aspects of policies and processes of fisheries management.

There are immediate opportunities that NOAA Fisheries could take to incorporate habitat as the Regional Fishery Management Councils develop ecosystem-based fishery management plans and by working with Councils to incorporate these efforts into regional ocean planning constructs such as those under the National Ocean Plans. As another example, both the U.S. Commission on Ocean Policy (2004) and the Pew Oceans Commission (2003) Reports stressed the need to address the broad ecosystem impacts of bycatch. When considering biogenic habitats, reducing bycatch of habitat-forming organisms such as deep-sea corals and sponges translates directly into reducing impacts on priority habitats. The North Pacific Council explicitly identified the link between its 2005 Groundfish EFH amendments and the goal to minimize bycatch of benthic habitat-forming invertebrates. Strengthening both bycatch monitoring and bycatch reduction of deep-sea corals and sponges will benefit habitats and the fishes that depend upon them (NOAA 2010).



The Councils, as governing bodies which include state representatives, offer unique opportunities to strategically partner with states on specific, priority coastal and offshore habitat protection issues. The formal and consistent engagement of the Councils in consultations on non-fishing impacts to EFH can improve the conservation of habitat for commercially and recreationally important fish species (NMFS 2013). The North Pacific and Mid-Atlantic Fishery Management Councils have already used their fishery management public process for some discrete habitat conservation activities. For example, the North Pacific Fishery Management Council used the public fishery management planning process to determine priorities for establishing Habitat Areas of Particular Concern.

Expand Partnerships and Build Alliances

Identifying habitat priorities, setting management objectives, and implementing management actions all require a public policy dialogue with affected stakeholders, many of which will be outside the traditional fishery management groups. In certain cases, as when the primary threats to high-value habitats in Federal waters are due to fishing impacts, the responsibility to protect these habitats rests clearly with NOAA Fisheries and the Councils. Fishery participants and managers will only have credibility with other stakeholders to the extent that we effectively address habitat impacts of our fishing activities, particularly bycatch and gear impacts. In most cases, however, both the threats and the solutions are outside the direct control of fisheries managers. In these cases we have the opportunity to find common ground with others and build alliances to protect our priority habitats.

These partnerships need to be approached from the local, watershed, state, regional, national and international level. For example, through the National Fish Habitat Partnership and its network of regional partnerships, NOAA is able to work with state and Federal agencies, non-profit organizations, and fishing industry representatives towards achieving our mutual goals for fish habitat conservation using voluntary and non-regulatory approaches.

We encourage the Councils to become more actively engaged in both selected consultations that affect our identified priority habitats, as well as in other fora—e.g., regional ecosystem and marine spatial planning with an influence over activities that influence priority fisheries habitat. We should also further engage states through the interstate commissions that serve vital roles in coastal waters, estuaries, and rivers that are integral components of an ecosystem-based approach.

A Blueprint for Conserving Habitats and Rebuilding Fisheries

As we explore these and other options for integrating habitat in ecosystem-based fishery management, the primary mechanism to achieve this objective is through the NOAA Habitat Blueprint. This is the "lens" for how we set programmatic and operational priorities. The NOAA Habitat Blueprint is a forward looking framework for the agency to think and act strategically across programs and with partner organizations to address the growing challenge of coastal and marine habitat loss and degradation. It is a centerpiece in our efforts both to integrate habitat into ecosystem-based management and to strengthen the partnerships that will benefit from the conservation of habitats important to fisheries. These efforts are expected to yield benefits for marine fisheries, as well as for protected resources and coastal communities. Many of the themes mentioned above are mirrored in the guiding principles of the Blueprint:

- Prioritize resources and activities across NOAA to improve habitat conditions;
- Implement innovative place-based habitat solutions to address coastal and marine resource challenges;
- Make natural resource management decisions and recommendations in an ecosystem context that considers competing priorities;
- Foster and leverage partnerships;
- Integrate and improve the delivery of habitat science across disciplines to facilitate conservation actions; and
- Anticipate and address changes to coastal and ocean habitats due to development, climate, and other pressures.

These guiding principles are being executed through three primary approaches: establishing Habitat Focus Areas; implementing a systematic and strategic approach to habitat science; and strengthening policy and legislation. Through these Blueprint approaches we aim to better integrate habitat considerations into NOAA's management activities in order to achieve the multiple outcomes of sustainable and abundant fish populations, recovered threatened and endangered species, and resilient coastal communities. The concepts we are proposing in this paper are key to achieving these goals.

We are currently selecting Habitat Focus Areas in each of NOAA's regions. The goal of establishing these Focus Areas is to prioritize long-term habitat science and conservation efforts, and concentrate resources in a place where by working collaboratively we can achieve measurable benefits for marine resources and coastal communities in a three to five year timeframe. The first Habitat Focus Area has already been selected, the Russian River watershed in California, and others will be established across the country over the coming year.

The science approach of the Blueprint is strengthening the linkages between habitat science and decision-making needs. We are prioritizing our research and using a more integrative approach for planning and conducting quality habitat science. The concept of ecosystem services provides a common denominator for prioritizing habitats and building partnerships. This will enable us to address the greatest needs and ensure that the information necessary to incorporate habitat into ecosystem-based fisheries management is in place.

The NOAA Habitat Blueprint challenges us to better use NOAA's habitat conservation authorities in the MSA to achieve sustainable fisheries. To do so we will explore the development of habitat conservation objectives for fisheries management and develop policies that better integrate habitat considerations into fisheries management decisions. This will involve a culture change within NOAA Fisheries, challenging us to become a nimble, dynamic and cohesive organization to achieve the tenets of the Blueprint, partnering more across NOAA and with other Federal agencies.

Conclusions

The Managing our Nation's Fisheries 3 conference offers an important forum to discuss these and other steps that could further integrate habitat considerations into existing fishery management efforts, and integrate fisheries (and fisheries habitat) into broader ecosystem-based management. While we believe that many of the steps outlined above can be accomplished within existing legislative authorities, we are also interested in beginning a dialog on areas where additional authorities might benefit our habitat and fisheries goals.

With the Blueprint as our framework, NOAA Fisheries is committed to working together with the Councils and other partners to protect and restore habitats that support vibrant fisheries and coastal communities. If we are successful, improved geographic focus, clearly defined habitat objectives, improved integration with mainline fisheries management and expanded partnerships will provide a number of benefits:

- Protection of the most important habitats from fishing impacts and more targeted and effective agency conservation recommendations for non-fishing impacts;
- Councils that are better able to determine when to engage in consultations on non-fishing impacts to habitats essential for priority stocks;
- Direction in establishing Habitat Areas of Particular Concern;
- Focus for NOAA's habitat research;
- Increased effectiveness of our habitat conservation programs to rebuild and maintain sustainable fisheries;
- Clearer opportunities to partner with states and others proactively on shared habitat conservations needs, including those related to fisheries managed by interstate commissions; and
- Focus for decisions on funding opportunities related to habitat restoration, stock dynamics, socio-economics, and other NOAA Fisheries programs with benefits to our MSA mandates or our state partnerships.

Over the last ten years, NOAA Fisheries and the Regional Fishery Management Councils have made significant progress in addressing overfishing and the adverse impacts of fishing gear on vulnerable benthic habitats. The stage is set to consolidate these gains and further incorporate habitat into the nation's goal of adopting ecosystem-based management as a foundational principle for the comprehensive management of the ocean, our coasts, and the Great Lakes.

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DISCUSSION SUMMARY AND FINDINGS
Session 2 Topic 3

Integrating Habitat Considerations: Opportunities and Impediments

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Discussion Summary and Findings:

Integrating Habitat Considerations: Opportunities and Impediments

Background

Healthy habitats are fundamental to healthy and productive fisheries, as recognized by the 1996 reauthorization of the Magnuson-Stevens Act. The Act and implementing regulations direct Regional Fishery Management Councils to identify and describe essential fish habitat (EFH) in fishery management plans, minimize adverse impacts to habitat from fishing, identify other activities that may adversely affect EFH, and recommend actions to avoid, minimize, or compensate for these effects. The Act also requires Federal agencies to consult with NOAA Fisheries when Federally permitted or funded activities may adversely impact EFH, and provides Councils with the discretionary authority to comment on these activities as well. More recently, NOAA Fisheries has undertaken initiatives to coordinate, advance, and invest in habitat science and policy in support of sustainable fisheries through the Habitat Assessment Improvement Plan and the NOAA Habitat Blueprint.

Despite this progress, participants and speakers in this session felt that we are still falling short of our potential to reverse habitat loss and decline, achieve targeted and effective habitat conservation, and link habitat conservation to sustainable fishery outcomes and successful rebuilding programs. While legislative solutions—primarily a National Standard for habitat conservation—were discussed, this discussion focused primarily on policy and regulatory changes and "best practices."

Summary

With management increasingly oriented toward ecosystem-based decision-making, habitat conservation must likewise be focused at the landscape or ecosystem level. In this context, habitat conservation will require NOAA Fisheries, the Councils, and the interstate fisheries commissions to collaborate and build partnerships that extend beyond the fisheries sector, while fully utilizing existing habitat authorities and refining their guidance and implementation. In particular, the EFH designation serves a useful purpose but at present is so broadly defined and compartmentalized by species and life history stage that meaningful habitat conservation has been difficult to apply and evaluate. Habitat conservation in support of healthy fisheries will benefit from bringing an ecosystem perspective to the meaning of "essential," establishing clear objectives tied to the fishery as well as ecosystem productivity and resilience, developing metrics for impacts and success, and evaluating tradeoffs relative to achievement of optimum yield.

Potential Legislative Changes: Should There be a National Standard for Habitat?

The primary legislative change considered in this session was a National Standard for habitat: "Minimize adverse impacts on essential fish habitat to the extent practicable." While participants recognized that healthy habitats are fundamental to sustainable fisheries and fulfilling the mandates of the Magnuson-Stevens Act, participants and speakers held divergent perspectives on whether a National Standard is the ideal course for achieving habitat conservation goals.

A National Standard for habitat would explicitly elevate habitat conservation to the level of consideration afforded to the fundamental management goals recognized by the existing ten standards, and help support fishery management plan objectives including rebuilding programs. A National Standard for habitat could also empower NOAA Fisheries with greater authority to influence and monitor non-fishing activities that may adversely affect EFH, and shift the burden of proof to permitting agencies to demonstrate no adverse impact. Additional reasons for considering a National Standard could include elevating the importance of EFH, supporting Councils in refining habitat objectives, refining habitat research and monitoring, and establishing the value of habitat with regard to ecosystem-based management and coastal and marine spatial planning initiatives. Potential downsides could include the investment of time, information, and personnel needed to comply with an additional standard. The habitat conservation benefits of a National Standard for habitat would also depend on the wording and interpretation of terms such as "minimize" and "to the extent practicable."

Some participants were supportive of a National Standard for habitat conservation, while others expressed concern that this would increase the potential for litigation and slow the FMP amendment process. Further discussion focused on alternatives to legislative changes, which could include strengthening, refining, and fully utilizing existing habitat authorities. Specific ideas related to EFH authorities included evaluating whether the EFH guidelines are up-to-date and being fully implemented, assessing whether the conservation recommendations resulting from EFH consultations are effective and properly implemented, and strengthening the Council role in EFH consultations. More generally, the group recommended integrating habitat into other aspects of management, and taking a more strategic approach to designating and making decisions regarding "essential" fish habitat. These ideas are discussed in greater detail below.

Policy, Guidance, and Best Practices for Habitat Conservation: Think Comprehensively to Act Strategically

In the course of discussion, the group identified two broadly important values related to habitat conservation. First, while healthy fish habitats are essential to healthy fisheries and those who depend on them, habitats for all species are part of a broader marine ecosystem that is impacted by activities other than fishing. Effective habitat conservation, and the concept of "essential" habitat, must recognize that species are linked to one another within this broader ecosystem, and address non-fishing activities that impact fishery and ecosystem productivity and resilience. Second, given limited resources, habitat research and actions should be strategically aligned with the Councils' legal mandates and decision-making needs. Effective habitat conservation should support clear objectives and measurable benefits to fisheries, while taking into account the tradeoffs and range of considerations associated with achieving optimum yield.

Consider an Ecosystem Perspective on "Essential"

EFH is broadly defined, yet compartmentalized by species and life history stage. The meaning of "essential" could be re-envisioned to better recognize linkages between and among life history stages and species. A more efficient and comprehensive approach to protecting "essential" habitat could focus on maintaining and restoring productivity at the ecosystem level. Ecosystem-level habitat conservation is critical for building resilience to impacts from non-fishing activities and the effects of a changing climate. There is still a need and purpose for species-specific habitat protection measures, which can be complementary to an ecosystem-oriented habitat conservation approach.

Strengthen the Essential Fish Habitat Designation

The group suggested strengthening the scientific basis for EFH designations, to help refine EFH as a tool for focusing habitat conservation, and to maintain the coordinating function and "seat at the table" that EFH provides for the fishery sector to interact with other Federal agencies. First, it was strongly recommended that we improve our understanding of the relationship between habitat and productivity. This information would support informed decision-making at the Council level, including actions to minimize adverse impacts from fishing. Outside the fisheries realm, information about habitat-dependent productivity could lend weight to EFH consultations, and, by extension, to the fishery sector, by clearly demonstrating the value of habitat to a managed fishery. A related suggestion would be to set measurable goals and a timeline for improving the scientific basis for designating EFH; for example, moving EFH designations to a higher level of detail for a certain number of species within a set period of time.

Finally, it will be important to continue exploring and providing guidance on how EFH should be interpreted and applied, and to fully consider the implications (positive or negative) of a National Standard for habitat. Specific suggestions including resolving the status of artificial substrate as EFH, and considering the guidance that relates forage to EFH.

Set Clear Objectives and Establish Metrics

Many ideas and recommendations focused on supporting a strategic, outcome-oriented approach to habitat conservation. A starting point would be to identify priority stocks and the threats they face, and set clear objectives for habitat conservation, protection, and restoration. These objectives might communicate the rationale for why a stock or habitat is considered a priority, as well as clarify the desired endpoint or state and how it compares to past or current conditions. On a related note, a different term could be used to distinguish stock depletion due to habitat-related factors from stock depletion due to overfishing. Finally, clear objectives would help focus and lend weight to the recommendations resulting from EFH consultations.

Objectives must be paired with metrics in order to characterize impacts and track progress toward a desired outcome. Long-term, standardized habitat monitoring would provide valuable information for characterizing long-term trends, cumulative impacts, and the benefits of habitat conservation, as well as enable rapid identification of and response to short-term threats such as oil spills. Likewise, habitat-related closures could be evaluated to determine whether they are meeting their objectives.

This discussion raised an important underlying question about information needs and the burden of proof. Must habitat protection be justified and linked to measurable benefits, or should habitat protection also serve a precautionary purpose? Measuring the benefits of habitat conservation to fisheries and ecosystems, and definitively linking these benefits to specific habitat protection actions, is a challenging prospect given that complex marine ecosystems are impacted by many other activities amid a changing environment. Some participants felt that it is important to be able to proactively utilize precautionary tools and approaches, such as "freezing the footprint" of existing habitat impacts. Other precautionary approaches could include augmenting habitat protection for important or vulnerable areas and/or events, such as spawning aggregations, as an additional precaution for data-poor and/or depleted stocks.

Make Clear and Transparent Tradeoffs and Decisions

Healthy habitats are critical to healthy fisheries that yield benefits to stakeholders and to the nation, yet some level of impact from fishing is often necessary to obtain these benefits. The mandate to "minimize to the extent practicable adverse impacts…caused by fishing" is challenging because this language references the range of considerations, including social and economic impacts, associated with National Standard 1 and optimum yield. Additional guidance on the interpretation of this language could support Councils in articulating an acceptable level of impact, and considering options for minimizing adverse impacts. Related to the discussion of objectives above, metrics for impacts could help characterize cumulative impacts, as well as inform options for minimizing adverse impacts. Furthermore, Councils could adopt a risk management approach to minimizing adverse impacts that more explicitly considers risks, consequences, and outcomes to avoid relative to an acceptable level of impact.

Building Effective Habitat Networks and Partnerships

In order to sustain productive fisheries and ecosystems through habitat conservation, it is necessary to support engagement with agencies and entities beyond the Federal fisheries sector. Participants and speakers spoke to the importance of collaboration at the Federal level, among Federal agencies, specifically noting the Bureau of Ocean Energy Management, Environmental Protection Agency, and U.S. Army Corps of Engineers. Speakers and participants spoke to the value of improving coordination between statutory authorities including those that pertain to inland and coastal activities impacting marine fish habitat, such as the Clean Water Act, Farm Bill, and Atlantic Coastal Fisheries Cooperative Management Act. Also important is ensuring complementary habitat conservation efforts at the state and interstate level. Finally, the interests of stakeholders within the fishery sector, including industry and communities, may translate to other issues, such as energy exploration and siting of activities.

As stated, there were divergent perspectives on whether empowering NOAA Fisheries with greater regulatory authority is the most effective way to support coordination at the Federal level. It will also be valuable for NOAA Fisheries to identify shared values and synergies, build new partnerships, and find new ways to engage with other agencies and ocean users. Strengthening the scientific basis for designating EFH, and setting clear objectives and metrics, could also support increased engagement with other ocean users and agencies. Better defining and valuing the role of habitat relative to the benefits derived from fisheries could also support the fishery sector in an ecosystem-based management and coastal and marine spatial planning context.

In addition to looking outward, NOAA Fisheries and the Councils can take action to engage and build support for habitat conservation within the fishery sector, including commercial and non-commercial sectors and stakeholders, communities, and tribal nations. The group emphasized that many of the ideas discussed above–particularly setting clear objectives, linking habitat protection to measurable outcomes, and evaluating the effectiveness of habitat-related closures—are important for building stakeholder support and reinforcing a perception of strategic, objective-oriented habitat decisions. Participants also proposed periodically revisiting assumptions about gear impacts, providing for tools other than spatial closures for addressing adverse impacts from fishing, such as gear modification and innovation, and engaging in cooperative habitat research.

TWO FRIENDS LUG A COOLER FULL OF FISH. PHOTO: GJ CHARLET III, FLICKR CREATIVE COMMONS.