IMPLEMENTING ECOSYSTEM-BASED MANAGEMENT OF FISHERIES IN THE CONTEXT OF U.S. REGIONAL FISHERIES MANAGEMENT: RECOMMENDATIONS OF THE NMFS ECOSYSTEM PRINCIPLES ADVISORY PANEL

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ABSTRACT

The Sustainable Fisheries Act of 1996 requires the National Marine Fisheries Service (NMFS) to convene an expert panel to assess the current application of ecosystem principles in U.S. fisheries conservation, management, and research and to make recommendations for increasing their application. The panel identified eight ecosystem principles and six associated policies for ecosystem-based fisheries management, with the goal of maintaining ecosystem health and sustainability. These principles, policies, and goals were used to evaluate current fisheries management practices in the United States. The panel concluded that there are some encouraging examples of ecosystem approaches, but they are limited in scope and not comprehensive. Similarly, U.S. fisheries research tends to parallel traditional single-species fisheries management, although notable ecosystem research is being conducted.

To increase the application of ecosystem-based management, the panel recommends developing fishery ecosystem plans (FEPs) for each major ecosystem in the U.S. Exclusive Economic Zone (EEZ). These plans will coordinate actions taken under existing single-species or species-complex fishery management plans (FMPs). The panel also proposes enhanced research on (1) the ecosystem effects of fishing, (2) ecosystem trends and dynamics, and (3) institutional and governance aspects of ecosystem-based fishery management. To implement these recommendations, a practical, iterative approach is envisioned which would generate a rapid increase in the use of existing ecosystem knowledge in fisheries management and prioritization of research.

INTRODUCTION

The first commissioner of the U.S. Commission of Fish and Fisheries, Spencer Baird, initiated marine ecological studies as one of his earliest priorities. Seeking to reverse the decline of New England's fisheries in 1871, he argued that our understanding of fish "...would not be complete without a thorough knowledge of their associates in the sea, especially of such as prey upon them or constitute their food...." (Hobart 1995). Baird understood that the presence or absence of fish was related not only to removal by fishing, but also to the dynamics of physical and chemical oceanography. Despite more than a century of research and fisheries management, we still fall far short of managing marine living resources sustainably in an ecosystem context.

This paper is based on the recommendations of a panel convened to advise the Congress on how to better use ecosystem principles in fisheries management and research. It begins with a brief, baseline description of the U.S. fishery management system and its performance. It then outlines the task of the panel as mandated by Congress and how the panel developed its recommendations. It concludes with a discussion of implementing the recommendations.

U.S. FISHERY MANAGEMENT

Since the 1976 passage of the Fishery Conservation and Management Act (FCMA), later known as the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), fisheries in federal waters fall under the management authority of eight regional councils comprising representatives of the fishing interests in the region, state officials, and the federal regional fisheries administrator. The councils' decisions are advisory to the secretary of commerce, who is charged with oversight at the national level and the implementation of decisions through the National Marine Fisheries Service (NMFS). Congress explicitly stated that fishing interests should be represented prominently on the councils because they would understand fisheries concerns and would have to live with the consequences of decisions. Thus, there would be a competitive balancing of interests, and there would be direct incentives to conserve the resource.

The record of fisheries management under the FCMA is mixed. There are resounding successes and some dismal failures. All success and failures are achieved under the same management rules, with access to the same levels of competent science, using the same management structure, and implemented by the same agency. Typically, failure can be traced to councils making decisions based on short-term economic and social pressures and not using the best available scientific advice on how to man-

age fish stocks conservatively and sustainably (Dobbs 2000; Hennessy and Healy 2000).

Fisheries management in the United States is now under internal and external pressure to reform. In 1996, Congress responded to the growing public demand for actions to end overfishing, reduce impacts of fishing on the environment, and avoid bycatch or harm to other marine wildlife by significantly amending the FCMA. The Sustainable Fisheries Act (SFA), as the amendments are known, targets specific ecosystem concerns by ending overfishing, minimizing bycatch, and increasing the councils' authority to protect essential fish habitat (EFH).

With respect to overfishing, Congress changed the formula for defining optimum yield. Councils were no longer permitted to set total allowable catch of fish stocks at higher than maximum sustainable yield (MSY) for economic and social reasons. Congress set MSY as a limit and encouraged councils to be more conservative, noting the inherent difficulties of using MSY itself. Furthermore, the councils had to develop a rebuilding plan for fish stocks that were defined as overfished, to achieve their recovery within ten years. The new requirements for bycatch were intended to deal with the biological harm and waste associated with certain fisheries discarding fish. The Congressional mandate included economic discards and regulatory discards and sought to "minimize bycatch to the maximum extent practicable."

The EFH provisions of the SFA were an attempt by Congress to give the councils more opportunity to protect habitat "essential" to fish. This portion of the act was written very broadly and allowed councils to be proactive in encouraging measures to reduce nutrient run-off into coastal waters and to balance other uses harmful to fish habitats. Most significantly, however, it charged councils with evaluating and avoiding fishing effects on ecosystems.

Besides these ecosystem-oriented amendments, Congress called on the National Academy of Sciences (NAS) to convene studies to examine the use of individual fishing quotas and community development quotas, and to review Northeast (U.S.) fishery stock assessments. (The NAS study on sustaining marine fisheries was initiated earlier; National Research Council 1999.) In addition, the National Marine Fisheries Service was asked to develop an annual report to Congress on incidental harvest (bycatch), to expand Gulf of Mexico red snapper research, and to appoint an ecosystem principles advisory panel.

ECOSYSTEM PRINCIPLES ADVISORY PANEL

The SFA's most direct action to initiate an ecosystem-based management approach was to mandate the formation of the NMFS Ecosystem Principles Advisory Panel. Congress specified that NMFS, with the advice of the NAS, would appoint a panel to advise Congress on ways to increase the application of ecosystem principles in conservation and management of fisheries. The new panel, consisting of not more than 20 people, would include individuals with expertise in the structures, functions, and physical and biological characteristics of ecosystems, as well as representatives from the regional councils, states, fishing industry, conservation organizations, or others with expertise in managing marine resources. The panel would produce a report that includes an analysis of the extent to which ecosystem principles are being applied in fishery conservation and management activities, including research activities, and would propose actions that should be undertaken by the secretary of commerce and by the Congress to expand the application of ecosystem principles in fishery conservation and management.

After intensive internal and external consultation, the NMFS appointed members to the panel (Appendix). The panel began deliberations immediately. Some of its early decisions set the context for the nature of the report. First, the report would be the product of the panel alone; the NMFS was the convener and provided staff to the panel. Second, the report would be advisory to the Congress and the secretary of commerce. This clarification was important in terms of keeping the target audience in mind. Whereas the earlier NAS study (1999) was meant for a scientific and a broader public audience, the panel report was requested by those who make and implement the rules in fishery management. Third, panel members would write the report on a consensus basis and would control its content. If consensus was not achieved, dissenting members would have an opportunity to explain their views. Fourth, the panel's meetings and discussions would be open to anyone who wanted to participate, and there would be opportunity for public comment. Only the drafts of the report would be treated as confidential to the panel. Finally, the consensus draft would be sent out for peer review, and all panel members would help make changes to the report as requested by the reviewers. Reviewers would remain anonymous to the panel unless they chose to reveal their identities.

Principles

The panel's first task was to agree on what was intended by the term *ecosystem principles*. Congress did not define *ecosystem* or *ecosystem principles*. As might be imagined, this was a difficult task for a disparate panel. We ransacked the literature and our own experience, but realized that no ready-made set of principles could satisfy us, so we set about to construct our own.

The panel clearly agreed that the subject was ecosystem-based management as opposed to ecosystem man-

agement. We regarded "ecosystem-based management" as applying what we know about marine ecosystems and their processes in fisheries management. We felt it was premature to apply "ecosystem management" to marine ecosystems given our state of knowledge and the vast uncertainties. The panel also agreed that effective fishery management, as exemplified by full implementation of the SFA amendments to U.S. fisheries legislation, is a prerequisite for ecosystem-based management. Ecosystem-based management depends on, and cannot substitute for, all of the traditional fishery management tools, the best available scientific information, and the collective political will to implement tough decisions in favor of sustainable fisheries. Ecosystem-based fishery management puts effective management into an ecosystem context.

In developing the principles, we were able to agree that each fisheries ecosystem is unique, but that each ecosystem presents four fundamental problems:

- We do not have a complete understanding of the ecological systems that produce and support fisheries.
- We cannot forecast weather or climate and their effects on ecosystems.
- Systems evolve over time, and knowing how the system works does not necessarily mean that an ecosystem would respond predictably to future changes in the weather, climate, or fisheries.
- Our institutions are not configured to manage at the ecosystem scale. Fish and the fisheries that pursue them are not easily aligned with political and jurisdictional boundaries.

Considering these constraints, the panel developed a set of eight principles that capture our understanding of fisheries ecosystems.

1. The ability to predict ecosystem behavior is limited. Uncertainty and indeterminacy are fundamental characteristics of the dynamics of complex adaptive systems. The behaviors of these systems cannot be predicted with absolute certainty, regardless of the amount of scientific effort invested. We can, however, learn the boundaries of expected behavior and improve our understanding of the underlying dynamics. Thus, while ecosystems are neither totally predictable nor totally unpredictable, we can manage fisheries within the limits of their predictability.

2. Ecosystems have real thresholds and limits which, when exceeded, can affect major system restructuring. Ecosystems are finite and exhaustible, but they usually have a high buffering capacity and are fairly resilient to stress. Often, as stress is applied to an ecosystem, its structure and behavior may not change noticeably at first. Only after a critical threshold is passed does the system begin to deteriorate rapidly. Because there is little initial change in behavior with increasing stress, these thresholds are very difficult to predict. The nonlinear dynamics which cause this kind of behavior are a basic characteristic of ecosystems.

3. Once thresholds and limits have been exceeded, changes can be irreversible. When an ecosystem is radically altered, it may never return to its original condition, even after the stress is removed. This phenomenon is common in many complex, adaptive systems.

4. Diversity is important to ecosystem functioning. The diversity of components at the individual, species, and landscape scales strongly affects ecosystem behavior. Although the overall productivity of ecosystems may not change significantly when particular species are added or removed, their stability and resilience may be affected.

5. Multiple time scales interact within and among ecosystems. Ecosystems cannot be understood from the perspective of a single time, space, or complexity scale, and the next lower scale of interest must be considered when effects of perturbations are analyzed.

6. Components of ecosystems are linked. The components within ecosystems are linked in complex patterns by flows of material, energy, and information.

7. Ecosystem boundaries are open. Ecosystems are far from equilibrium and cannot be adequately understood without knowledge of their boundary conditions, energy flows, and internal cycling of nutrients and other materials. Environmental variability can alter spatial boundaries and energy inputs to ecosystems.

8. Ecosystems change with time. Ecosystems change with time in response to natural and anthropogenic influences. Different components of ecosystems change at different rates and can influence the overall structure of the ecosystem itself and affect the services provided to society in the form of fish catch, income, and employment.

Goals

It is necessary to have a goal or goals for management to serve. The panel agreed on a simple goal statement: maintain ecosystem health and sustainability. We could not arrive at a consensus definition of ecosystem *health*. We also lacked a common way of defining *sustainability*. We realized that our goal for ecosystem-based fishery management was broad and could be obtained in a variety of ways—one size did not fit all. Similarly, we did not want the concept to be too vague. Thus we found it easier to use the "maintain ecosystem health and sustainability" standard by thinking in terms of management actions to avoid on the way to accomplishing the goal. Clearly, overfishing, ignoring bycatch, and damaging the habitat are not likely measures for achieving ecosystem health and sustainability.

Policies

To assess the application of ecosystem principles, the panel devised six policies that we thought would be used in ecosystem-based management. The extent to which management institutions applied these policies would help to show how their management went beyond the scope of effective fishery management.

Briefly stated, ecosystem-based fishery management policies include:

1. Change the burden of proof. We live in a world where humans are an important component of almost all ecosystems. Thus it is reasonable to assume that human activities will affect ecosystems. The *modus operandi* for fisheries management should change from the typical mode of restricting fishing activity only after it has demonstrated an unacceptable impact, to a mode of allowing only fishing activity that can be reasonably expected to operate without unacceptable effects.

2. Apply the precautionary approach. The precautionary approach is a key element of the United Nations Agreement for Straddling Stocks and Highly Migratory Species (United Nations 1996) and the Food and Agriculture Organization of the United Nations (FAO 1995) Code of Conduct for Responsible Fisheries. The United States is a signatory of both.

3. Purchase "insurance" against unforeseen, adverse ecosystem impacts. Even under the precautionary approach, there is a risk of unforeseen, adverse effects on ecosystems. Insurance can be used to mitigate these effects if and when they occur. Designation of marine reserves can provide insurance.

4. Learn from management experiences. Management actions and policies can be considered as experiments and should be based upon hypotheses about the ecosystem response. This requires close monitoring of results to determine to what extent the hypotheses are supported.

5. Make local incentives compatible with global goals. Human behavior is most easily changed by changing the local incentives to be consistent with broader social goals. The lack of consistency between local incentives and global goals is the root cause of many "social traps," including those in fisheries management (Costanza 1987). Changing incentives is complex and must be accomplished in culturally appropriate ways.

6. Promote participation, fairness, and equity in policy and management. Ecosystem approaches to management rely on the participation, understanding, and support of multiple constituencies. Policies that are developed and implemented with the full participation and consideration of all stakeholders, including the interests of future generations, are more likely to be fair and equitable and to be perceived as such.

Application in Fishery Management

Lacking the time and the resources to perform a systematic appraisal of how the panel's ecosystem principles are applied in current fishery management, we chose to conduct an overview based on presentations by fishery managers and scientists from the eight regions, on fishery management literature, and on the experience of panel members. After studying all of these materials, the panel concluded that the regional councils and NMFS already consider and apply some of the principles, goals, and policies. But they are not applied comprehensively or evenly across the regions or ecosystems under council and NMFS jurisdiction. This is not the result of these entities' intransigence toward adopting ecosystem-based management. Rather, they lack the clear mandate and resources from Congress to carry out such an approach. Further, the panel recognized that the concept of ecosystem-based management in fisheries is relatively new and that there are considerable gaps in knowledge and practice.

RECOMMENDATIONS

We strongly believe the key to an effective ecosystem approach is to fish more conservatively. The depressed condition of many U.S. stocks relates primarily to unsustainable levels of fishing effort, rather than to ecosystem effects. With few exceptions, fishery managers understand the levels of fishing effort required to produce sustainable yields, but are challenged by a highly politicized process to exceed those levels for short-term gains. Setting maximum sustainable yield and optimum yield conservatively, and respecting these conservative goals in the face of political and economic pressure is essential in any ecosystem approach. Fishery management plans for single species or species complexes should continue to be the basic tool of management for the foreseeable future. But management actions under FMPs alone are not sufficient to implement ecosystem-based management.

The panel has divided its fishery management and policy recommendations to Congress into two parts. First we recommend that a fisheries ecosystem plan (FEP) be prepared by each council to continuously guide management decisions. Second, we recommend immediate measures to start implementing the FEP concepts under current fishery management authority. The panel's recommendations for research derive from the information needs of the FEP.

The Fisheries Ecosystem Plan

Our primary recommendation is that each council (including the NMFS in the case of Atlantic highly migratory species) develop an FEP as a mechanism for incorporating ecosystem principles, goals, and policies into

the present fisheries management structure. The objectives of FEPs are to

- provide council members with a clear description and understanding of the fundamental physical, biological, and human/institutional context of ecosystems within which fisheries are managed;
- direct how that information should be used in the context of FEPs; and
- set policies by which management options would be developed and implemented.

Councils would develop FEPs for each major ecosystem under their jurisdictions. For example, the North Pacific Fishery Management Council might have two FEPs—one for the Bering Sea/Aleutian Islands and one for the Gulf of Alaska. Councils with overlapping ecosystems or with significant species migration across ecosystem boundaries would work together on a joint FEP. In the event of transnational ecosystems, international arrangements would be sought to implement an ecosystem approach.

The FEP should be used as a metric against which all fishery-specific FMPs are measured to determine whether or not management effectively incorporates the ecosystem principles, goals, and policies. The FEP should also contain regulations or management measures which would extend across individual FMPs. The FEP should serve as a nexus for existing FMPs and provide a context for considering council management actions with respect to all living marine resources, whether managed or not.

The FEPs must contain information about ecosystems that allows managers to make informed decisions, but the primary purpose of the plans is to prescribe how fisheries will be managed from an ecosystem perspective. Careful consideration must be given to the structure and required content of an FEP to balance the needs for plans to be both substantive and realistic. It is appropriate that NMFS lead a deliberative process (including a broad range of interests and expertise) to prepare guidelines for FEPs (analogous to the processes that have been used to prepare guidelines for implementing national standards under the MSFCMA). Preparation of such specific guidelines was beyond the scope of the panel's charter (NMFS 2000), but we did identify council actions that must be taken when guidelines are prepared, to be consistent with our recommendations.

Each FEP should:

1. Delineate the geographic extent of the ecosystem(s) within council authority, including characterization of the biological, chemical, and physical dynamics of those ecosystems, and "zone" the area for alternative uses.

The first step in using an ecosystem approach to management must be to identify and bound the ecosystem. Hydrography, bathymetry, productivity, and trophic structure must be considered, as well as how climate influences the physical, chemical, and biological oceanography of the ecosystem, and how, in turn, the food web structure and dynamics are affected. Transfers across ecosystem boundaries should be assessed.

Within each identified ecosystem, councils should use a zone-based management approach to designate geographic areas for prescribed uses. Such zones could include marine protected areas, areas particularly sensitive to gear impacts, and areas where fishing is known to negatively affect the trophic food web.

2. Develop a conceptual model of the food web.

For each targeted species, there should be a corresponding description of both predator and prey species at each life-history stage over time. FEPs can then address the anticipated effects of the allowed harvest on predator-prey dynamics.

3. Describe the habitat needs of different life-history stages for all plants and animals that represent the "significant food web" and how they are considered in conservation and management measures.

Essential fish habitat (EFH) for target and nontarget species at different life stages should be identified and described. Using habitat and other ecosystem information, councils should develop zone-based management regimes, whereby geographic areas within an ecosystem would be reserved for prescribed uses. FEPs should identify existing and potential gear alternatives that would alleviate gear-induced damage to EFH, as well as restrict gears which have adverse effects. Further, FEPs should evaluate the use of harvest refugia as a management tool to provide habitat for target and nontarget species.

4. Calculate total removals—including incidental mortality—and show how they relate to standing biomass, production, optimum yields, natural mortality, and trophic structure.

Total removals (i.e., reported landings, unreported landings, discards, and mortality to fish that come into contact with fishing gear but are not captured) should be incorporated into qualitative food web and quantitative stock assessment models. These models will allow managers to reduce uncertainty, monitor ecosystem health, and better predict the relative abundance of species affected by the harvest of target species.

5. Assess how uncertainty is characterized and what kind of buffers against uncertainty are included in conservation and management actions.

Given the variability associated with ecosystems, managers should be cognizant of the high likelihood of unanticipated outcomes. Management should acknowledge and account for this uncertainty by developing risk-averse management strategies that are flexible and adaptive.

6. Develop indices of ecosystem health as a target for management.

Ecosystem health refers to a balanced, integrated, adaptive community of organisms with a species composition, diversity, and functional organization that has evolved naturally. Provided that a healthy state can be determined or inferred, management should strive to generate and maintain such a state in a given ecosystem. Inherent in this management strategy would be specific goals for the ecosystem, including a description of unhealthy states to be avoided.

7. Describe available long-term monitoring data and how they are used.

Changes to the ecosystem cannot be determined without long-term monitoring of biological indices and climate. Long-term monitoring of chemical, physical, and biological characteristics will provide a better understanding of oceanic variability and how climate changes affect the abundance of commercially important species and their corresponding food webs.

8. Assess the ecological, human, and institutional elements of the ecosystem which most significantly affect fisheries, and are outside council/Department of Commerce authority. A strategy should be included to address those influences in order to achieve both FMP and FEP objectives.

Councils and the secretary of commerce have authority over a limited range of human, institutional, and natural components of a marine ecosystem. It is important to recognize the components of the ecosystem over which fisheries managers have no direct control, and to develop strategies to address them in concert with appropriate international, federal, and state agencies as well as tribes and local entities.

Implementing FEPs

Two general types of actions are required to implement FEPs in U.S. fishery management. The first type consists of short-term actions taken under existing authority. The second is a direct legislative mandate from Congress that might be developed as a part of reauthorization of the MSFCMA. Examples of these measures are elaborated below.

Short-Term Actions.

1. Encourage the councils to apply ecosystem principles, goals, and policies to ongoing activities.

   Councils should begin to apply the ecosystem principles, goals, and policies to the conservation and management measures of existing and future FMPs. Three actions are particularly important:

   A, Consider predator-prey interactions affected by fishing allowed under the FMP; B, consider bycatch taken during fishing operations and the effects of such removals on the species and the ecosystem as a whole, in terms of food web interactions and community structure; and C, minimize impacts of fisheries operation on EFH.

   Councils have received copies of the panel's report, but so far no council has taken significant action to formally adopt the approach. Most council and agency attention has been focused on implementing the Sustainable Fisheries Act and developing other instruments to bring fishery management into full environmental compliance.
2. Provide training for council members and staff.

   To facilitate an ecosystem approach and to aid the development and implementation of FEPs, the NMFS should give all council members basic instruction in ecological principles. Further, training materials should be made available to the fishing industry, environmental organizations, and other interested parties. To date, only limited efforts have been made to educate councils about the nature of the panel's recommendations.
3. Prepare guidelines for FEPs.

   The secretary of commerce should charge the NMFS and the councils with establishing guidelines for FEP development, including a regular amendment process. The NMFS and the councils should conduct a deliberative process similar to that for developing guidelines for the national standards to ensure that FEPs are realistic and adaptive. The NMFS has convened a workshop on incorporating ecosystem principles into stock assessments but, because of all its other responsibilities, has not made a systematic effort to further develop guidelines.
4. Develop demonstration FEPs.

   While encouraging all councils to develop framework FEPs, the secretary of commerce should designate a council or councils to develop a demonstration FEP as a model to further advance the concept as spelled out by the panel. This will contribute a better empirical understanding of the management context and applicability of the recommendation. It can also facilitate more rapid implementation of full FEPs if required by Congress. The NOAA Chesapeake Bay office has taken the initiative to develop an FEP for Chesapeake Bay and convened a workshop in Solomons, Maryland, in July 2000. Other efforts are being made in academic institutions to advance the FEP concept, e.g., Field et al. (this volume).
5. Provide oversight to ensure the development of and compliance with FEPs.

   To ensure the development of FEPs, the secretary of commerce should establish an oversight panel. Implicit in this action is the establishment of a timetable for developing a draft demonstration FEP and review.

Legislation. The panel recommends that Congress enact legislation requiring FEPs. In 2000 three bills in-

troduced into either the House or the Senate carried provisions to require FEPs in U.S. fishery management as part of MSFCMA reauthorization processes. One of the legislative approaches (that of Senator Snowe) is extremely close to the panel recommendations. Another (that of Representative Gilchrest) tracks the recommendations closely but makes the FEP mandatory, with a short time line for preparing the plans once legislation is enacted. The third bill (that of Senator Kerry) revises the recommendations somewhat, but in ways quite compatible with their intent. Although no action was taken by Congress on any of the measures, the fact that they all appear to embrace the recommendations of the panel does bode well for subsequent action.

Research

In its review of the application of ecosystem principles in U.S. fisheries management activities, the panel also found that the information required to develop and implement FEPs is limited. In order to provide the broader ecosystem information required to implement this approach, additional research is recommended. The panel identified three general areas of research that are essential for providing information to underpin ecosystem-based management. First, there is a need to increase understanding of the ecosystem effects of fishing. Fishing can affect target species, nontarget species, habitat, and marine ecosystems as a whole. Second, we must do a better job of monitoring trends and dynamics in marine ecosystems. This will require an expanded monitoring of broadscale ecosystem parameters and must be undertaken with the best available technology. Third, because many of today's fisheries problems stem from governance systems which create incentives that are incompatible with, or inimical to, ecosystem-based fishery management, alternate governance systems and approaches must be identified consistent with the scale and needs of fisheries management in an ecosystem context.

CONCLUSIONS

Under an ecosystem-based management system, U.S. fisheries are likely to be quite different from fisheries today. New management tools, including share-based systems, will be employed. Fisheries and gear types that significantly affect other ecosystem components may be modified or phased out, and other types of fisheries and gears may replace them. In many cases, fish stocks may have to be exploited at lower harvest levels than presently indicated in order to sustain other ecosystem components. Some areas that are now fished may become reserves where harvests are restricted to protect a spawning stock or other sensitive life-history stages. The short-term consequences of such changes, which may be painful, must be balanced against future benefits in the form of sustainable fisheries for fishing communities and for the ecosystems on which they depend.

The next ten years are critical for the future of U.S. fisheries. Already, important changes are under way as a result of the SFA, and the next round of legislation/reauthorization of the MSFCMA should provide additional impetus for reform. Implementation of an ecosystem-based approach will take time, and there will be trials and errors. A great deal of education about this new approach will be required, and all involved must be prepared to learn. The two hardest changes in policy are likely to be shifting to the fishery the burden of proof to demonstrate that the ecosystem will not be damaged by fishing, and developing a truly precautionary approach to fishery management. The learning curve will be steep for all involved; society as a whole will be increasingly challenged to help define ecosystem health and the limits of acceptable change in marine ecosystems, while still allowing sustainable fishing practices.

ACKNOWLEDGMENTS

The panel would like to thank John Pope and four anonymous reviewers for their peer review of the panel's report. In addition, those who provided input at panel meetings or through written comments added important context for the panel's deliberations.

LITERATURE CITED

Costanza, R. 1987. Social traps and environmental policy. Bioscience 37: 407–412.

Dobbs, D. 2000. The great gulf. Washington, D.C.: Island Press/Shearwater Books.

FAO. Food and Agriculture Organization of the United Nations. 1995. Code of conduct for responsible fisheries. Rome: FAO.

Hennessey, T., and M. Healy. 2000. Ludwig's ratchet. Coast. Manage. J. 28(3):187–213.

Hobart, W. L., ed. 1995. Bairds's legacy: the history and accomplishments of NOAA's National Marine Fisheries Service, 1871–1996. U.S. Dep. Commer. NOAA, NMFS Tech. Memo. NMFS-F/SP-18.

NMFS. National Marine Fisheries Service. 2000. Ecosystem-based fishery management: a report to Congress by the Ecosystem Principles Advisory Panel. U.S. Dep. Commer. NOAA, NMFS. Washington, D.C.

National Research Council. 1999. Sustaining marine fisheries. Washington, D.C.: National Academy of Sciences Press.

United Nations. 1996. Agreement for the implementation of the provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to straddling fish stocks and highly migratory fish stocks. New York: United Nations General Assembly.

APPENDIX: NMFS ECOSYSTEM PRINCIPLES ADVISORY PANEL

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