Science and Its Role in the National Marine Fisheries Service

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SCIENCE

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NATIONAL MARINE FISHERIES SERVICE

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Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions

or recommendations nor did they see the final draft of the report before its release. The review of this report was overseen by John E. Burris, Beloit College. Appointed by the National Research Council, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Preface

The National Marine Fisheries Service has one of the most difficult jobs in natural resource management. It manages hundreds of species whose habitats span arctic to tropical ecosystems. There are many stakeholders in marine-fisheries management who have often opposing goals. Of the federal agencies, it is fourth in the number of regulations it promulgates, just behind the Environmental Protection Agency. Despite NMFS's management efforts, many important stocks continue to decline. Moreover, fishing impacts not only target species but threatens the existence of some marine mammals and sea turtles. It is not surprising that, as management goals have grown from obtaining the optimum harvest to responsible and sustainable harvesting in an ecosystem context, that litigation has increased dramatically. This increase in litigation led to the formation of our NRC committee to review the quality of science that underpins NMFS decisions in fisheries management.

This report presented several challenges to the committee. First, the subject was complex. NMFS uses science to underpin and inform the development of Fishery Management Plans (FMPs) by the regional councils that include population dynamics, fishery science, ecology, oceanography, socioeconomics, as well as other areas of science. Science is used in meeting the mandates of laws that direct NMFS's actions and under a governance system that includes the guidance of fisheries-resource users and fisheries managers. Second, the committee had less than five months from their

first meeting to submission of the report to external review. To meet this short-time frame and the focus of the study, the National Research Council chose committee members to serve who had worked on at least one previous NRC report that had addressed fisheries issues. This experience was particularly valuable because the committee members were familiar with previous reviews of NMFS science and the findings and recommendations from the NRC reports they helped write. The committee included members who had expertise in economics, ecology, fisheries (including a commercial fisherman), law, population dynamics, and social science. Members also had experience in the process of using science from their memberships on international commissions, Regional Fishery Management Councils, Science and Statistics Committees to these councils, and other government advisory committees.

The committee would like to thank the following people who made presentations at its meetings: Luke Nachbar, U.S. Senate Committee on Appropriations; Margaret Spring, U.S. Senate Committee on Commerce, Science, and Transportation; Eric Bilsky, Oceana; Val Chambers, NMFS; Kevin Collins, NOAA General Council; David Cottingham, NMFS; Arnold Donahue, National Academy of Public Administration; William Hogarth, NMFS; Eldon V.C. Greenberg, Garvey, Schubert, and Barer; Lamont Jackson, NMFS; Ray Kammer; Jon Korland, NMFS; Rebecca Lent, NMFS; Garry Mayer, NMFS; Mariam McCall, NOAA General Counsel; Jim McCullum, NMFS; Joe Mitchell, National Academy of Public Administration; Craig O'Connor, NOAA General Council; John Oliver, NMFS; Terrance Quinn, University of Alaska; Alan Risenhoover, NMFS; Stephen E. Roady, Oceana; Lamarr Trott, NMFS.

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The committee extends its thanks to the staff members of the National Research Council, Ocean Studies Board who provided leadership and who assisted us so ably. Ocean Studies Board Director Morgan Gopnik helped us to interpret our Statement of Task and kept us on track. Study Director Terry Schaefer contributed tirelessly to all aspects of the committee's work. His contributions were important, kept us timely, and made this a better report. We thank Greg Symmes, Associate Executive Director, Division on Earth and Life Studies for his assistance during the review process and for

his recommendations. Special thanks are due to Senior Project Assistant Darla Koenig, who also did much of the work integrating the committee's edits, and editing the manuscript prior to review. She provided superb logistical support throughout the meetings.

Cynthia M. Jones
Chair

Contents

Executive Summary

The mission of the National Marine Fisheries Service (NMFS) is to manage the marine fisheries of the United States to serve the nation now and to benefit future generations. The physical domain that NMFS manages is the largest exclusive economic zone (EEZ) in the world, with an area of 3.4 million square nautical miles (11 million square kilometers). This area spans arctic to tropical ecosystems and is home to 905 identified stocks of fish and invertebrates, and over 100 species of marine mammals and sea turtles. Of the marine mammals, 44 populations are strategic, that is, they are either listed as threatened, endangered, or they are declining populations that are at risk. As NMFS manages marine fisheries, it operates under a complex set of laws. The centerpiece of fisheries legislation is the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), an act that had its origins in 1976 when the United States extended federal management to fisheries within the Fisheries Conservation Zone (now named the Exclusive Economic Zone or EEZ) that had been established the year before, from 3 to 200 miles offshore. Under the MSFCMA, eight regional fishery management councils work with NMFS in developing fishery management plans (FMPs). With the enactment of this law, the fishing industry, through its membership on the regional fishery management councils (FMCs), had a far greater voice in marine-fish management.

Since 1976, the original legislation has been modified by repeated efforts to halt the ongoing decline of fish populations and to reflect the chang-

ing values of the nation. The modifications have increasingly provided more detailed mandates for management, yet the governance structure has been largely untouched. The latest modifications and amendments require that fishing be at or below the optimum yield and that depleted stocks be recovered in no more than 10 years. Moreover, MSFCMA mandates that fisheries be managed with ecosystem considerations, prevent bycatch, and protect essential fish habitat.

Fishing impacts non-targeted organisms both directly and indirectly: directly by entangling them in nets, or indirectly by diminishing their prey and destroying marine habitat. NMFS must also comply with a number of acts that ensure proper procedures are followed, including the National Environmental Policy Act (NEPA), the Regulatory Flexibility Act (RFA), and the Administrative Procedure Act (APA). Thus, NMFS must achieve a delicate balance as it manages marine fisheries under overlapping and sometimes divergent laws. On one hand, these laws emphasize the importance to the nation in using these important renewable resources; on the other hand, the laws emphasize the importance of rebuilding depleted stocks and protecting threatened and endangered marine animals.

Not surprisingly, NMFS regulations are contentious, given the complexity of managing marine fisheries today. In the past 10 years, the National Research Council has undertaken a dozen studies of marine fisheries at the behest of Congress and NMFS itself. A review of these studies shows that many of the same issues and recommendations are revisited in study after study. This pattern occurs not primarily because Congress and NMFS have ignored the recommendations in these studies, but because these problems are difficult to rectify. The contentiousness of the regulations among stakeholders is seen in the history of the litigation. Litigation has increased dramatically since the enactment of the Magnuson Fishery Conservation and Management Act (MFCMA) in 1976 and the Sustainable Fisheries Act in 1996 (which significantly amended the MFCMA). As of January 2002, there were in excess of 110 legal cases pending against NMFS (NMFS, personal communication). Though NMFS wins many lawsuits based on the strength and quality of its science, lost cases are a special concern because they may indicate where NMFS's science and policies are vulnerable to future legal challenge, as well as where NMFS management of marine fisheries may be failing.

Based in part on its concern over the dramatic increase in recent lawsuits against NMFS, Congress requested in 2001 that the National Academy of Public Administration provide "a thorough review of NMFS's legal-

defense capabilities, financial-management capacity, constituent relations, and organizational structure," and that the National Academy of Sciences [through the National Research Council] provide "a summary review of the adequacy of the data, scientific foundation, models, and processes used by NMFS to guide resource management, meet regulatory requirements, and provide support in response to litigation." To provide this review, a committee of experts was formed by the Ocean Studies Board of the National Research Council. The statement of task specified that the committee, in making its assessment, should rely largely on previous NRC reports that examined NMFS's stock assessment models, data-collection methods, and other aspects of the NMFS science program and the actions taken by NMFS in response to the reports. Therefore, the committee was drawn from experts who had served on one or more previous NRC studies of NMFS and marine fisheries issues. In addition to reviewing previous NRC reports, the committee also reviewed recent legal cases, and heard presentations by NMFS personnel, the NOAA General Counsel, and people involved with recent litigation.

RECOMMENDATIONS

NMFS has a difficult and complex task in managing U.S. marine fisheries. Despite some successes, too many stocks continue to decline. Over the past decade, several problems have been identified that have contributed to the current dissatisfaction with how marine fisheries are managed. This dissatisfaction is evident from the large number of lawsuits filed by the fishing industry and environmental organizations. One central problem is overfishing. Overfishing issues have been discussed in a series of NRC reports, and these reports identify overcapitalization, and technological and gear improvements as some of the causes. The reports recommend ways to stem these problems and to advance the practice of fishery science at NMFS. This report reiterates some of these recommendations, and makes new recommendations to enhance the use of data and science for fisheries management.

Recommendations to NMFS

NMFS should maintain and advance its tradition of excellence in fisheries science.

NMFS has been a world leader in the development of fisheries stock assessment models. Traditionally, these have been single-species models de-

veloped over decades. Most fisheries scientists now consider the development of new models to be of the utmost importance, especially those that incorporate ecosystem considerations and multiple species dynamics. Recent papers demonstrate that NMFS scientists are actively participating in or leading the development of such models. For example, these models help clarify the effect of fishing on species other than the target.

Despite the future promise of multispecies models and models that include ecosystem considerations, such models have not yet attained a level of reliability sufficient for accurate stock assessment predictions. Until multispecies models can be applied reliably, this committee supports the recommendation from previous NRC reports that NMFS rely on single-species models with risk-averse and precautionary constraints, consistent with the mandates in the MSFCMA. NMFS should also continue to develop new models and to use several models for the same data to observe the robustness of model predictions. Recommendations in several reports, particularly *Improving Fish Stock Assessments*, were detailed and thorough and are still relevant. Many of the recommendations that did not require new funding have already been implemented by NMFS. NMFS should continue to find ways to implement the other recommendations.

NMFS must balance its traditional emphasis on sustainable exploitation with its duty to protect vulnerable species and habitats harmed by fishing.

Fishing can have unintended consequences, such as causing mortality to vulnerable species. Such species include marine mammals and sea turtles, as well as overfished species that are killed as bycatch in other fisheries. Several of the lawsuits that NMFS lost concerned the impact of fishing on marine mammals and the unknown magnitude of bycatch. These are areas where the necessary data collection and research either were not done in a timely manner or were not done at all. Additionally, the MSFCMA clearly specifies that essential fish habitats must be preserved, while the ESA clearly mandates the protection of threatened and endangered species. These are areas where NMFS needs to develop additional expertise and analyses.

NMFS should create an atmosphere that encourages innovation and rewards excellence, as recommended in previous National Research Council reports.

Many of the nation's best fisheries scientists are employed at NMFS. The contribution that NMFS scientists make to advance the field is no-

table. As it has in the past, NMFS should continue to encourage and reward excellence in innovative science. NMFS has often promoted its best scientists to leadership positions. However, a threat to its tradition of excellence is the demoralizing atmosphere that can develop in an agency that is given unclear and difficult mandates that often result in litigation, or which fails to make the best use of its scientific expertise to guide management decisions. With its current heavy load of cases, time is taken away from the necessary tasks of stock assessment and scientific innovations.

NMFS should develop and implement a plan for rapid response to research needs identified in recovery and conservation plans.

NMFS has lost at least two lawsuits because of its lack of timely information on marine mammal and fishery interactions. NMFS knew this information was needed, but was unable to provide it on time. This may be due to a lower priority given to such analyses, or to inadequate funding for the type of data collection needed to support such analyses. One challenge to responding rapidly to newly identified research needs is the nature of the funding cycle. Budgets must be planned years ahead, but response and analysis to new research needs must often be rapid. Appropriate budgeting mechanisms must be developed to cover such exigencies.

NMFS should continue to use and seek advice and review from independent sources.

In the past, NMFS has been criticized for the lack of independent review of its stock assessments. Even though the agency employs some of the world's best fisheries scientists, they are not infallible, and their mistakes can have grave impact on fisheries and fishing communities. Hence, independent review should be a fundamental component of developing stock assessments. In this way, stock assessments can be improved before they are used as the basis of an FMP. A problem that faces NMFS is the scarcity of independent expertise. The field of fishery science is small, and the same knowledgeable people are asked repeatedly to participate throughout the process. This participation can become burdensome, since these fisheries scientists have other responsibilities. NMFS has recently developed the Center for Independent Experts (CIE) to conduct such independent reviews. The CIE is a good start, but NMFS may need to encourage even broader participation from scientists in other disciplines, especially as NMFS develops broader models (multispecies, ecosystem) that are capable of accurate predictions.

NMFS and the councils should develop quantifiable management goals and collect data to measure progress toward these goals.

NMFS and the councils participate in managing fisheries by developing FMPs. Once the plans are approved, and regulations are promulgated, the assumption is that goals of the FMP will be obtained. Such goals may include biological reference points and minimum impact to fishing communities. Stock assessments are currently made with retrospective analyses that track past predictions to their actualizations. However, without collection of socio-economic data, it is difficult to evaluate whether other goals are realized, such as minimum impact to fishing communities.

NMFS must build a scientific workforce to meet the future needs of the agency.

In summer 2000, at the request of NMFS, the NRC held a one-day workshop on recruiting scientists to careers with the agency. NMFS built its current workforce from scientists born during the baby-boom years when quantitative training was good, educated people were more plentiful than jobs, and concern for the environment was high. NMFS now faces the daunting task of replacing its near-retirement workforce of quantitative scientists at a time when fewer of these scientists are being trained and other industries are offering better salaries and more prestige for scientists with these skills. The report *Recruiting Fishery Scientists* provided ideas for building this workforce and we reiterate the message contained in that report; NMFS must begin now to meet these needs or it will not have trained people to manage marine fisheries in the future.

Five areas of science, identified in previous NRC reports, should receive increased emphasis.

Listed below are the five areas of science identified as inadequate which may have been responsible for some of the increased litigation in the past few years. It may be necessary to redirect budgets or augment them to bolster these activities.

- Development of research plans and analysis relevant to MMPA and ESA mandates.
- Collection and analysis of spatial data to meet the needs of managing using spatial models, marine-protected areas, and essential fish habitat designations.

- Development of new models with multi-species interactions, trophic structure, and ecosystem effects.
- Development of analytic techniques that link social and economic data to biological data.
- Linking market and non-market values with management scenarios.

Recommendations to Congress

Congress should fund continued acquisition and deployment of new vessels and the Fisheries Information System, as recommended in previous NRC reports.

The report *Improving Fish Stock Assessments* emphasized the importance of fishery-independent surveys to provide estimates of abundance that could be used to refine stock-assessment models. Without these fishery-independent estimates, model predictions can be severely biased and unreliable. To conduct such surveys, NMFS must be able to have access to ocean-going vessels that are outfitted with modern equipment. Continued acquisition of these data will diminish some of the inherent uncertainty in our knowledge of fish-population dynamics. Similarly, the report *Improving the Collection, Management, and Use of Marine Fisheries Data* concluded that Congress should provide adequate funding to develop and implement a database of fisheries data, the Fisheries Information System (FIS), on a regional basis. The FIS would provide a national umbrella for these data as previously requested by Congress and by the Secretary of Commerce. These remain priority items, and Congress should move ahead with these initiatives.

Congress should initiate a review of the fisheries governance system and the use of science in governance.

Although the laws governing the management of marine fisheries have been amended since the inception of the MFCMA in 1976, the governance structure remains virtually unchanged. In 1994, the report *Improving the Management of U.S. Marine Fisheries* recommended changes in the governance structure, including the composition of the regional fishery management councils. There has been no full-scale evaluation of the effectiveness of the governance structure since. It appears that some of the court rulings against NMFS were due to unwise compromises made in regards to stock-assessment advice used for FMPs developed by the councils.

Congress should examine the cost of collection, analysis, and management of data required by NMFS to fulfill its current mandates.

The mission of NMFS has expanded greatly since its inception along with the legislative mandates for managing marine fisheries. Although the NMFS budget has grown, the base budget has remained almost constant, with most of the increase going to earmarked projects. When NMFS's science failed under legal challenge, there were indications that part of the underlying problem may have been insufficient funding to accomplish the mandated science. A first step would be to examine the current and projected costs of data collection, analysis, and management under all of the legal mandates that guide NMFS management to assess whether resources are adequate to comply with existing laws. Unfortunately, the limited duration of the study did not allow the committee to perform such an examination.

Recommendation to NMFS and Congress

The importance of social and economic data and analysis to marine fisheries management should be recognized in the reauthorization of MSFCMA, resulting federal regulations, fishery management plans, NMFS budget requests, and congressional appropriations.

Overfishing has resulted in the depletion of many fishery stocks. It is driven by economic factors, such as overcapitalization, and social conditions in fishing communities, such as the lack of alternate employment opportunities. The MSFCMA mandates that stocks should be rebuilt, and that this should be done, where possible, in a manner that minimizes the economic dislocation in fishing communities. Many previous NRC reports have considered economic and social aspects of marine fisheries and made recommendations for NMFS to increase the collection of these data, and hire scientists with this expertise so that socio-economic analyses can be completed as part of the fisheries management planning process. This committee recommends that NMFS fully implement its plan to hire social scientists and economists. Having the necessary expertise within NMFS is an important component of collecting and analyzing these data as a part of fisheries management. However, the committee also recommends that NMFS increase the collection of social and economic data for use in the development of FMPs.

1

Introduction

"It is a mistake to suppose that the whole ocean is practically one vast store-house."

Ray Lankster 1884

AGENCY RESPONSIBILITIES

The National Marine Fisheries Service (NMFS) manages the living resources in all federal waters from 3 nautical miles (and in some places 9 nautical miles) from shore to 200 nautical miles offshore, a jurisdiction covering 3.4 million square miles (11 million square kilometers) of coastal and oceanic waters. That is the largest exclusive economic zone (EEZ) of any nation in the world. The diverse habitats that NMFS manages range from arctic to tropical. The United States is the world's fifth largest fish producer, with commercial landings of 9.1 billion pounds in 2000 that were worth in excess of $3.5 billion, with an estimated value to the U.S. gross domestic product of more than $20 billion (NMFS, 2001a; NRC, 1999b). By weight, almost 50 percent of the commercial catch comes from only three species: walleye pollock (*Theragra chalcogramma*) in the Pacific Ocean and two species of menhaden (*Brevoortia tyrannus* and *B. patronus*) in the Atlantic Ocean and the Gulf of Mexico. An estimated 17 million or more recreational anglers land another 254.2 million pounds. Combined, the recreational and commercial fisheries add more than $40 billion per year to the nation's economy (NRC, 1999b).

In EEZ waters, NMFS manages 905 stocks. The status of 674 (75 percent) of these stocks is unknown (NOAA, 1999; NMFS, 2001a), but most of the species involved are of minor commercial importance (Hogarth, 2002). Of the 283 stock groups whose status is known, 14.6 percent are

overfished, and 39 percent are fished at or near their long-term potential yield. In addition, biological data on only 119 of those species are sufficient to permit the use of size- or age-structured models. Age-structured models provide the most reliable management advice regarding the status of fish stocks. As data collection is improved and more species are analyzed with age-structured models, more species may be shown to be overfished or fished at their long-term potential yield.

NMFS manages not only fish but also other marine organisms, including marine mammals and sea turtles. About 195 stocks of over 100 species of marine mammals reside in U.S. waters. Forty-four of those stocks are considered "strategic," because (1) they are listed as threatened or endangered under the Endangered Species Act (ESA, 1973), (2) they are declining and likely to be listed as threatened or endangered, or (3) the directly human-caused mortality exceeds the potential biological removal rate (NMFS, 1999a). In 1999, 47 marine mammal species were listed as endangered, 27 were listed as threatened, one was proposed to be listed, and 37 were candidates for listing under the ESA, for a total of 112.

Endangered or threatened marine animals include all the large whales, all species of sea turtles in U.S. waters, the Steller sea lion *(Eumetopias jubatus),* the Hawaiian monk seal (*Monachus schauinslandi)*, and the Gulf sturgeon (*Acipenser oxyrhynchus desotoi*). In 2001, the smalltooth sawfish (*Pristis pectinata),* a cartilaginous fish, was the first domestic marine fish to be listed under the ESA, and the white abalone (*Haliotis sorenseni)* became the only marine mollusk to be listed as endangered. According to a study by the American Fisheries Society, 31 species of marine fish are thought to be at risk of extinction in North America, including the Atlantic cod (*Gadus morhua),* several Puget Sound species of rockfish, two herring-type fish, and groupers along the southeast Atlantic coast (Musick et al., 2000).

Signs of success in NMFS management are also evident, including the recent rebuilding of stocks such as summer flounder (*Paralichthys dentatus*), Atlantic mackerel (*Scomber scombrus*), surf clams (*Spisula solidissima*), some yellowtail flounder (*Pleuronectes ferrugineus*), and sea scallop (*Placopecten magellanicus*) stocks on the Atlantic coast; and a major increase in pollock in the North Pacific region; and king mackerel (*Scomberomorus cavalla*) in the Gulf of Mexico. While it may be true that there may have been strong recruitment events or favorable environmental factors that have resulted in increases to the abovementioned stocks, NMFS management did not simply increase catch limits, but instead has allowed dominant year classes to contribute to the rebuilding of the stocks.

To simultaneously manage U.S. fisheries and protect and recover stocks of marine mammals and other protected species, NMFS must implement the mandates of several major laws that have potentially conflicting objectives and provisions. And the laws themselves sometimes appear to mandate the attainment of multiple goals that contradict one another and to provide unclear guidance on how to reach an appropriate balance among goals. That is common in resource-management legislation, and often it is only through litigation that the intent of Congress is clarified. The primary law that Congress enacted to manage the exploitation of marine fish species was the Fishery Conservation and Management Act of 1976. Amendments changed the act's name to the Magnuson Fishery Conservation and Management Act in 1980. The act was modified substantially in 1996 by the Sustainable Fisheries Act and is now known as the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). Under the MSFCMA, NMFS is charged with rebuilding overfished stocks while creating opportunities for commercial and recreational use, minimizing adverse social effects on fishing communities, and protecting marine habitats and endangered species. Court decisions after the 1996 amendments have clarified that Congress intended the rebuilding requirement to take precedence over the requirement to minimize socio-economic impacts. NMFS manages marine mammals under the direction of the ESA and the Marine Mammal Protection Act (MMPA, 1972). NMFS also operates under several acts and executive orders that ensure that government agencies follow particular procedures and analyses, including the National Environmental Policy Act (NEPA, 1969), the Regulatory Flexibility Act (RFA, 1980; amended in 1996), and the Administrative Procedure Act (APA, 1946).

Two of the major laws that NMFS implements require the direct involvement of the fishing industry in decision-making. The MMPA requires industry members to help prepare "take-reduction plans" to reduce the incidental take of marine mammals in commercial fisheries. The greatest degree of industry involvement, however, is mandated under the MSFCMA. The Secretary of Commerce is legally responsible for implementing this Act, but NMFS works with eight regional FMCs to develop plans and regulations for fisheries in their regions of the EEZ. The regional FMCs (also referred to as "councils") are composed largely of members of commercial and recreational fisheries interest groups and state fishery officials. The councils have substantial authority in determining policies and regulations for commercial and recreational fisheries in their regions.

The concept of regional councils was heralded as a promising new

approach to managing a public resource (Rogalski, 1980). It was based on the theory that people from various sectors of the fishing industry, the states, and other stakeholders would share relevant knowledge and could agree on conservation and management measures for the marine fishery populations they exploit. Each council determines its organization, practices, and procedures. Councils establish a scientific and statistical committee, advisory committees, and advisory panels as needed. They hire their own scientific and administrative personnel, who receive and analyze information from the NMFS fishery science centers, the fishing industry, and academic and consulting institutions. Scientific information generally flows from NMFS's regional fishery science centers to stock assessment review committees, to the councils' plan development teams and scientific subcommittees, and finally to the full councils. A full council adopts a fishery management plan (FMP) or annual specification of catch limits or other measures and then sends it on to the NMFS regional administrator for review and approval.

That process has worked relatively well when the scientific information delivered to the councils has indicated healthy stock levels. When stock assessments have indicated population declines, poor recruitment, or the need to reduce fishing-associated mortality, the process has not worked as well. In some cases, NMFS has been inconsistent in using its authority to disapprove FMPs or FMP amendments that allow for unsustainably high levels of fishing. During the 1990s, NMFS's attention shifted from developing domestic fisheries toward the management and control of resources. Managing access to resources has been difficult and not altogether successful, because of demands by competing sectors of the fishing industry.

In less than 25 years, NMFS has changed from a largely scientific agency to a major regulatory agency (it is the fourth-greatest promulgator of regulations in the United States). To judge from the number of legal challenges that the agency faces, the transition has been difficult. It is important to note that NMFS's legal authority, especially under the ESA, gives it responsibility for some of the most controversial issues in environmental policy and natural resource management. High-quality science, data, and models are essential for NMFS to meet its increasing regulatory responsibilities. The importance of science is emphasized in the NMFS mission statement:

> Stewardship of living marine resources for the benefit of the Nation through their science-based conservation and management and promotion of the health of their environment.

The purpose of this report is to provide a brief review of the scientific foundation, data, models, and processes used by NMFS to meet its regulatory requirements and respond to litigation.

APPROACH OF THE COMMITTEE

The conference report that accompanied the 2001 appropriations bill for the National Oceanic and Atmospheric Administration (NOAA), and specifically for NMFS, directed the National Academy of Public Administration (NAPA) and the National Academy of Sciences (NAS) to conduct companion studies to review NMFS's ability to meet its legal mandates. The objectives of the NAPA study are to provide a thorough review of NMFS's legal-defense capabilities, financial-management capacity, constituent relations, and organizational structure. The charge to the NAS (through the Ocean Studies Board of the National Research Council) was to provide a summary review of the adequacy of the data, scientific foundation, models, and processes used by NMFS to guide resource management, meet regulatory requirements, and provide support in response to litigation.

The Ocean Studies Board convened a committee to conduct the assessment and prepare this report. Because of the very short time frame available, the statement of task specified that the committee should rely largely on previous NRC reports that examined NMFS's stock assessment models, data-collection methods, and other aspects of the NMFS science program and review the actions taken by NMFS in response to the reports in conducting its assessment (see Appendix D). Therefore, the committee was comprised of experts who had served on one or more previous NRC studies of NMFS.

The committee held three meetings and heard presentations from NMFS personnel in response to the findings and recommendations of the abovementioned reports, the NOAA General Counsel, and persons involved in recent litigation. Because time for the study was limited (less than 6 months from the formation of the committee), the committee was unable to visit NMFS regional offices and science centers or the FMCs to supplement the presentations and reports mentioned above. The committee selected and summarized a sampling of recently reported cases against NMFS involving the MSFCMA, ESA, NEPA, and MMPA. Specifically, it reviewed cases in which the court's judgment was against NMFS and cases that illustrated points of law concerning potential failures in science or the

application of science. No formal budget analysis of NMFS was completed by this committee.

2

Adequacy of NMFS Data, Scientific Foundations, and Models

ADEQUACY OF SCIENCE FOR STOCK ASSESSMENTS

Issues

Stock assessment is the scientific and statistical process whereby the status of a marine fish population or subpopulation (stock) is assessed in terms of population size, reproductive status, fishing mortality, and sustainability. NMFS allocates a substantial portion of its personnel and resources to stock assessment, and the resulting assessments form the basis of biological reference points and management decisions, such as quotas, restriction of effort, and closing of seasons or areas to fishing. Previously, study committees sponsored by the National Research Council have conducted reviews of stock assessments, including reviews at the species level (such as Atlantic bluefin tuna, NRC, 1994; Pacific salmon, NRC, 1996b) and at the regional level (such as Northeast marine fisheries, NRC, 1998a), and have reviewed stock assessment methods (NRC, 1998b) and data issues (NRC, 2000a) generally.

Uncertainty

Why is the stock assessment process reviewed and questioned so frequently? As indicated in the Research Council report *Improving Fish Stock Assessments* (NRC, 1998b), stock assessments are intrinsically uncertain.

The uncertainty arises as a result of several factors, including the inherent variability in populations, variability associated with the process of observing populations and measuring them (sampling error), and the uncertainty associated with modeling assumptions (such as model misspecification).

Gathering more information on fish stocks is important because it generally leads to greater certainty and confidence, but increasing the amount of data collected does not necessarily solve the problem of uncertainty in assessments. If NMFS could conduct a complete census of the fish in the ocean, scientists and decision-makers would still have to deal with uncertainties of natural variation in populations resulting from processes of birth, death, growth, immigration, and emigration, each of which is affected by environmental factors in ways that are not entirely understood. Furthermore, scientists would still need to base their analyses and managers make their decisions on *predictions* of future stock size and of how fishing activities will affect the stock. The science and management of marine fisheries can be improved as more data are collected (NRC, 2000a), but uncertainty will still exist because of the nature of the system.

Uncertainty can lead decision-makers, stakeholders, and even fisheries scientists to be overly skeptical of predictions made through the stock assessment process. As Colin Clark noted, "any admission of scientific uncertainty only destroys the credibility of the science" (Clark, 1966). That is unfortunate because even uncertain scientific results contain valuable information. Perfect predictions will never be available, but useful predictions can be developed, and less risky management actions can be based on such predictions. Scientists and non-scientists view uncertainty differently, but this does not justify ignoring stock assessment advice, just as it would not justify ignoring weather predictions, national economic forecasts, or health advisory alerts.

Data

In stock assessments, constant attention must be given to how fisheries data are collected and how they are used. The information content of data can be improved through technological and methodological advances, the use of efficient estimators and design protocols, an increase in the capacity of NMFS to gather and analyze data, and active communication among scientists, managers, and stakeholders. Several aspects of those issues have been discussed at length in previous Research Council reports and are briefly revisited here.

Sampling Protocols

The sampling protocols and methods set up by NMFS initially were of good quality. However, as agency responsibilities changed and sampling methods improved, earlier sampling protocols became less appropriate. Previous reports recommended that standardized and formalized data-collection protocols be established nationwide to allow for greater efficiency in overall sampling design and quality assurance. NMFS has responded to that recommendation by supporting the development of federal-state partnerships in the collection, management, and storage of fishery-dependent data through regional protocols, but progress on standardized protocols has been slow. NMFS has also addressed problems in communicating the rationales for fishery-independent sampling protocols to fishing-industry personnel on sampling cruises and in cooperative research.

Fishery-Dependent Data: Bycatch Data

Previous reports (NRC, 1998a; 2000a) have discussed aspects of fishery-dependent data collection that could be improved by NMFS. To various degrees, NMFS has been able to address their recommendations. The committee's review of the recent series of lawsuits found that collection of bycatch data remained problematic and was, in part, the basis of several lawsuits, e.g., cases challenging FMP amendments for Pacific and Northeast groundfish.

"Bycatch" refers to fish that are caught but not retained (discards) plus fish killed because of encounters with gear. Bycatch data can be collected in several ways, including vessel logbooks, dealer reports, and observers. Logbook data come from fishers who self-report their catch, dealer reports list the amount of bycatch that is landed and sold when it is not prohibited and when the catch is salable, and observers directly observe the catch of species that are kept and species that are later discarded as they are brought onboard the vessel at sea. Of the three, observers offer independent, unbiased data collection that is especially important for non-targeted or prohibited species. Observer programs are expensive, and their use is mandated for specific fisheries, such as the Georges Bank scallop fishery, and in fisheries that have interactions with protected species. Observer coverage is used for commercial fisheries and is virtually nonexistent for recreational fisheries. In 1999, NMFS spent $9.2 million and the fishing industry another $10 million for observer coverage compared with $28.8 million on fishery-

independent surveys, $3.9 million on recreational surveys, and $2.8 million on vessel monitoring system (VMS) programs.

In the case of *Natural Resources Defense Council (NRDC) v. Evans*, NMFS and the Groundfish Management Team (GMT) of the Pacific Fishery Management Council (PFMC) used historical studies to ascertain the proportion of bycatch currently taken. Plaintiffs challenged NMFS's use of the historical data, and these data were found unacceptable by the court. The court made the following points indicating its understanding of trip limit-induced discards:

> An irony exists in that as fishing allowances are lowered to protect a species, the bycatch percentage increases. Fishing boats continue to catch multiple species of fish at the same time, but they are compelled by regulation to discard a greater percentage of the protected species. As bocaccio and lingcod fishing allowances have decreased in recent years, it is therefore, as both sides agree, a virtual certainty that the bycatch mortality rates for each fish have in turn increased.

NMFS admits that it is a "virtual certainty" that their (bocaccio and lingcod) bycatch mortality rates have risen.

> A Northwest and Alaska Fisheries Center report (Pikitch, 1988) also corroborates evidence that regulatory bycatch increases as landing limits are reduced, and both bocaccio and lingcod have been protected by reduced landing limits. It must follow that bycatch discard has increased since the Pikitch Study was conducted and the 16 percent and 20 percent figures that NMFS has arbitrarily set are no longer accurate, if they ever were.

The GMT used values from Pikitch (1988) and its expert knowledge to estimate discard rates for various species. It was those values that the court found to be too low, but there were no more recent data to document the magnitude or even the direction of change in total discards and discard rates. Some discard rates may have risen, some may have declined; consequently, the court concluded that estimates of discards based on past behavior are not relevant for today's fishery. In fact, estimates from the Pikitch study may have never been accurate estimates of West Coast discard rates, because they were limited to only a few vessels and ports.

Why were there no current data to improve critical estimates of regulatory discards? As mentioned previously, the preferred method of collecting discard data is via at-sea observers. The annual cost of each full-time observer may exceed $50,000. The total cost of an adequate observer program for West Coast groundfish may be about $5 million. Total revenue of

the West Coast groundfish industry (excluding whiting) is about $45 million. Thus the cost of an adequate observer program may easily exceed 10 percent of the gross revenue of the fishery. There is a special "disaster" appropriation of about $2.5 million for a pilot observer program in the NMFS budget, but no data have been obtained yet. Industry suggested other methods of obtaining bycatch data, but the PFMC and NMFS rejected these suggestions. Because at-sea observers were too expensive and other methods were not pursued, no information regarding discards is now obtained. The general lesson learned is that fishery-dependent data on bycatch are severely limited and additional resources are needed to increase the number of at-sea observers to avoid future litigation of this type.

Fishery-Dependent Data: Recreational-Catch Data

There are often problems with the use of fishery-dependent data for stock assessment. One of the major problems, the lag between data collection and their availability for use in stock assessment, is highlighted in the recreational fisheries. Recreational fisheries present a concern because they form an important and growing component of some marine fisheries. Recreational fisheries are characterized by a large number of people entering marine waters from many access points and individually harvesting only a few fish each. Because of how recreational fisheries operate, differences exist from commercial fisheries in how data are collected, how the fish and the fishers are managed, and consequently how these fisheries should be modeled in contrast with commercial fisheries. The statistical-survey methods (NMFS Marine Recreational Fishery Statistics Survey) that have provided reliable data estimates have been slow, with many months passing between harvest by the angler and complete catch and effort estimation by NMFS. Because the recreational catch makes up only a small portion of most fisheries, this is usually not a point of contention. However, in the summer flounder fishery (see NRC, 2000a) and some other fisheries, the recreational catch is a substantial portion of total catch. The delay in obtaining catch statistics contributed to the court's sanction of NMFS in *North Carolina Fisherman's Association, Inc. v Daley*. The National Research Council (NRC, 2000a) recommended that alternative statistical approaches be developed to provide these data more quickly. NMFS has recently amended the annual quota-setting process to set a cut-off date for catch statistics in early fall to eliminate the need for possible cuts in the quota in mid-spring.

Fishery-Independent Surveys

For most species, fishery-independent surveys offer the best choice for providing a reliable index of fish abundance. Surveys allow formulation of an unbiased statistical design for the collection of fish population data, control over sampling location and intensity, and quality assurance. NOAA research vessels have provided the cornerstone of this data-gathering venture for many years, but less and less funding has been made available to NOAA to support this important function. NOAA fishery research vessels that conduct fishery-independent surveys are aging. The Research Council (NRC, 2000a) recommended that these vessels be replaced or modernized, and that new vessels be acquired to increase NMFS's capacity to collect high-quality scientific information and to conduct research.

Technological Advances in Data Collection Previous NRC reports (NRC 2000a; 1998a) recommended that NMFS evaluate the usefulness of such modern electronic data-gathering devices as electronic logbooks and VMSs in conjunction with the value-added features that each of these offers to fishermen. All vessels in the New England scallop fleet now use VMSs. Environmental groups that have at times sued NMFS have filed briefs in support of NMFS's required use of VMSs in the Atlantic longline fishery—a requirement under legal challenge by the fishing industry.

Ecosystem Data

Ecosystem-level information is being gathered through fishery surveys, commercial and recreational catch monitoring, and all the other means of data collection at NMFS's disposal. Methods must be developed to use this information effectively and to gather broader ecosystem-level information to understand the role of fisheries science in the context of ecosystem management, and to evaluate the role of fishing and the dynamics of individual fish populations in marine ecosystems. The NMFS Ecosystem Principles Advisory Panel recommended the development of fisheries ecosystem plans to modify single-species approaches to incorporate ecosystem attributes, evaluate how trophic interactions and oceanographic processes affect recruitment, document the role of habitat in supporting fisheries and ecosystem productivity, and develop aggregate models that can be used to predict single-species and ultimately multispecies harvest objectives (NMFS, 1999). The committee encourages the development of such plans because they

address unmet needs under the MSFCMA to supply new means of assessing the effects of fishing on habitat and ecosystems.

Database Management

The purview of NMFS science involves a great deal of data collection, and this task has expanded greatly in recent years. An avalanche of data now overwhelms existing data collection and management systems. The volume of data is sure to grow, and the technological means for handling it are advancing rapidly. Improving the means for data processing and management should be a central focus for NMFS over the next decade. This is not a trivial task. Many scientists keep track of the data they collect and use, but the data now in use represent several human lifetimes' worth of work and should continue to be available for future generations to use in managing fish populations. Data management is essential and requires substantial expertise. NMFS should build on its existing capacity to manage data more effectively. In the process, commercial data-management firms should be consulted to obtain real-time value-added data-management advice and products (NRC, 2000a).

Scientist-Stakeholder Communication

Because scientists are involved in management, they are often viewed as regulators. The regulator-regulated dichotomy often disrupts communication between the two groups (scientists and fishermen), which is unfortunate because a great deal of information could be and should be exchanged. Information could increase understanding and result in better management of the fish resources. NMFS should facilitate greater cooperation among fisheries scientists, regional fishery management council advisory panels, fishery participants, and other stakeholders to improve the quality and efficiency of data collection and create a shared sense of confidence in what the data indicate. That has begun in earnest. In response to previous National Research Council (NRC, 1998a,b; 2000a) recommendations, NMFS developed cooperative research projects with the fishing industry, for example, a cod-tagging project in the Northeast and monkfish surveys.

Management-Data Interaction

It may be clear that data quality and quantity can influence the quality of management (by the FMCs and NMFS), but little consideration is given to how management can influence the quality of data. Some management regimes and changes therein can increase problems in collecting data and monitoring fisheries. The role of management is to maintain an optimal fishery and not necessarily to optimize data collection, but if the results of management actions are not monitored (through data collection), they cannot be improved. Adequate consideration should be given to how management actions will influence the ability to monitor fish populations and to the social and economic effects of those actions. Furthermore, methods should be developed for minimizing bias and data misreporting when a change in management goes into effect. Also related is the issue of allowing a management action to endure long enough to be evaluated. Fishermen complain when management changes too rapidly. This influences science and monitoring as well. Those considerations point to the need to develop management plans for a longer term and with a broader perspective in mind (NRC, 2000a).

Modeling

Stock-assessment modeling not only provides an important structure for synthesizing information and determining fish abundances but also serves as a useful predictive tool to evaluate alternative management scenarios and the consequences of potential actions before they are implemented. Stock assessment modeling is undergoing rapid development. NMFS has done well at using state-of-the-art methods and even creating new methods for population assessment, but, as with data collection and management practices, its stock assessment modeling can be improved (NRC, 1998b; 2000a).

Alternative Models

Every model is a simplified representation of a complex system. Different models characterize a fish population in different ways. By using alternative models, we gain a broader understanding of the nature of the system and the behavior of the models themselves than if we apply a single model to a specific dataset. Thus, previous stock assessment and modeling

reviews have recommended that a range of alternative assessment models be used to improve understanding of assessment biases and consequences (NRC, 1998b; 2000a). Alternative models need not be more complex models. Some alternative models could be constructed on soft-computing principles, such as fuzzy arithmetic, or they could be based on alternate methods of estimation (maximum likelihood versus least squares versus Bayesian methods). NMFS has responded to previous recommendations by initiating broader training for its stock assessment scientists. For example, in the fall of 2001, the NMFS Northeast Fisheries Science Center held a 5-day workshop to introduce AD Model Builder (a program new to the center) to its modelers as an alternative approach to the standard models. In March 2002, the Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish used this approach to revise estimates of stock biomass and biomass targets, an effort in part undertaken to respond to litigation (*Conservation Law Foundation v. Evans,* 2001) concerning the rebuilding of these stocks (Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish, 2002).

Uncertainty in Models

Assessment models are used to estimate abundance and to formulate predictions. There is always uncertainty in the processes of estimation and prediction. Uncertainty does not imply that nothing is known; it implies that a range of possibilities exists and that some outcomes are more likely than others. Historically, scientists proposed the most likely scenario garnered from a single point estimate. That did not allow for the evaluation of alternative strategies from the range of estimates. One action may offer a 50 percent probability that a managed stock will recover within a given period, whereas an alternative action may offer a 90 percent probability. Greater effort should be devoted to characterizing the uncertainty associated with stock assessment so that scientists, decision-makers, and stakeholders can assess risk better. Alternative methods for addressing uncertainty, or for assessing the level of confidence in estimates and predictions, should be considered. Several examples have been given in this regard here and in previous NRC reports, for example applying alternative assessment models to evaluate the effects due to model assumptions and structure, using survey variance to appropriately weigh observations going into assessments, providing confidence bounds or posterior distributions for current biomass and total allowable catch (TAC) estimates, determining costs and

gains associated with biomass levels so that risk can be assessed, and incorporating estimates of variation in prediction simulations used to explore management control rules.

Ecosystem-Level Perspective

Marine ecosystems are complex. Many marine-ecosystem models have been and are being developed, but they generally are not ready to be used in the day-to-day arena of fisheries management. Single-species models now used in stock assessment provide quantitative predictions of stock size and harvest potential. Multispecies models and ecosystem models that reliably predict the population sizes of targeted and associated species have yet to be developed. The lack of a comprehensive multispecies or ecosystem model for specific marine environments, however, should not preclude the use of ecological and environmental information or models to the extent feasible when population assessments and predictive management models are being developed. As pointed out in the NRC report *Sustaining Marine Fisheries* (NRC, 1999b), "ecosystem-based management is an approach that takes major ecosystem components and services—both structural and functional—into account in managing fisheries." Important ecosystem-level factors that consider predator-prey relationships and marine habitats should be considered, even in single-species models that foster precautionary, risk-averse management. Incorporation of ecological and environmental information into management plans, although important, should not be sought at the expense of a reduction in the quality of single-species stock assessments themselves.

Harvesting Strategies and Decision Rules

Fish-population estimation has been the central focus of stock assessment scientists for many years. When projecting estimates forward, particularly when examining the effect of different potential harvest levels on a fishery, one usually takes an optimal equilibrium. This coupling of the assessment with an equilibrium analysis has become the default approach for defining benchmarks in fishery performance. But, the strategies for making optimal use of a resource have expanded greatly. Even the concept of optimal harvest has been expanded beyond the simple concept of yield to include other biological and socioeconomic criteria.

A variety of new approaches have been developed by biological and

social scientists to model populations so that strategies for harvest can be examined and the consequences of management actions can be explored before FMPs are enacted. The new approaches can evaluate both short-term dynamics and long-term predictions under different harvest and control conditions. Harvest strategies are the means by which a fishery operates on a resource to obtain and control yield. The fishery may operate early or late in the season, harvest fish over a particular size; fish in one area or another, fish with one gear type or another, or operate with less intensity now so that more or larger fish are available later. Harvest strategies can be explored in a theoretical context through modeling and can be compared with other strategies to help form a basis of decision-making. In recognition that a wide variety of potential harvesting strategies and decision rules exist, it is sensible to explore management options. Stock assessment models should be developed and used in conjunction with harvesting strategies and decision rules so that they can be evaluated simultaneously to provide information for sustaining fisheries (NRC, 1998a).

3

Adequacy of Science for Ecosystem and Biological Considerations

SCIENCE ISSUES: BEYOND STOCK ASSESSMENTS

The core activity of NMFS science in the last three decades has centered on stock assessments. The needs for more and better stock assessment science are fully recognized and will remain a challenge for NMFS. However, demand has grown in the last decade for information in other fields of science, particularly because of the increased recognition of ecosystem effects of fishing activities (NRC, 1999b; 2000b). Many of the criticisms of agency performance mirrored in much of the recent litigation are related to real or perceived deficiencies in the ability of NMFS to conduct ecological research to support or supplement its stock assessments.

Conserving or restoring fish habitats, reducing bycatch, protecting threatened and endangered species, and reducing effects of fishing on biological communities and habitats are at the forefront of public concerns with respect to fisheries management. Those concerns and others were identified nearly a decade ago (NRC, 1994). In a report mandated by Congress, a strong call for increasing emphasis on ecosystem approaches to support conventional fisheries management was issued by an NMFS-appointed expert panel (NMFS, 1999). Since 1998, NRC reports (supported in large part by NMFS to address issues of concern to the agency) have recommended increased research on ecosystem science and on ecosystem approaches to management (NRC, 1996a; 1999b; 2001). The MSFCMA reauthorization process is expected to increase the demand to understand

how fishing affects habitats and multispecies interactions (predator-prey relationships), the structure of biological communities, and sustainable yields and productivity of fished ecosystems.

NMFS has not ignored these scientific needs. There are notable examples of ecosystem research conducted by NMFS in the Bering Sea and Gulf of Alaska ecosystems and in other regions. NMFS, of course, does not have sole responsibility to conduct science on ecosystems and ecosystem processes in the U.S. EEZ, but it bears a large part of the responsibility for this research because of fishing's large "footprint" on marine ecosystems. The challenge is worldwide, and the development of multispecies and ecosystem models since the pioneering work of Anderson and Ursin (1977), although considerable, has been notably slow (Sissenwine and Daan, 1991). Nevertheless, the development of multispecies models, some by NMFS scientists, is important and holds promise for future management applications (Hollowed et al., 2000a). So far, the models have not proved to have the predictive power required for most fisheries management. It is uncertain whether NMFS has the financial or personnel resources to respond to the challenge, although ecological and ecosystem issues are the source of a large fraction of the agency's litigation problem.

Therefore, it is important for NMFS to define its responsibilities for ecosystem research. There are pockets of expertise in NMFS to address ecological issues. For example, the agency has high-quality expertise in systematics, genetics, hydroacoustics, organism behavior, trophic ecology, multispecies modeling, fisheries oceanography, toxicology, and disease. Research conducted outside the agency also could be used to improve much of the ecological and ecosystem science in fisheries management. However, timely research on marine ecosystems to address water quality, habitats, trophic relationships, and threatened and endangered species needs to be coordinated with stock assessments to respond quickly to management needs. A recent NMFS report recommended that the regional FMCs develop fishery ecosystem plans (FEPs) for major fished ecosystems in each council region (NMFS, 1999). Regional FMCs and NMFS are responding to that recommendation, and plans for FEPs are being considered. If adopted, the FEPs will further challenge NMFS to conduct, interpret, and review ecosystem science in support of fisheries management. Part of the challenge will be to coordinate ecosystem science efforts effectively with other federal agencies, state agencies, and academic institutions.

The call for broad ecosystem science would probably be less urgent if fewer fish stocks were overfished. Solutions to the overfishing problem

would reduce the urgency (but not eliminate the need) for ecosystem science (NRC, 1999b). In the future, management may succeed in controlling fishing effort and capacity, and this would relieve stress on marine ecosystems. But in the short term, a multitude of fundamental biological and ecological studies and modeling approaches should be initiated to understand how ecosystems respond to heavy fishing pressure. New models should devote greater attention to predator-prey interactions, habitat needs, life-history variability among species, and the effects of variability in the environment, which magnify the uncertainty of conventional assessment models (NRC, 1998b).

Performance: Perception and Reality

Science is best pursued in an atmosphere where the objectivity required to interpret data and advance understanding can be achieved with minimal pressure from stakeholders, who often have vested interests in maintaining the status quo or wish to change the fisheries-management system. In fisheries, it is unrealistic and perhaps impossible to remove industry demands and management needs from the science process. NMFS and the regional FMCs are so tightly bound in the science-management process that it is difficult for NMFS to conduct objective, independent science. In recent years, environmentalists have increased pressure on the agency to conduct research that is beyond the scope of NMFS's traditional stock assessment focus. The status of many overfished stocks requires that NMFS conduct quick and effective investigations and provide prompt interpretations. However, scientists and the scientific process do not function effectively under such pressures. Science tends to be careful and deliberate, which can give the impression of being "slow and unresponsive." It is not surprising that NMFS is subject to criticism, given the circumstances within which it operates.

Many of the perceived problems of NMFS science are related to the quality of stock assessment science and models that form the basis of decisions by managers on allocation and fishing effort. Yet, when challenged in litigation or in mandated independent reviews, the stock assessments usually stand up well to criticisms. From 1997 to March 2002, NMFS has lost only three cases where management actions were challenged on the basis of National Standard 2 ("Conservation and management measures shall be based on the best scientific information available"—see Appendix C) of the MSFCMA (NAPA, in press). The perception of inadequate stock assess-

ment science results as much from troubled relationships between NMFS and the industry as from the occasional errors in assessments that are exacerbated by regulations necessary to restore overfished stocks. In a recent issue of *National Fisherman* (2002), the editor repeats the oft-stated lament that "questionable science" from NMFS is the consequence of failing to "seek the everyday wisdom of fishermen." The perception of poor science in stock assessments can obscure the reality that NMFS stock assessment science is generally good.

In the broader arena of ecological and ecosystem science, there is a perception in the environmental community that NMFS is not conducting its science at a level or with the quality that is necessary to define fishing effects on habitats, biological communities, and ecosystems in a way that will allow achievement of the directives of the MSFCMA. The lack of necessary information hinders managers' ability to regulate fishing to account for those concerns. In that regard, perception may be closer to reality. NMFS has been subject to litigation on ecosystem effects and in some instances has not done timely studies on environmental effects or essential fish habitats or on effects of bycatch on fisheries and ecosystems or, in several cases, has not conducted the science necessary to understand how fishing may affect threatened or endangered mammals, turtles, and seabirds. Even broader mandates probably will be required of NMFS as marine protected areas (MPAs) become more common in FMPs. NMFS is aware of its responsibility to learn about ecosystem-based management, and it has created the Ecosystem-Based Approach to Management Task Force of the Marine Fisheries Advisory Committee that held a workshop January 15-17, 2002. An example of a new responsibility in ecosystem science evolves from Presidential Executive Order 13158 (May 30, 2000, 65 Fed. Reg. 34909), which directs NOAA (through its National Ocean Service and NMFS line offices) and other agencies to develop and design networks of MPAs. The designated agencies are undertaking the task, but unless the scientific evaluations and modeling research in support of specific MPAs are excellent, it seems certain that lawsuits will be brought by both the fishing and environmental communities to challenge the scientific basis of designations and recommended implementations of MPAs.

4

Adequacy of Social and Economic Data

The 1996 amendments to the MSFCMA and recent court cases have increased pressures on NMFS and the regional FMCs to carry out detailed economic and social impact-assessment analyses of management alternatives. Few data have been systematically collected for that purpose. Preliminary efforts to improve the collection of social and economic data are being undertaken by several bodies, including NMFS, and there is planning for the development of centralized databases at regional science centers.

Although several recent NRC reports (NRC, 1996b; 1998b; 1999a,c; 2000a,b) recognized the importance of social and economic factors for fisheries, virtually no evaluation of social-science data or models appeared in any of these previous reports, even though several committees involved social scientists and addressed social-science questions. With National Standard 1 as a reference point, a review of the ability to perform required economic and social analysis could be based on National Standards 5 and 8 (see Appendix C for a listing of the National Standards). The National Standards of the MSFCMA are not the only legislative mandates that require analysis of the economic and social dimensions of fisheries management. For example, "efficiency in the utilization of fishery resources" in National Standard 5 can refer to the end use of the fishery resource, and management decisions can result in a shift of fish production to lower-valued goods (for example, fish suitable for top-grade human consumption could be shifted to fishmeal production because a "race to fish" results in

flooding the market with product). Or it can refer to the cost of harvesting and processing, which can also be affected by management.

National Standard 8 requires determining whether "fishing communities" are affected (there are some guidelines, but there is considerable debate about what constitutes a fishing community within the intent of MSFCMA); assessing what is required for their sustained participation in the fisheries and minimizing the economic effects on communities to be consistent with the conservation mandates of National Standard 1; and carrying out economic and social impact analyses. In addition to the MSFCMA, economic impact analyses are required by the Regulatory Flexibility Act (RFA) and have been a focus of litigation and have important social and economic implications.

NMFS has taken important steps to address the issue of economic and other social-science research, but much remains to be done. NMFS has developed guidelines for economic analysis of fishery management actions and has recently revised its guidelines for social-impact assessment. Those guidelines specify the types of questions that should be answered (How will income and employment be affected? How will the costs and benefits of an action be distributed among the various stakeholders?) and the types of analyses that are necessary to answer them. If the guidelines were followed in every instance, litigation resulting from noncompliance with the RFA probably would be reduced drastically. However, NMFS and the council system do not have the data or the personnel necessary to complete all such required studies.

NMFS has adopted a plan to improve social-science capability in the fisheries management system. The plan calls for 96 new social science positions in the next few years, with a balance of experts to be spread throughout the regions and at NMFS headquarters and hiring that will take place in stages. The first round of searches is currently under way, and some appointments have been made. Until these positions are filled, NMFS's ability to do the social-science research and monitoring necessary to accomplish its goals will be seriously compromised.

NMFS has recently instituted a policy change that will require the regional councils to complete the documentation to comply with NEPA, RFA, and other statutory or executive order requirements for analysis of management alternatives before a final vote on a FMP. In the past, councils and NMFS have been criticized for focusing on one management alternative (the council's preferred alternative) and then doing the NEPA and RFA analysis to justify the selected option after electing to adopt it; this violates

the intent of the laws. NMFS has provided the councils with supplemental funds to collect data and hire temporary staff to perform the required analysis. The regional approach will be useful because the availability of the required data varies from region to region and from fishery to fishery. In some cases, especially for the more valuable fisheries, the quantity and quality of data appear to be quite good, and the work done in the regions to collect them is commendable. In other cases, virtually no data are available; this is especially true for non-economic data concerning the social and cultural dimensions of fisheries.

NMFS hopes this change in procedure will ensure that the analytical requirements of its legal mandates are met and, as a result, should allow NMFS to have greater success in defending its management actions and reducing the number of legal challenges brought against it. However, it was necessary to consider the long-run implications of the policy in terms of the charge to this committee. With respect to adequacy of data, the supplementary funds for data collection may help in the short term, but plans need to be made for the regular collection, storage, and retrieval of this type of data in a manner that is analogous to those of data collected for stock assessment analysis. There have been many reports on what types of social and economic data are necessary to perform the required analyses, but NMFS does not appear to have an organized plan for determining social-science data needs and beginning the collection process. NMFS has cooperated with states and the Atlantic States Marine Fisheries Commission to carry out a pilot study of the routine collection of economic and social data from commercial fishing enterprises; this is being done through the Atlantic Coast Cooperative Statistics Program with NMFS port agents collecting the data, but it is not clear whether there will be a sustained federal commitment to the effort or whether the states will follow through.

The development of new methods is less of an issue for social-science analyses than for stock assessment. With stock assessment analysis, NMFS scientists make up a substantial proportion of the total professionals in the field, and the issues can be case-specific for a particular stock of fish. Conversely, much of the social-science methodological work that is being done in other areas can be transferred to fisheries in a relatively straightforward manner. Some councils and NMFS regional offices may be able to redirect personnel to accomplish these studies with minimal training.

However, considerable innovative social-science research will be necessary to answer questions of population dynamics and resource access and this research must be integrated into assessment methods. The scientific

foundation of economics and other social sciences will also be central to fisheries applications if impact analyses are subject to the same degree of critical review as stock assessment analyses. The new attention of the councils to social and economic impact analysis has not been tested, but there probably will be greater focus by the councils and constituents on socioeconomic analyses and greater demands for high-quality stock assessments. When the analyses of preferred alternatives are presented *before* council decisions, they will be subject to more critical scrutiny than in the past. The analyses will provide an assessment of the likely distribution of costs and benefits of different regulatory alternatives. Projecting the impacts of regulatory alternatives on small businesses and communities requires dealing with very high levels of uncertainty and complexity; this is analogous to the current situation in fish stock assessment. In addition, new tools, such as geographic information systems, and greater theoretical attention to the spatial dimensions of fishing will require higher levels of training and expertise.

NMFS would be wise to assign some of its new social scientists exclusively to monitoring and peer-review activities. NMFS must ensure that the personnel who prepare analyses for management plans are not called on to act in a review capacity as well. In developing a plan for the effective use of its new social scientists, NMFS and the councils should consider other alternatives to ensure high-quality social science by continuing the fellowships in marine resource economics (discussed in the next chapter) but expanding or redefining them to include support for talented doctoral students in other social-science fields, using the existing cooperative agreements and joint institutes to tap the pool of academic social scientists, and by using scientific and statistical committees of the regional councils or similar units for peer review.

5

Adequacy of the Use of Science in Fishery Management

IDENTIFICATION AND EXPECTATIONS OF SCIENCE AND INFORMATION NEEDS

The changing mission of NMFS reflects to some degree the changing values of the nation (Heinz Center, 1999). This mission reflects the balance of both harvest and protection of marine fisheries that the nation expects for these renewable resources. This mission expands the tasks that NMFS must undertake. The 1996 revisions to the MSFCMA added three new National Standards to the Act and two of these, 8 and 9, along with the strengthened prohibition on overfishing and duty to rebuild stocks, add major analytical tasks to NMFS's already full plate. These new tasks include the acquisition and analysis of socioeconomic (National Standard 8) and bycatch data (National Standard 9) and their inclusion into the decision-making process (See Appendix C for a list of the National Standards). Unless NMFS is given the support it needs to achieve its mission and the agency continues to evolve scientifically, the nation's expectations may begin to outpace the agency's capability to provide the scientific research and guidance needed to carry out its mission. Some might see the recent trend of increased litigation as a reflection that there is a mismatch of expectation and capabilities to some extent already. In identifying its future workforce needs, NMFS needs to continue to develop its capacity to do good science by recruiting and training science personnel (NRC, 2000b). NMFS has a workforce of about 2,670, of whom 1,130 are technical experts (NRC, 2000b). NMFS expects that 30 percent of its workforce will retire in the next five years and that perhaps 20 percent

more will take early retirement. Fisheries science demands broad training and a high degree of quantitative competence. NMFS must compete for qualified people with other enterprises, such as engineering, computer, biomedical, computer software and information, and environmental sciences that can often provide higher salaries. NMFS is addressing the expected shortfall of quantitative scientists through the establishment of the NMFS-Sea Grant Joint Graduate Fellowship Program in Population Dynamics and Marine Resource Economics. Despite the good intentions that motivated the development of that program, there are only five fellowships in population dynamics and three in marine resource economics, with a potential for only six fellows in each discipline at any specific time. Because these are multiyear fellowships, they will result in fewer than a dozen fellows ready to enter the workforce each year—woefully inadequate when balanced against the projected retirement of 500 fisheries scientists within the next 10 years and the need for an additional 358 stock assessment and data collection personnel needed to upgrade stock assessments to a nationally acceptable level (NRC, 2000b).

Some of this work will be done by new hires, especially socio-economic studies and analyses. However, not all new tasks require additional NMFS staff. NMFS can contract some of its work to private industry and academia (NRC, 2000b). NMFS has successfully used this approach in data acquisition for the Marine Recreational Fishery Statistics Survey (MRFSS). For example, access-intercepts and telephone surveys of recreational anglers are done by contract employees working for private industry and this has been both cost-effective and expedient. Partly, though the success of this contract approach lies in the cadre of specially-trained scientists at NMFS who analyze these data and oversee their integration with stock assessments. NMFS scientists are sufficiently familiar with these studies and from a daily oversight basis, they are able to assess the subtleties in these data. Wholesale contracting of NMFS work is inappropriate without sufficiently trained scientists within NMFS to maintain daily oversight and who then use the resulting data in a meaningful way. Outsourcing without sufficient scientific involvement by agency personnel would degrade the quality of NMFS science. Moreover, some of these new tasks such as the inclusion of ecosystem approaches to stock assessment require collaboration among experts from diverse disciplines. Proximity is important and much is gained through day-to-day contact and discussion between scientists. Finally, if the scientists are NMFS employees, they are more likely to share a common mission.

Identifying and anticipating science and information needs for an expanding mission may be more difficult. The ESA gives the responsibility and authority for the protection and recovery of most endangered and threatened marine species to NMFS. The scientific requirements for monitoring and maintaining threatened or endangered species are different from those for supporting recreational or commercial fisheries for exploited species in terms of the questions posed, the thresholds of concern, and the actions needed to satisfy objectives. For exploited species, monitoring often occurs in tandem with resource use (fishing), thresholds can be identified with a reasonable margin of error (typically well above extinction thresholds), and sustainability is sought through adjustments in total effort expended or through a specified TAC. For endangered species, independent monitoring must take place, thresholds are just above extinction, and protection is the management objective. However, similarities in the science do exist. Both require information about the population response to changes typically brought about by human intervention, both seek to limit conditions that affect mortality while promoting conditions that induce optimal productivity. But the differences in the nature of the science required between endangered species and exploited species create challenges for NMFS.

The MSFCMA directs NMFS (through the Secretary of Commerce) to describe and identify essential fish habitat (EFH) and to take actions to conserve and enhance such habitat. That requires NMFS to move in a different direction from the past, both scientifically and managerially. There is increasing recognition of and interest in the critical role that habitat, and marine ecosystems in general, plays in sustaining marine populations (NRC, 1996a; 1999b; 2001). However, the task given to NMFS through the MSFCMA has major repercussions that have not yet been fully realized. Forced by the act to identify EFH for the species for which they have responsibility, the councils initially identified almost the entire area in their jurisdictions as EFH, following NMFS's precautionary guidance on how to proceed when data are scarce. Although that may have been an appropriate initial estimate, it creates an enormous need for scientific information and analysis and greatly adds to NMFS's administrative challenges. The scientific community is only beginning to work through the definitions and methods necessary to develop the applications to identify and protect EFH. Yet NMFS must still manage fish stocks using the concept without a clear definition of what constitutes EFH.

In addition to the challenges of managing fisheries, conserving habitat,

developing ecosystem plans, and protecting endangered species, NMFS must translate the biological and ecological results of FMPs and council decisions into economic and social dimensions. Several laws and policies—including the MSFCMA, the RFA, the NEPA, and Executive Order 12866—require social and economic analysis of the effects of regulatory decisions. NMFS has become the fourth most prolific generator of federal regulations (Kammer, 2000). As noted in *Sharing the Fish: Toward a National Policy on Individual Fishing Quotas* (NRC, 1999a), the federal government has extensive public-trust responsibility for fisheries.

THE ROLE OF SCIENCE IN DECISION-MAKING

Even in situations in which the quality of NMFS science is high, the interpretation and application of science may be limited by factors that influence objectivity, and the transparency and timing of the process by which it is transmitted. Some of those limitations result from the relative scarcity of independent, qualified people available to conduct peer review. Other limitations arise because information and advice may become commingled and value-laden. Limitations also arise in obtaining sufficient information to balance short-term versus long-term payoffs appropriately. Each of the limitations, although information-based, develops as a consequence of the structural organization of the scientist-decision-maker interface.

NMFS provides the personnel for developing and evaluating stock assessments, but the councils and their advisory groups also provide expertise. Council advisory committees—in which NMFS scientists, council staff, and independent scientists (such as council scientific and statistical committees) participate—provide analysis, review, advice, and judgment as to the adequacy of stock assessments. In some instances, scientists independent of those entities are called on to provide additional analyses, review, advice, and commentary. A variety of approaches exist for developing and transmitting information, and numerous alternatives have been explored regionally by NMFS and the councils. However, there is still a need to determine who bears responsibility for the information so that objectivity is maintained and the conduit for information remains transparent for the good of both the science and the management process.

NMFS has begun to recognize some aspects of the problem. The agency's creation of the Center for Independent Experts (CIE) has added some objectivity and independence to the peer review of NMFS' stock

assessment work. However, in some parts of the process, peer reviewers participate in completing the stock assessment and thus end up sharing with NMFS scientists the responsibility for creating the final product. A byproduct of that situation is that the participants can lose some of their objectivity in providing review advice. The structure is probably intended to inject broader scientific consensus into the production of the assessment and to shield NMFS stock assessment scientists from the political process. However, the net effect is that no person or group is fully responsible for the final product. That is unfortunate because NMFS stock assessment scientists are fully capable of providing high-quality assessments on their own. It is important to review this work and to allow it to progress without the inappropriate influence of politics, but the current process can reduce the objectivity and transparency of the process. This, in turn, influences confidence in the information and obscures the communication needed to improve the process.

Increasing the pool of qualified people available to work on those problems obviously would help; however, a clarification of roles is needed. Specifically, at the NMFS-council organizational level, a clearer identification of responsibility and authority for providing information, conducting analyses, and making management decisions is required.

The transmission of scientific information can be limited by the nature of the information and the real or perceived motivations of those developing it. Do regional council members see reports by NMFS as information or as advice? Can, or should, NMFS and the various advisory groups warn councils when particular mandates of the MSFCMA are not being met? Can information and advice be differentiated? Part of the answer lies in maintaining a sharp distinction between descriptions of what is and what ought to be. The former is science-based, and the latter is a value judgment about a person's preference among outcomes, although science certainly may be used to explore those outcomes. Moreover, opinions about the value of an outcome should be kept separate from the science used to develop preferences and to explore the outcome. The focus for analysts should be on what is or what will be if particular events occur. That allows analysts to defend their science as the "best available." It also encourages managers to interpret the results objectively and compare them with the statutory and FMP benchmarks or reference points.

The timeliness and availability of information also play important roles. The usual procedure in the NMFS-council decision-making process requires NMFS to provide scientific information in the form of a measure of

current fishing pressure compared with associated benchmarks, referred to as biological reference points, which indicate critical population and fishing mortality thresholds. NMFS often provides trajectories of likely responses of the population and associated harvest under a variety of fishery management scenarios, including a "status quo" scenario. The council then uses that information to make a decision, typically in the form of an FMP, which will guide the fishing pressure to a point that is optimal for the fishery. In this scenario, NMFS provides the science; the council makes the plan; NMFS approves the implements the FMP. The development and analysis of scenarios based on the science are time-consuming and involve a high level of interaction between those developing them and those analyzing them. The decisions that need to be made are difficult, and the availability of information is not always timely.

Even when the necessary information is available, it may not be welcome. A lack of understanding by some council members of the scientific information and advice they are provided may result in an unwillingness to trust it. NMFS and council staff must deal with challenges to the science and the exploration of management scenarios based on the science, but because time is limited, councils may not be able to consider the available information with enough background to ask the right questions. To facilitate the decision-making process, NMFS may try to anticipate the scenarios that should be explored, given the results of their scientific analysis. Shifts in the ability to provide information and advice lead to shifts in authority and responsibility for decision-making and a resulting loss of control. Uncertainty is often identified as a major cause of a lack of reasonable decision-making, but the cause is often the loss of control.

For example, the Gulf of Maine cod stock is heavily fished. Current fishing mortality is estimated at around F = 0.7 per year. That is, roughly 50 percent of the standing stock is harvested directly or caught and killed incidentally in other fisheries each year. There is some dispute about what optimal fishing mortality should be but little doubt that it should be reduced from the present F = 0.7 per year (50% annual mortality). NMFS's assessments indicate that a fishing mortality of about F = 0.2 may be appropriate, but a peer review of this work found that a higher mortality, perhaps F = 0.3, might be more realistic. This mortality is in the range of 20 to 25% annual mortality. Is there too much uncertainty to use that information? The council would prefer to have perfect information because it must make some difficult decisions about reducing the harvest, controlling the bycatch, and even closing the fishery. When the uncertainty is represented

by a range of optimal fishing mortality levels, such as F = 0.2 or F = 0.3, staying with the status quo fishing mortality level of F = 0.7 is unacceptable. In other words, it is imperative to act when target exploitation levels range from 20 to 25 percent and the actual exploitation level is 50 percent. The mere presence of uncertainty does not invalidate scientific advice. Instead, the dimensions and implications of uncertainty should be explored so that they can be incorporated into the decision-making process.

The council could ask NMFS, the council staff, or the council advisory committees to develop some predictive simulations to show what would happen to the stock and to harvesting under alternative management scenarios. What would happen if the directed harvest or incidental catch were reduced by 50 percent? Additional questions could be asked: What are the economic consequences of reducing directed harvest versus reducing incidental catch? What sector of the industry is most likely to be affected? The council has the ability to ask the right questions if it has the correct information. NMFS has the ability to explore the options quantitatively from which it could make solid, informed projections and recommendations. The stalemate results because the information is perceived to be dangerous, and NMFS, not the council, possesses the information. Even though there is uncertainty about the choice of which fishing mortality is optimal, there is no scientific justification for a default decision that allows the current fishing mortality to continue (that is, the uncertainty is between fishing mortality of F = 0.2 and F = 0.3, not F = 0.7).

When the advice is to increase fishing, managers seem quite willing to accept scientific opinion and are capable of implementing action. When the advice is to restrict fishing, managers seem reluctant to accept, or even act on, the best available science. That was seen in December 2001 with the failure of the New England FMC to reach consensus on an adjustment in management measures for Gulf of Maine cod.

The important question seems to be why it is so difficult to restrict fishing even when there is sound evidence that not doing so will have adverse long-term consequences. The answer is complex and revolves largely around the issue of balancing the payoffs of a management decision.[1] Fun-

[1]The terms *costs* and *benefits* will be avoided here because they may be somewhat confusing (for example, negative costs are the same as benefits, and negative benefits are the same as costs) so the term *payoffs* will be used. Also, biological, ecological, economic, and social payoffs, although they exist, are not distinguished here.

damentally, there are important differences between current and future payoffs that strongly influence how decisions are made. Future payoffs are subject to the following factors:

1. Future payoffs are discounted. The following example illustrates the importance of discounting. The table gives the net present value of gaining $1 per year for 5 years and for 20 years at discount rates of 7, 10, and 15 percent.

Net Present Value of $1 per Year

		Time	
		5 years	20 years
Discount rate	7%	4.10	10.59
	10%	3.79	8.51
	15%	3.35	6.26

a) The rate required (Circular A-32) by the Office of Management and Budget for government projects is 7 percent and typically a person would have a higher rate. (Considerations of intergenerational fairness and equity would suggest a discount rate lower than 7 percent.) Even at the low government rate, about 40 percent (4.10/10.59) of the net present value of a 20-year annuity accrues in the first 5 years. At higher rates, about 50 percent of the value accrues in the first 5 years. In broad terms, if a person can maintain an income stream for only 5 years, that is half as good as maintaining the income stream for 20 years. Stated in another way, if one can delay reductions in fishing for 5 years, that is almost as good as delaying them for 20 years. Strictly speaking, this example applies only to monetary values, but similar rationales apply to non-monetary payoffs as well. As economic and social stresses increase, individual discount rates tend to rise, leading to ever-greater emphasis on short-term results.

2. Future payoffs are uncertain, and uncertainty is endemic in fisheries management. There are many unknown factors, such as the current state of the stock, the transition from one management regime to another, and the values of important exogenous variables. Therefore, one can never know exactly how many fish will comprise a specific stock tomorrow. Even given

perfect knowledge of the state of a fish stock today, its status would be uncertain tomorrow. The farther into the future one seeks to forecast, the greater the uncertainty.

3. If allocations can vary over time, individuals or groups may expect future costs to be shifted to someone else. That depends on how politically adept various groups are at influencing the management system, and not everyone can win with this strategy. Nonetheless, because costs can be shifted, even if there is a negative outcome in the future, people may believe that they can avoid the consequences of their decisions in the present.

a) Expectations about the future are formed from experience, and participants frequently underestimate deviations from their experience. If all one has ever experienced is a healthy, productive fishery, one tends not to believe forecasts of calamity. When degradation in a fishery has been extremely slow, the current situation may not look so bad to someone who has participated in a fishery for only 5 or 10 years. Comparing the fishery with where it was 20 or 50 years ago may provide a different perspective, but many current participants have not had that experience.

4. Larger short-term benefits may be desired to match short-term costs (for example, of vessel mortgages and licenses) to maintain adequate cash flows.

Current payoffs are subject to none of the above influences. They are not discounted, they are not uncertain, and they usually affect well-defined groups.

When the scientific advice is to restrict catches today to avoid depleting the resource tomorrow, it is frequently ignored. Any adverse results are in the future, so they have less impact than the very clear adverse results that will accrue today. The arguments for ignoring the future are familiar: adverse results might not happen, adverse results have not happened yet, and if an adverse outcome does happen, maybe someone else will incur the cost. Moreover, everyone evaluates the complex biological, ecological, economic, and social outcome of a fishery in different ways. What may seem a terrible result from one viewpoint may not seem bad from another.

One may seek to bring more science into the decision-making process by doing the following:

1. Carefully specify management goals. Biological, economic, and social goals are important.

2. Quantify goals, and collect data designed to measure progress toward them.

3. Conduct research to increase understanding of the natural system and to determine the influence of management actions on goals. Monitor past management actions, and consider adaptive approaches to future management actions.

4. Recognize that the world is uncertain, that our knowledge is imperfect, and that rectifying mistakes may take a long time. Adopt a cautious approach to fisheries management. A cautious approach should apply to actions that may lead to biological, ecological, social, and economic effects.

5. Deliberately seek management alternatives that minimize the total costs of achieving management goals. Remember that total costs include biological, ecological, economic, and social dimensions, and that the distribution of total costs over time and among stakeholders is important.

Carefully specifying management goals will minimize the disagreement among decision-makers that leads to conflicting emphasis on different aspects of outcomes. Quantifying goals will place the focus on measuring outcomes, providing objective measures to assess decision-makers' performance, and guiding analysts in evaluating alternatives. Monitoring past actions will reduce ignorance about the fisheries system and thereby reduce uncertainty associated with the future. Focusing on total costs of an action encourages both exploring and developing least-cost alternatives and reveals the extent of "cost-shifting" that is contained in some proposals.

6
Legal Challenges Related to NMFS Science: A Sampling of the Litigation

Under the Fishery Conservation and Management Act of 1976 (also known as Magnuson Fishery Conservation and Management Act), lawsuits challenging NMFS decisions focused on the allocation of TACs among competing sectors of the fishery (such as, the recreational and commercial sectors or different components of the commercial fishery).[1] In reviewing these and other cases, Greenberg (1993) concluded that courts appeared unwilling "to delve into the intricacies of fishery management," including whether the best available science is being used properly, and that "even relatively scant evidence may be enough to support management measures on judicial review." In his view, that was unlikely to change without the adoption of a standard requiring management measures to be supported by a "preponderance of the scientific evidence."

Shortly after that prediction was made, the courts began to consider more fishing-industry challenges to the scientific basis of commercial quotas that the industry believed were too low. A flood of litigation engulfed NMFS after passage of the Sustainable Fisheries Act (SFA) amendments to the MFCMA, and the Small Business Regulatory Enforcement Fairness Act (which amended the RFA) in 1996. The latter made compliance with the RFA's economic-impact analytic requirements subject to judicial review.

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[1]See, for example, *American Factory Trawlers Assoc. v. Baldrige,* 831 F.2d 1456 (9th Cir. 1987); *C & W Fish Co., Inc. v. Fox*, 931 F.2d 1556 (D.C. Cir. 1991).

Plaintiffs have used those laws and the requirements of the NEPA and the ESA to open the federal fishery management process to increased judicial scrutiny under a broader set of environmental and social policy goals than was probably anticipated by Congress in 1976. The ESA and the NEPA have also emerged as major legal levers for requiring an ecosystem-based approach to managing the fisheries of the U.S. EEZ.

The committee did not have the time to complete thorough review of NMFS litigation. As a result, the committee decided to examine a sampling of the litigation that provided examples in which the court's judgment was against NMFS and illustrated points of law concerning potential failures in science or in the application of science.

In *Fishermen's Dock Cooperative, Inc. v. Brown*, 867 F.Supp. 385, District Court Judge Robert Doumar invalidated the 1994 commercial fishing quota for summer flounder of 16 million pounds and ordered that it be reset to 19 million pounds. Judge Doumar found that the quota set by the council and approved by the Secretary of Commerce deviated downward from the figure reached by using the "best scientific information available" in that the scientific committee had used an estimate of recruitment that was one standard deviation below the geometric mean rather than the geometric mean itself. According to Judge Doumar, that led to a commercial quota that was too low. On appeal, the U.S. Court of Appeals for the Fourth Circuit reversed his decision, holding that the district court judge had overreached his authority in setting a new quota rather than remanding the decision to NMFS. The appeals court found that the district court had misapplied the "best scientific information available" standard for setting the quotas by giving insufficient weight to the requirement that the quota prevent overfishing and therefore had erred in invalidating the quota set by NMFS.[2]

The litigation surrounding the summer flounder FMP continued, however, as Judge Doumar proved receptive to industry criticism of the process by which NMFS deducted overages in one fishing year from the state's allocation in the next year. Judge Doumar was also the first to remand a quota to NMFS on the grounds of the RFA of 1980.

NMFS did not amend the quota-setting process for summer flounder until late 2001, when it proposed and then adopted a regulatory amend-

[2]*Fishermen's Dock Cooperative, Inc. v. Brown,* 75 F.3d 164, 1996 (4th Cir. 1996).

ment to allow the agency to set the cutoff date at October 31 for landings data that would be used in calculating overage deductions in the following year's specifications. Had the agency taken that action earlier, it might have deprived the industry plaintiffs of a major legal point of their case.

The decision in *Natural Resources Defense Council (NRDC) v. Daley* illustrates the difficult position into which the council process puts NMFS with respect to applying scientific advice to basic fishery management decisions. The court of appeals found that the 1999 summer flounder quota that NMFS set was unreasonable in that it had only an 18 percent chance of meeting the conservation requirements (the target fishing mortality rate) of the MSFCMA. By adopting that quota, NMFS may have opted for a middle ground between the scientific monitoring committee's quota recommendation (representing a 50 percent chance) and the full Mid-Atlantic Council's decision (a 3 percent chance). One may speculate that NMFS decision-makers believed they could not adopt the scientific committee's recommended quota because it would be too low, perhaps reasoning that as long as the final quota was not as high as that recommended by the Mid-Atlantic Council, it was meeting the requirement of MSFCMA to end overfishing. Whatever NMFS's reasoning, the court was critical of the agency, noting that "only in the Superman Comics' Bizarro world, where reality is turned upside down, could the Service reasonably conclude that a measure that is at least four times as likely to fail as to succeed offers a fairly high degree of confidence."

This case suggests that NMFS interpreted the MSFCMA requirements to prevent overfishing leniently because of pressure from the councils and the states and because a valuable fishery was involved, even though very good stock assessment information supported a stricter interpretation (for example, see NRC, 2000a). It illustrates the councils' risk-prone management decisions and NMFS's reluctance to require more stringent measures from the councils to rebuild overfished stocks. Those are two of the most serious and persistent problems that NMFS has had in using fishery scientific information. The councils have the discretion to reject the advice of scientific advisory committees, and NMFS has in many instances been unwilling to require greater fidelity to the scientific advice (J. Eagle and B. H. Thompson, Jr., personal communication).

The above case and criticisms suggest that Congress should give much more explicit guidance on how NMFS and the councils should proceed in the face of uncertain information. The National Standard 2 directive to use the best scientific information available has not provided sufficient

guidance. Instead, it appears to have served as an invitation to challenge the validity of the scientific information used for stock assessments and for decisions on ecosystem aspects of management. The result is a long list of requests for independent peer review of NMFS science.

After the 1996 MSFCMA amendments, the pace and intensity of judicial review of fishery management decisions increased dramatically. A good proportion of these cases reflect the resistance of the fishing industry to reductions in council discretion and the requirements to prevent and end overfishing. The increasing interest of environmental groups in the management and protection of marine fish populations has also resulted in increased litigation. Those groups have used litigation to push NMFS and the councils to adopt a more ecosystem-based approach. Reinvigoration of the MSFCMA's conservation goal by the SFA provided the basis of such intervention.

While advisory panels were preparing reports and recommendations on how to apply ecosystem-based approaches, environmental groups sought to force fishery managers, through litigation, to adopt such approaches now rather than after further study. One of the legal levers they have chosen to use is the NEPA. Failure to follow NEPA has been a central claim in their challenges to NMFS and council decisions since the 1996 amendments to the MSFCMA. Over the years, the councils and NMFS have developed the practice of avoiding the preparation of full environmental impact statements by making a "finding of no significant impact" (FONSI) after a more limited environmental assessment to accompany framework adjustments and amendments to FMPs, even for those implementing the new requirements of the SFA.[3] Environmental group plaintiffs have successfully argued that that approach is inadequate.

The environmental groups' challenge to the councils' EFH amendments adopted after 1996 argued that NMFS has analyzed a limited set of alternatives in its environmental assessments on the EFH amendments. In most cases, one alternative was the status quo (no EFH identification or habitat-protective measures), while the other alternative considered was a broad identification of EFH but no additional habitat-protective measures. The latter was usually the preferred alternative of the councils. In *American Oceans Campaign v. Daley*, the court held that although the five councils' EFH amendments were adequate under the MSFCMA, their NEPA assess-

[3]See 40 C.F.R. §§ 1501.4, 1508.9, 1508.13.

ments were insufficient and violated the mandates and principles underlying NEPA. The EFH amendments included little or no assessment of fishing gear impacts on EFH.[4] The court enjoined the enforcement of the amendments and ordered NMFS "to perform a new and thorough environmental assessment (EA) or environmental impact statement (EIS) with respect to each EFH amendment."[5] In exchange for the plaintiffs' dropping their appeal of the MSFCMA part of the court's ruling, NMFS entered into a court-approved joint stipulation and order. NMFS agreed to prepare full EISs for all the FMPs challenged in the lawsuits, including an analysis of the effects of fishing on EFH, which included both direct and indirect effects; an analysis of the effects of a full range of reasonable alternatives for meeting the act's requirement to "minimize, to the extent practicable, adverse effects on [EFH] caused by fishing"; and a decision on whether action is needed to meet that requirement.[6] In guidance to his regional administrators, the NMFS assistant administrator encouraged them to prepare the EISs "in the context of the best scientific information that is available today" even though the EFH amendments were completed in 1998.[7]

In a case that was a major victory for environmental plaintiffs, *Greenpeace v. NMFS,* Federal District Court Judge Thomas Zilly agreed that the NEPA effectively enlarges the scope of fisheries management to require consideration of the entire marine ecosystem, specifically the North Pacific Ocean, home of the largest single-species U.S. fishery, for Alaskan pollock.[8] NMFS was ordered to prepare a programmatic EIS that considers a full range of potential management regimes and the combined effects of all the fisheries in the Bering Sea-Aleutian Islands ecosystem. Meeting that order will entail consideration of the cumulative impact of successive years of fishing under a particular management regime. It will also require consideration of the impact of alternative management strategies that use the full range of management measures to influence the timing and place of

[4]No. 99-982 slip opinion (D.D.C. 2000).

[5]Id. at 42-43.

[6]*AOC v. Daley*, No. 99-982, Joint Stipulation and Order (Dec. 2001).

[7]Memorandum from W.T. Hogarth, Ph.D., Director, NMFS, to Regional Administrators, Guidance for Developing Environmental Impact Statements for Essential Fish Habitat per the AOC v. Daley Court Order, Jan. 22, 2001.

[8]*Greenpeace v. NMFS*, 55 F.Supp.2d 1248 (W.D. 1999).

fishing, not merely the overall catch levels. Circumstances that warrant the same kind of analyses are likely to be found in several other marine ecosystems: major changes in the sizes of exploited and non-target populations, the presence of an endangered or threatened species, and major changes in the marine ecosystem since the preparation of the last, full EIS on FMP.

7

Findings and Recommendations

Since 1996, NMFS Operations, Research and Facilities (OR&F) funding (the main source of NMFS operational funds) has increased by 125 percent (NAPA, 2002). At the same time, the percentage of funding directed to pass-through or earmarked funds for specific purposes has also increased. Kammer (2000) found that there was a plateau in NMFS's base funding for stock assessments and other science operations, particularly those with a long-term focus. The plateau in base science funding has had serious effects on NMFS's ability to pursue research needed to enable effective management and minimize lawsuits against the agency.

In general, litigation results when stakeholders are dissatisfied with the outcome of the fishery management process. Two major groups are typically interested in fisheries: fishers are interested in the amount of the catch, and others are concerned with the magnitude of the standing stock of fish and the preservation of marine biological diversity and habitat. A fundamental conflict exists between those groups over the allocated catch and the effects of fishing on marine ecosystems. Great pressure is often brought on NMFS and the regional FMCs by harvesters because of excess capacity and other incentives that drive a "race for fish." When scientific knowledge is available in support of restrictions and is properly documented, NMFS usually wins lawsuits. However, a substantial fraction of the litigation that NMFS faces is a consequence of real or perceived deficiencies in data or science. The committee developed recommendations related to:

- Adequacy of scientific information for fisheries management—for stock assessments, related to marine ecosystems and protected species, and for social and economic data and analyses.
- Use of available scientific information and advice to manage marine fish and protected species.
- Adequacy of scientific expertise available to NMFS.
- High-priority areas for augmentation of NMFS science activities.
- Funding.

ADEQUACY OF SCIENTIFIC INFORMATION FOR FISHERIES MANAGEMENT

Finding: Past National Research Council committees found that NMFS stock assessments generally have been done correctly given the data available and have used reasonable assumptions.

Data on fish population characteristics collected by NMFS generally are adequate to guide management of fished species, particularly those of major economic and social importance. NMFS wins most lawsuits brought on grounds of its stock assessments.

Funding available for collection and analysis of fisheries data is small relative to the immensity of the task if all fish stocks need to be analyzed at the same high level. Given the current state of knowledge, conservative single-species management is the most important (and probably most cost-effective) approach for many fisheries (NRC, 1999b). At the same time, NMFS has been urged to develop techniques to move beyond single-species management (NRC, 1994b; 1999b; 2001).

Assessments might be improved for some fisheries through increased expenditures for data collection and analysis, including observer programs, and though greater use of commercial data and data obtained through cooperative and collaborative surveys (NRC, 2000a). For some fisheries, however, the incremental gain in assessment accuracy and precision per incremental expense for data collection and analysis may be a decreasing function because of the general phenomenon of diminishing returns on investments.

Recommendation: NMFS should maintain and advance its tradition of excellence in fisheries science.

Several NRC studies (NRC, 1998a,b; 2000a) have concluded that NMFS's stock assessment techniques are second to none among govern-

ment fishery-management agencies worldwide. However, those studies also recommended some actions that NMFS should take to improve the use of stock assessment models. For example, NMFS's scientists should use several models (depending on the data available) to analyze the same data as a means of understanding the data better and uncovering peculiarities that arise from assumptions implicit in the models rather than from the data themselves. To accomplish that goal, it will be necessary for NMFS stock assessment scientists to be trained more broadly in the use of different models and to be less prone to use models as "black boxes." Other important recommendations from those NRC reports are that NMFS and the regional FMCs should find ways to use fishery-dependent data more effectively and collect and use more social and economic data in the stock-assessment process to evaluate the social and economic impacts of different management strategies.

NMFS cannot afford to assess all fisheries to the same degree. It is appropriate for NMFS to continue to focus its resources on assessing the most economically and ecologically important species. The National Research Council (NRC, 2000a) recommended a comprehensive cost-benefit analysis of fisheries data collection and stock assessments nationally to help set funding priorities. Many stock assessments are conducted only once every few years, and every assessment is reviewed. For many Atlantic Coast fisheries, peer review is a slow process and is the rate-limiting step, forcing the councils to use out-of-date assessments. For some stocks, peer review may only be necessary if a major change in stock status is detected or a major change in the management approach is proposed.

Finding: Fisheries management depends on the availability of a variety of biological, environmental, economic, and social data on a timely basis, and NMFS is involved in a variety of activities to collect and manage such data (NRC, 2000a).

The National Research Council (NRC, 2000a) described the current status of data collection for marine fisheries management in the United States and made recommendations for improving it. It (NRC, 1998a) pointed out the importance for fisheries management of a reliable indicator of the abundance of fish populations over time. For most fisheries, the most reliable indicator is obtained from fishery-independent surveys conducted by NMFS. Surveys are conducted on relatively old, technically obsolete NMFS fishery research vessels. The National Research Council (NRC, 2000a) endorsed the efforts of Congress and NMFS to maintain a

strong fleet of NOAA survey vessels—particularly for trawl and acoustic surveys—by replacing aging vessels with newer, more capable, and quieter ones. Congress should not only fund the construction of new vessels but also provide adequate funding for survey and research work performed by these vessels (NRC, 2000a). NMFS has documented the need for six replacement, special-purpose research vessels. Only one of the approved vessels has received full funding, and a second has received partial funding.

Data from fishery-independent surveys and other sources are stored in a variety of locations and formats with relatively little coordination making access to the data difficult for managers and scientists. At the request of Congress, NMFS submitted a plan to Congress for a Fisheries Information System (FIS) to coordinate fisheries data regionally and nationally, but the FIS has not yet been funded. The National Research Council (NRC, 2000a) states (p. 156):

> The committee agrees with the directive of Congress in requesting a plan for a nationwide Fisheries Information System (FIS). The FIS design (based on coordinated regional systems) is good and its reliance on national standards is a positive feature. The FIS is ambitious; however, for it to be successful (1) Congress must provide adequate funding and (2) cooperation and balance among the regions must be ensured.

Recommendation: Congress should fund continued acquisition and deployment of new vessels and the Fisheries Information System, as recommended in previous NRC reports.

NMFS cannot support either the continued acquisition of state-of-the-art fishery research vessels or implement the proposed FIS without new funding. Both items are essential to increase the likelihood of successful fisheries management.

ADEQUACY OF SCIENCE RELATED TO MARINE ECOSYSTEMS AND PROTECTED SPECIES

Finding: NMFS is responsible for administering a wide array of legislative mandates, requiring broader scientific knowledge than is available from scientific activities traditionally conducted by NMFS.

In the science that it conducts and the weight given to mandates of legislation, NMFS appears to place greater emphasis on the MSFCMA than ESA, MMPA, and NEPA. NMFS appears to conduct its science on the basis of traditional fisheries-oriented priorities and does not always have

scientific knowledge available to meet important legal mandates that arise from the ESA, MMPA, and NEPA.

Many fisheries are in a rebuilding status and are managed to stay as close as possible to (or to exceed) fishing mortality designed to rebuild populations to levels that will produce optimum yield within 10 years. In the last decade, increasing pressure has arisen from the environmental community to improve data on protected species and essential habitats. Yet NMFS still appears to focus most of its activity on protecting fish harvests. NMFS is responsible for implementing several major laws that are perceived to conflict with objectives and provisions without clear guidance on how to maintain balance, such as among the MSFCMA, ESA, MMPA, and NEPA. Therefore, preservation of biodiversity, maintenance of marine food webs, and protection of habitat are important goals that must also be included in fisheries management. Moving toward an ecosystem orientation will place new demands on fishery managers. With improved understanding of how various fish stocks interact as parts of marine ecosystems, there is increasing recognition that landings are not adequate measures of the health of ocean resources.

NMFS has the capabilities and facilities through its science centers and its relationships with academic scientists to obtain observations and conduct the experiments necessary to improve our biological understanding of fish populations and marine ecosystems sufficiently to improve the management of fisheries and such protected resources as marine mammals, marine turtles, and seabirds. However, much of NMFS's scientific capacity in recent years has been devoted to collecting and analyzing data for stock assessments, conducting other work directly related to short-term needs to fulfill regulatory requirements of the MSFCMA, and responding to litigation. That leaves less in financial, facility, and human resources to conduct the fundamental research that is necessary for NMFS to fulfill its current and long-term resource management mission in relation to the MSFCMA and other laws. The situation has persisted and worsened as NMFS's core budget has plateaued and pressures to defend stock assessments against councils and courts have increased. Ecosystem and biological research will be increasingly important in the context of changing environmental conditions, including climate change. Data and research necessary to fulfill mandates of the ESA, MMPA, and NEPA are particularly lacking in relation to EFH requirements and availability, predator-prey relationships, and health and reproductive status of the organisms sampled.

Recommendation: NMFS must balance its traditional emphasis on sustainable exploitation with its duty to protect vulnerable species and habitats harmed by fishing.

A new focus will require enhanced research on bycatch, fish habitats, marine ecosystems, and the biology and ecology of threatened and endangered species. NMFS should address the gaps in scientific understanding and legal vulnerabilities in setting priorities for future research.

New types of information will need to be collected by NMFS and obtained from other agencies to ensure management that accounts for a target species' place in marine food webs, the effects of fishing on marine ecosystems, and the effects of changing environmental conditions on fish populations. It is important that NMFS staff employed in protected resources, habitat, and sustainable resources communicate effectively to plan, coordinate, and conduct needed research. Ecosystem research will have substantial costs and should be considered in NMFS funding priorities without diminishing support for routine stock assessments and biological research. NMFS managers should consult with the NOAA General Counsel to identify the research whose lack of funding and conduct would create the agency's greatest potential legal vulnerability (see Kammer, 2000). A strategy to address such vulnerability is needed.

ADEQUACY OF SOCIAL AND ECONOMIC DATA AND ANALYSES

Finding: Social and economic data collected by NMFS are inadequate for understanding the effects of past management on fisheries and fishing communities and for predicting outcomes of management alternatives. Fishery management plans often do not include adequate social and economic goals.

In addition to collection and analysis of biological data, fisheries management requires economic and sociological-anthropological analysis of how participants respond and adhere to management regulations and how the regulations affect their livelihoods and general well being. Lack of social and economic data hinders the development and implementation of acceptable and effective management measures. The lack of data results from a variety of factors (such as inadequate funding, restrictions imposed by the MSFCMA, and concerns of fishers about the confidentiality of social and economic data that they provide) that are largely beyond NMFS's

control. The National Research Council (NRC, 2000a) listed a variety of social and economic data that should be collected and made recommendations to Congress for changes in the MSFCMA to make economic data more easily available to managers and social scientists.

Economic and social goals of FMPs are not expressed clearly and quantitatively. Consequently, important economic and social values are not documented or measured continually, and it is impossible to measure progress toward goals, anticipate the effects of alternative management measures on social and economic values, and calculate the total costs of alternative management measures. Without critical baseline data, such as would be obtained through standard and regular collection of data to track economic and social changes, it is difficult to examine the effects of fishery-management decisions on commercial fishers, recreational anglers, and their associated communities. Because critical social and economic data are not routinely collected and analyzed, it is difficult to determine whether population fluctuations measured by landings, for example, result from changes in the magnitude of the stock or from changes in associated economic or social factors.

Without adequate social and economic data and analysis, it is often impossible to determine the total cost of management alternatives. Therefore, it is difficult to discuss rationally how total costs might be minimized and the distributional effects alleviated as public preferences for the use of fishery resources change. Sufficient information must be available to design programs that will reduce fishing capacity and restore economic viability to the harvest sector and keep total harvests within the bounds required to rebuild stocks within a reasonable period. Usually, managers choose among alternatives on the basis of biological concerns without objectively considering economic and social implications. The MSFCMA requires calculations of stock sizes relative to their unexploited states and relative to measurable definitions of overfishing, but it does not include similar requirements for economic and social values.

It is clear that excess harvesting capacity is one of the major problems in U.S. fisheries, as well as fisheries worldwide, and that not enough attention is being devoted to collecting data and conducting analyses to quantify overcapacity in each fishery. Such information is fundamental for preparing plans to reduce overcapacity, which is an important step in reducing the tendency for risk-prone management decisions and for reducing bycatch and overfishing.

Recommendation: The importance of social and economic data and analysis to marine fisheries management should be recognized in the reauthorization of the MSFCMA, resulting federal regulations, fishery management plans, NMFS funding requests, and Congressional appropriations.

Many NRC reports have recommended increased collection of social and economic data (for example, NRC, 2000a); it is well past time to give economic and social data equal consideration with biological data in the development of FMPs. With respect to adequacy of social and economic data, plans need to be made for the regular collection, storage, and retrieval of this type of data in a manner that is analogous to data for stock assessments. NMFS needs to develop a comprehensive plan to determine social-science data needs and to implement the data-collection process. The MSFCMA should be amended to require such data collection, given that fishers are exploiting a public-trust resource, while appropriate protection of data confidentiality is maintained. The availability of such data will help managers to choose from among different possible management scenarios, balancing biological, social, and economic factors.

As NMFS assimilates its new social scientists, their first tasks should be to quantify overcapacity, where it exists, in all fisheries managed under FMPs and to develop plans to reduce it that take into account social and economic factors in individual fisheries. Plans for reducing overcapacity should consider all the fish stocks in a fishery region, inasmuch as reductions in overcapacity in some fisheries will spill over into other fisheries (primarily in the same region) as fishers shift target species. Congress should encourage such analyses, because solving the overcapacity problem could make fisheries management easier and less expensive. Other tasks with very high priority are to develop regional and national consensus on the standards to be used in addressing the social impact assessment and National Standard 8 requirements and to establish regional or national systems for the standardization and collection of social, demographic, and other data on the socioeconomic, cultural, and community aspects of marine fisheries.

USE OF AVAILABLE SCIENTIFIC INFORMATION AND ADVICE FOR MANAGEMENT OF MARINE FISHERIES AND PROTECTED RESOURCES

Overfishing can result from a lack of sufficient scientific information or from a fisheries management process that ignores available scientific advice or has insufficient resources to enforce management regulations. In the former case, prevention of overfishing depends on better data collection and analysis (discussed previously). In the latter case, prevention of overfishing depends on changed procedures for using science in the management process and for allocating resources to enforcement.

Finding: The use of science in the marine fisheries management decision-making process is impeded by the governance system created by the MSFCMA and the resulting mismatch between institutional authorities and responsibilities.

The use of science in fisheries management is a multistage process. NMFS generates stock assessments and other information about managed fisheries, habitats, and protected species. The information is provided to the regional FMCs (usually to their science and statistical committees) to develop FMPs.

Regional FMCs sometimes disregard the scientific advice provided by NMFS and their science and statistical committees in setting total allowable catches (TACs) and in deciding other aspects of FMPs. NMFS has the legal right to approve, disapprove, or partially approve FMPs; but when councils have disregarded the scientific findings of NMFS and the advice of their science and statistical committees, NMFS has sometimes sought compromises with the councils rather than upholding their original findings. The entire process is subject to intense political pressure, directly from stakeholders and indirectly through their representatives in Congress.

Many issues arise in how science is used to manage marine fisheries in the United States. The committee discussed examples in which NMFS stock assessment scientists or the science and statistical committees made clear recommendations about target fishing mortality and harvest levels and the councils ignored the recommendations in developing their FMPs (correspondence of Coleman, 1997, and Pikitch, 1999). NMFS does not always defend its own science after council decisions. NMFS and the Secretary of Commerce bear the legal responsibility for the content of FMPs, although in practice much of the responsibility for the content rests with the councils.

Recommendation: Congress should initiate a review of the fisheries governance system and the use of science in governance.

Crucial breakpoints in the production and use of science in the fishery management process are discussed below:

From NMFS to the Scientific and Statistical Committees (SSCs) and the Regional FMCs

NMFS scientists and the science and statistical committees (SSCs) of regional FMCs focus on data collection and analysis needed to meet the requirements of the MSFCMA and to some extent the ESA, MMPA, and NEPA. SSCs are usually composed of scientists in academe and in NMFS. They are responsible for recommending FMP options to the full councils. Some councils rely more on plan development teams (PDTs) than on their SSCs. PDTs are smaller but with similar compositions.

Council members need to understand the manageable uncertainties and that uncertainty can be quantified, accounted for in stock assessment predictions, and used to make better decisions. Councils should explore different techniques to present relative uncertainties and effects on decisions (such as decision tables; see NRC, 1998a). It is not necessary for council members to understand the details of stock assessment methods to use the results, but they should be helped to assess the relative merits of criticisms of stock assessments that may arise during the decision-making process, for example, by strong representation of the SSCs in FMC meetings.

From the FMCs to the Secretary of Commerce

It is important for science to be insulated from political influence at the level of the Secretary of Commerce and the NMFS staff to whom the Secretary defers in decisions on FMPs. A disconnect can occur between NMFS scientists (who advise the regional FMCs) and NMFS managers when the latter act on behalf of the Secretary of Commerce and compromise with council recommendations that are in violation of laws (for example, recommendation by NMFS and approval by the Secretary of Commerce of a quota with only an 18 percent chance of achieving target fishing mortality rates in the summer flounder fishery). The Secretary of Commerce should be more consistent in rejecting plans that clearly ignore cur-

rent laws and regulations. NMFS should design and use objective decision-making processes with maximal defensibility, for example, the Organized Decision Process that has been proposed for making determinations with respect to purse-seining and its potential for adverse stress-related effects on dolphin populations of the Eastern Tropical Pacific Ocean. The court decision described in *Brower v. Evans* criticized the agency for not following the structured process in reaching its interim findings on that question. The agency should make further use of decision methods that insulate scientific determinations from political pressure or considerations.

Finding: A better structure to conduct science in NMFS would improve outsiders' perceptions of NMFS scientists and science. A structure that allowed scientists to operate objectively and independently of the management body (but was responsive to requests for scientific investigations) could improve both the image and the performance of NMFS.

Some of the challenges and dissatisfaction with the fishery management process are related to science results that are judged to be questionable, insufficient, or wrong. The committee agreed that a different structure in the agency—one that better insulates the science from the management decision process—could improve the ability of NMFS to conduct science and enhance the quality of science available for fisheries management. The committee also believes that NMFS science needs to be open and transparent to their constituents, but at the same time, NMFS scientists need to be able to provide their best scientific work in an environment insulated from political influence that can occur in the management-decision process.

One way to depict the management process is with the fundamental input of science occurring at the first stage of the evaluation process, in a venue where NMFS scientists present their assessments to stock assessment review committees and the science and statistics committees. But by that point most of the work on the science advice is completed, and little opportunity remains to conduct new analysis during the decision-making process. Hence, the development of new ways to approach analysis must happen at or before the initial stages of the evaluation process.

The problem can be partly solved by improving conditions for undertaking scientific research in the agency. NMFS scientists can benefit from a workplace in which they can conduct the following:

• *Responsive science*. Scientists must be responsive to the issues and problems of resource management. To do so, they need the financial and staffing resources to respond. Ideally, scientists should be free of the political pressures of management-related issues, recognizing that they must produce timely results that respond to management needs.

• *Innovative science*. There is a need for innovative science to improve stock assessments and to reduce the personnel needs, costs, and uncertainties associated with stock assessments and modeling but also a need to address the new and complex concerns of ecosystem science.

• *Integrative science.* New demands for ecosystem science require broadly interdisciplinary approaches to solve problems that span climate, oceanography, individual species' biology, systems ecology, and fish-stock dynamics. Effective teams will be required to conduct such research in support of management. Furthermore, NMFS, other NOAA line offices, and other agencies will need to work collaboratively to solve the broad ecosystem problems faced by marine fisheries management.

• *Visionary science*. Science that anticipates management issues is needed. Being more than responsive to current issues will require an infusion of staff and funds into NMFS to conduct research at the cutting edge of theory, modeling, and anticipation of problems that either fishing or environmental variability will contribute to fisheries and fisheries management. Some would argue that other institutions—possibly academic institutions—should accept the responsibility for those aspects of research and science; however, the health of NMFS science, the morale of the agency's scientists, and the quality of advice to managers could improve if this element were instituted in NMFS.

Recommendation: NMFS should create an atmosphere that encourages innovation and rewards excellence, as recommended in previous National Research Council reports.

NMFS has already developed institutions, such as the NOAA-university cooperative institutes and the Northeast Fisheries Science Center's Cooperative Marine Education and Research Program that foster partnerships with universities. The partnerships provide environments to develop innovative science by combining efforts of agency and academic scientists. However, only a small number of scientists are participating in these groups, and the committee recognized the importance of exposing more NMFS scientists to such an environment. However, with the increasing demands on scientists to produce analyses based on the requirements of the 1996

MSFCMA amendments, a business-as-usual approach to conducting scientific analyses is increasingly problematic, as demonstrated by increased litigation. Development of cross-disciplinary teams of scientists within and across regions would seem to be one cost-effective way to follow the recommendation, but other approaches, such as the development of an NMFS national think tank, might also be appropriate.

Finding: NMFS is required by the MMPA and ESA to develop conservation or recovery plans for protected, threatened, or endangered species, such as marine mammals and sea turtles, listed under the ESA. Those plans often identify research needs related to understanding the biology and population dynamics of the target species and the causes of their decline that might be mitigated through regulation of human activities that affect them or their habitats.

Some recent lawsuits under the ESA and NEPA have resulted in injunctions against fishing activities and caused considerable economic disruption in relation to potential impacts of the Bering Sea and Aleutian Islands fisheries on Steller sea lions; the Hawaii-based, pelagic longline fleet effects on sea turtles; and the effects of the lobster fishery around the Northwest Hawaiian Islands on Hawaiian monk seals (*Greenpeace v. NMFS*, *Leatherback Sea Turtle v. NMFS*, and *Greenpeace Foundation v. Mineta*, respectively). In each of these cases, the species of concern were the subject of recovery plans prepared by teams of scientists familiar with the species and their habitat requirements. Each team recommended a suite of investigations that could help to determine the causes of the species' decline and the interaction with the fishery, but the research was not ranked high in budget requests and therefore was not conducted in a timeframe that made information available to the agency for use in EISs and biological opinions. Consequently, the agency was often left with limited information on which to make jeopardy determinations. A similar problem is occurring with respect to stock identity questions about the marine mammals that are the subject of take reduction planning efforts under the MMPA.

Recommendation: NMFS should develop and implement a plan for rapid response to research needs identified in recovery and conservation plans.

The NMFS research system should be able to initiate research outside the normal multi-year budget planning and appropriation cycle because delays of several years in research and application of results to management

can severely reduce the chance of averting a species' extinction. Consideration should be given to expanding recovery and conservation plans to include recovery of other threatened or endangered marine species.

Finding: NMFS receives independent scientific input from a variety of sources, including the National Research Council (see references for list of reports with advice to NMFS), academic scientists, the Marine Mammal Commission, independent groups commissioned by NMFS, and recovery teams set up pursuant to the ESA and MMPA.

National Research Council Reports

The committee reviewed the findings and recommendations of past National Research Council fisheries reports and received written updates from NMFS related to how it has responded to the reports' recommendations. It is obvious that NMFS has adopted many recommendations of previous National Research Council committees when it has been able to do so without extra funding or changes in the MSFCMA. However, NRC recommendations to NMFS require cooperation with Congress, FMCs, and others in making policy and securing funding, and NMFS has been less successful in implementing such recommendations. NMFS has attempted to create special initiatives in response to NRC recommendations [for example, the *Marine Fisheries Stock Assessment Improvement Plan* (NMFS, 2001b) in response to NRC, 1998 a,b], but such initiatives have generally not been funded.

Center for Independent Experts

Traditionally, most stock assessments and much of the science on which NMFS bases its regulations and recommendations to the councils were reviewed almost entirely in NMFS. That practice led to a distrust of NMFS science on the part of some constituents and increasing use of the courts to challenge NMFS scientific findings. It also led to requests for external peer review by such organizations as the NRC. NMFS responded to the trend by creating the Center for Independent Experts (CIE) in the late 1990s to provide relatively quick and inexpensive peer review of potentially controversial stock assessment results. That mechanism seems like a promising approach, although it is still fairly new.

Other Scientific Input from Academic Scientists

Academic scientists participate in advising NMFS in various ways. Traditionally, they participate in formal review of stock assessments by serving on stock assessment review committees, taking part in stock assessment workshops, and reviewing papers written by NMFS scientists for publication. Other venues have also been used, such as the NMFS Ecosystem Panel, which was composed primarily of scientists from outside NMFS and provided many recommendations in relation to the principles and procedures for incorporating a greater consideration of ecosystems into fisheries management under the MSFCMA.

Marine Mammal Commission and Recovery Teams

Both the Marine Mammal Commission and the recovery teams formed pursuant to the ESA and MMPA identify scientific uncertainties and subjects of research that should be pursued to reduce the uncertainties. Recommendations from those groups could provide useful input for NMFS science planning.

Recommendation: NMFS should continue to seek advice and review from independent sources.

Independent scientific advice and peer review has strengthened NMFS science and the committee endorses the continued use of such review and advice in fisheries management. The use of advice could be improved through more systematic processes for requesting advice and review and for implementing recommendations.

Finding: Fishery management plans do not always include enough measurable quantitative goals and specific data collection and analysis to monitor the achievement of goals.

Most FMPs include some quantitative goals, particularly in relation to fishing mortality and harvest levels, but fisheries management would be more effective if additional quantitative goals were included in FMPs and data were collected to monitor and evaluate the goals with a formal analysis that focused on specific plans. There has been little analysis of which fishery management measures are effective or ineffective, either for specific fisheries or nationwide. Until management measures are evaluated and

compared continually, there is no way to identify which fishery management measures are most effective.

Recommendation: NMFS and the councils should develop quantifiable management goals and collect data to measure progress toward these goals.

NMFS should conduct continuing analysis of the effectiveness of fishery management measures used in the United States and elsewhere. For example, *Sharing the Fish* (NRC, 1999a) recommended that "existing and future IFQ [individualized fishing quota] programs should provide an annual report describing trends in the fishery and the effects of the IFQ program on important management variables." The results of such analyses should be provided to regional FMCs on a regular basis and should be used to create new criteria to determine the acceptability of FMPs. An important aspect of setting quantitative goals in FMPs is that they be flexible enough to accommodate new scientific information as it is developed.

ADEQUACY OF SCIENTIFIC EXPERTISE AVAILABLE TO NMFS

Finding: The scientific expertise available to NMFS is focused largely on stock assessment science and fish biology, with increasing demands in ecosystem science, biology of protected species, and social sciences.

Most NMFS science activities are conducted internally. The academic community of marine fishery scientists is relatively small, and NMFS has substantial capabilities in its regional fishery-science centers with respect to fisheries biology and population dynamics. The present expertise of NMFS staff is adequate for the agency to continue its previous emphasis on stock assessment of single species. However, it is less well suited for the data and research needs of more ecosystem-oriented management to meet relatively new requirements imposed in the 1996 MSFCMA amendments and through new understanding of the requirements of the ESA and MMPA gained through litigation. NMFS is not well prepared to respond to new expectations and mandates regarding habitats, non-targeted species, endangered species, or the new demands of non-exploitative users of marine resources because budgets have not been favorable to expand expertise adequately in these areas. Plans have been developed to hire and deploy social scientists among NMFS headquarters, regions, science centers, and regional FMCs, but they have not yet been fully funded and implemented. NMFS

also faces substantial loss of skilled staff through retirements in the coming decade and is experiencing difficulties in attracting staff with quantitative skills (NRC, 2000b).

Recommendation: NMFS must build a scientific workforce to meet the future needs of the agency.

Because NMFS scientists often do not have the time to conduct fundamental research related to NMFS's mission, it is important in the short term for the agency to maintain strong linkages with academic scientists through joint projects and extramural funding. Many innovative ideas and techniques are developed in the academic community that can support the NMFS science mission. NMFS has developed joint and cooperative institutes and has located its regional fishery science centers near major ocean-science institutions. Such strategies have resulted in good cooperation between NMFS scientists and academic scientists.

NMFS has also begun to address the looming shortfall of stock assessment scientists and resource economists through implementation of a fellowship program for graduate students in the United States. But the program is too small to recruit a sufficient number of new quantitative scientists to replace the projected retirement of 500 fisheries scientists in the next 10 years (NRC, 2000b).

NMFS needs to increase efforts to attract new staff, particularly people with quantitative, economic, and social-science skills, while retaining its current staff. Those goals will require building on the historical excellence of NMFS science and improving morale in the agency through increases in both monetary and non-monetary incentives (see p. 16, NRC 2000b).

PRIORITIES FOR AUGMENTATION OF NMFS SCIENCE ACTIVITIES

Finding: NMFS science tends to be strongest in basic fish biology and population dynamics. NMFS has important but relatively small research efforts related to integrated bioeconomic analysis, climate effects on fish populations, how fish live in the context of ecosystems, and habitat-fisheries interactions.

Kammer (2000) noted that a high percentage of the NMFS science budget is earmarked for specific tasks. Although some of the tasks may have been conducted anyway in the absence of earmarks, they may have been funded at lower levels; and the overall effect has been to reduce the

base funding available for adjusting to new scientific priorities. Science priorities set by Congress through earmarking are unlikely to balance evenly among actual NMFS science needs that are based on its legal mandates and research planning.

Recommendation: Five areas of science, identified in previous NRC reports, should receive increased emphasis.

Listed below are the five areas of science identified as inadequate which may have been responsible for some of the increased litigation in the past few years. It may be necessary to redirect budgets or augment them to bolster these activities.

- Development of research plans and analysis techniques relevant to MMPA and ESA issues to yield information necessary for FMPs that protect endangered and protected species and to decrease the number of lawsuits filed against NMFS.
- Collection and analysis of spatial data and development of spatial stock assessment models so that required information will be available for spatial management techniques, such as the designation of marine protected areas (see NRC, 2001), and incorporation of knowledge of EFH in spatial stock assessment models. With the advent EFH definitions and the desire by most councils to use various forms of spatial management, new emphasis must be placed on collecting and analyzing fisheries data in a spatial context. Much remains to be done to obtain good spatial data. One promising approach that is being adopted widely in the United States is the vessel monitoring system (VMS), which can help to link catch locations to catch amounts in vessel logbooks. Traditionally, fisheries scientists have largely developed models that include temporal but not spatial features, although spatial stock assessment models are being developed.
- As more emphasis is placed on multispecies interactions and ecosystem effects, there should be continued development of new models that include multispecies interactions and trophic structure, as well as the effects of environmental variability on fish populations.
- Development of ways to link social and economic data with biological data in modeling and other analyses. Such models should help to make fishery-dependent data more useful in stock assessments by revealing how non-biological factors affect catch per unit effort and other variables important in stock assessments. Such models are necessary for predicting

economic and social effects of potential management scenarios and how different stakeholders may be affected.

- Development of an understanding of how the size, distribution, and time patterns of market and non-market values vary with different management scenarios.

FUNDING

Finding: NMFS faces the daunting task of maintaining its traditional stock assessment activities in the face of pressures to harvest the maximal sustainable yield for most fisheries, meeting the new requirements added by the 1996 MSFCMA amendments, and meeting the requirements of the ESA and MMPA for which NMFS does not have a strong workforce or focused data collection activities.

Kammer (2000) found that NMFS's base budget has been relatively stagnant because the budget increases have been largely offset by earmarks that may not match NMFS science priorities. The effect of earmarking on NMFS science priorities should be investigated. For example, it is important to determine the percentages of science funding that NMFS would devote to specific scientific issues compared with the percentages that result from earmarks. That could be done by comparing presidential budget requests with congressional appropriations.

Recommendation: Congress should examine the cost of collection, analysis, and management of data required by NMFS to fulfill its current mandates.

NMFS faces a dilemma. Regional FMCs tend to develop FMPs that require accurate and precise estimates of fish stock sizes and of the effects of alternative management options to prevent management failure. Many FMPs do not provide for a buffer to allow for uncertainties. As far as the committee is aware, there has been no analysis of the costs of such data collection and management. For example, the cost of full observer coverage in fisheries in which bycatch rates are unknown should be determined. Likewise, the cost of full VMS coverage should be determined.

The committee was unable to evaluate the question of whether NMFS has enough funding to fulfill its legal mandates but has identified some activities that merit increased funding, either through increased appropriations from Congress or through reprogramming of existing funds.

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Appendixes

APPENDIX

A

Committee and Staff Biographies

COMMITTEE MEMBERS

Cynthia M. Jones, a Professor at Old Dominion University, earned a Ph.D. in oceanography from University of Rhode Island in 1984. She has served on numerous fisheries advisory boards and is past-present of the Early Life History Section of the American Fisheries Society. She was selected for membership on this committee because of her experience as a member on the following NRC committees: Committee on Fish Stock Assessment Methods, Committee to Review Northeast Fishery Stock Assessments, and the Committee on Improving the Collection and Use of Fisheries Data. She was also selected for her expertise in fisheries, recreational fish data collection, and population ecology.

Lee Anderson, a Professor and Director of Marine Policy at the College of Marine Studies at the University of Delaware, earned a Ph.D. in economics from the University of Washington in 1970. He was selected for membership on this committee because of his experience as a member on the NRC committee, Committee on the Bering Sea Ecosystem and his review of other NRC studies. He was also selected for his expertise in fisheries economics and the economics of fisheries management.

Edward Houde, is currently a Professor in the University of Maryland's Center for Environmental Science. He served previously as Director of

NSF's Biological Oceanography Program, is a Fellow of the American Association for the Advancement of Science, and is the recipient of the Beverton (Fisheries Society of the British Isles) and Sette (American Fisheries Society) Awards for career achievement. He has served on the Ocean Studies Board and numerous advisory committees, including the ICES Living Resources Committee and the NMFS Ecosystem Principles Advisory Panel. Dr. Houde earned his Ph.D. in fishery science from Cornell University in 1968. Dr. Houde was selected for membership on this committee because of his service on the NRC Committee on Ecosystem Management for Sustainable Marine Fisheries and Committee on the Evaluation, Design, and Monitoring of Marine Reserves and Protected Areas in the United States. He was also selected for his expertise in fisheries science and management, fisheries oceanography, and aquatic resources management.

Bonnie McCay is a Board of Governors Distinguished Service Professor at Rutgers University and a member of the Department of Human Ecology at Cook College. She earned her Ph.D. in anthropology from Columbia University in 1976. She is currently a member of the Ocean Studies Board and is a past-president of the International Association for the Study of Common Property, a fellow of the American Association for the Advancement of Science, and president of the Anthropology and Environment Section of the American Anthropological Association. Dr. McCay was selected for membership on this committee because of her service on the following NRC committees: Committee on Ecosystem Management for Sustainable Marine Fisheries, the Committee to Review Individual Fishing Quotas, and the Committee on Protection and Management of Pacific Northwest Anadromous Salmonids. She was also selected for her research and expertise in social, cultural, and economic dimensions of managing fisheries; and on the intersections of science, lay knowledge and participation, and environmental policy.

Alison Rieser is professor of law at the University of Maine School of Law. Dr. Rieser earned an LL.M. from Yale Law School in 1990.She was selected for membership on this committee because of her service as a member of the following NRC committees: Committee to Review Individual Fishing Quotas and the Committee on Marine Area Governance and Management. Dr. Rieser was also selected for her research and expertise in natural resources law, fisheries law, property and coastal land use law, marine policy, and law of the sea.

Patrick Sullivan is currently an assistant professor in the Department of Natural Resources at Cornell University. Prior to that, he served for ten years as a staff scientist for the International Pacific Halibut Commission. He earned a Ph.D. in biostatistics from the University of Washington in 1988. Dr. Sullivan was selected for membership on this committee because of his service on the NRC Committee on Improving the Collection and Use of Fisheries Data and his expertise in the assessment and management of fisheries resources.

Edward R. Urban, Jr. is currently the executive director of the Scientific Committee on Oceanic Research (SCOR). He received his B.A. from the University of California, Los Angeles in 1979 and his M.S., M.B.A. and Ph.D. from the University of Delaware in 1982, 1986, 1989, respectively. Dr. Urban was selected for membership on this committee because of his expertise in fisheries science and policy and his experience as study director for the following NRC committees: Committee on Improving the Collection and Use of Fisheries Data,, Committee to Review Individual Fishing Quotas,and the Committee on Fish Stock Assessment Methods.

Richard D. Young participates in the Pacific Coast groundfish, crab, and shrimp fisheries as the owner and operator of the fishing vessel City of Eureka and the owner of the Willola, both based in Crescent City, California. Dr. Young earned a Ph.D. in economics from the University of California, Santa Barbara in 1979. He has participated in a variety of research and management activities related to fisheries and is a former member of the Scientific and Statistical Committee of the Pacific Fishery Management Council. Dr. Young was selected for membership on this committee because of his service on the NRC Committee on Improving the Collection and Use of Fisheries Data and his experience as a commercial fisherman.

NATIONAL RESEARCH COUNCIL STAFF

Terry Schaefer (Study Director) holds a Ph.D. in Oceanography and Coastal Sciences from Louisiana State University and a Masters degree in Biology/Coastal Zone Studies from the University of West Florida. Previously, Dr. Schaefer worked for the U.S. Environmental Protection Agency, National Oceanic & Atmospheric Administration, National Park Service, U.S. Army Corps of Engineers, U.S. Fish & Wildlife Service, and the U.S. Forest Service. His expertise is in recruitment processes of marine inverte-

brates, coastal zone management, marine policy, and experimental statistics. Terry has worked on studies involving living marine resources, fisheries issues, and coastal mapping.

Darla Koenig (Senior Project Assistant) received her B.A. in English and her M.Hum. in Humanities from the University of Dallas in 1992 and 1997, respectively. During her tenure with the Ocean Studies Board, she has worked on studies involving living marine resources, fisheries issues, and marine chemistry.

APPENDIX

B

Acronyms

CIE	Center for Independent Experts
EA	Environmental Assessment
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
ESA	Endangered Species Act
FEP	Fishery Ecosystem Plan
FIS	Fisheries Information System
FMP	Fishery Management Plan
FONSI	Finding of no significant impact
GIS	Geographic Information Systems
GMT	Groundfish Management Team
MFCMA	Magnuson Fishery Conservation and Management Act
MMPA	Marine Mammal Protection Act
MPA	Marine Protected Area
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
NAPA	National Academy of Public Administration

NAS	National Academy of Sciences
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NRDC	National Resources Defense Council
PDT	Plan Development Team
PFMC	Pacific Fishery Management Council
RFA	Regulatory Flexibility Act
SFA	Sustainable Fisheries Act
SSC	Scientific and Statistical Committee
TAC	Total Allowable Catch
VMS	Vessel Monitoring System

APPENDIX

C

National Standards in the Magnuson-Stevens Fishery Conservation and Management Act[1]

(a) IN GENERAL—Any fishery management plan prepared, and any regulation promulgated to implement any such plan, pursuant to this title shall be consistent with the following national standards for fishery conservation and management:

(1) Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry.

(2) Conservation and management measures shall be based on the best scientific information available.

(3) To the extent practicable, an individual stock of fish shall be managed as a unit throughout its range, and interrelated stocks of fish shall be managed as a unit or in close coordination.

(4) Conservation and management measures shall not discriminate between residents of different States. If it becomes necessary to allocate or assign fishing privileges among various United States fishermen, such allocation

[1]16 U.S.C. 1851, Sec. 201.

shall be (A) fair and equitable to all such fishermen; (B) reasonably calculated to promote conservation; and (C) carried out in such manner that no particular individual, corporation, or other entity acquires an excessive share of such privileges.

(5) Conservation and management measures shall, where practicable, consider efficiency in the utilization of fishery resources; except that no such measure shall have economic allocation as its sole purpose.

(6) Conservation and management measures shall take into account and allow for variations among, and contingencies in, fisheries, fishery resources, and catches.

(7) Conservation and management measures shall, where practicable, minimize cost and avoid unnecessary duplication.

(8) Conservation and management measures shall, consistent with the conservation requirements of this Act (including the prevention of overfishing and rebuilding of overfished stocks), take into account the importance of fishery resources to fishing communities in order to (A) provide for the sustained participation of such communities, and (B) to the extent practicable, minimize adverse economic impacts in such communities. [Added in 1996]

(9) Conservation and management measures shall, to the extent practicable, (A) minimize bycatch and (B) to the extent bycatch cannot be avoided, minimize the mortality of such bycatch. [Added in 1996]

(10) Conservation and management measures shall, to the extent practicable, promote the safety of human life at sea. [Added in 1996]

APPENDIX

D

Statement of Task

This study will provide a summary review of the adequacy of the data, scientific foundation, models, and processes used by NMFS to guide resource management, meet regulatory requirements, and provide support in response to litigation. In preparing its assessment, the committee will rely largely on previous NRC reports that examined NMFS's stock assessment models, data collection methods, and other aspects of the NMFS science program, and assess the actions taken by NMFS in response to these reports.