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NMFS Strategic Plan

NMFS STRATEGIC PLAN FOR FISHERIES RESEARCH

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NMFS Strategic Plan for Fisheries Research

August 2007

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

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CONTENTS

PREFACE 3

INTRODUCTION 7

LEGISLATIVE BACKGROUND 9
COMPREHENSIVE FISHERY RESEARCH PROGRAM 11
The Science Enterprise 11
Research Components 13

MAJOR FISHERY RESEARCH GOALS AND OBJECTIVES 39

NMFS FISHERIES SCIENCE CENTERS 45

Alaska Fisheries Science Center (AFSC) 46
I. Research to Support Fishery Conservation and Management 48
II. Conservation Engineering Research 57
III. Research on the Fisheries 58
IV. Information Management Research 61

Northwest Fisheries Science Center (NWFSC) 65
I. Research to Support Fishery Conservation and Management 67
II. Conservation Engineering Research 78
III. Research on the Fisheries 80
IV. Information Management Research 84

Southwest Fisheries Science Center (SWFSC) 85
I. Research to Support Fishery Conservation and Management 88
II. Conservation Engineering Research 91
III. Research On The Fisheries 92
IV. Information Management Research 94

Southeast Fisheries Science Center (SEFSC) 96
I. Research to Support Fishery Conservation and Management 100
II. Conservation Engineering Research 104
III. Research on the Fisheries 105
IV. Information Management Research 106

Northeast Fisheries Science Center (NEFSC) 108
I. Research to Support Fishery Conservation and Management 110
II. Conservation Engineering Research 118
III. Research on the Fisheries 119
IV. Information Management Research 126

Pacific Islands Science Center (PIFSC) 127
I. Research to Support Fishery Conservation and Management 129
II. Conservation Engineering Research 136
III. Research on the Fisheries 137
IV. Information Management Research 138

LITERATURE CITED 141

APPENDIX A: RELATIONSHIP OF THIS PLAN TO OTHER PLANS 145
Relationship Between the NOAA Strategic Plan and NMFS Programs 145
Relation of the NOAA Research Plan and This NMFS Strategic Plan for Fisheries Research ... 146
Relation of the NMFS Strategic Plan and This Plan for Fisheries Research 148
Overview of Planning Documents 150
Internal Planning Documents 150
External Reviews by the National Research Council (NRC) 151
External Review by the Institute of Medicine 152

APPENDIX B: RESPONSE TO COMMENTS ON PUBLIC DRAFT OF THE NSPFR 155

APPENDIX C: ABBREVIATIONS AND ACRONYMS 161

APPENDIX D: GLOSSARY 165

NATIONAL MARINE FISHERIES SERVICE

Mission Statement:

**Stewardship of living marine resources
through science-based conservation and management
and the protection and restoration
of healthy ecosystems.**

PREFACE

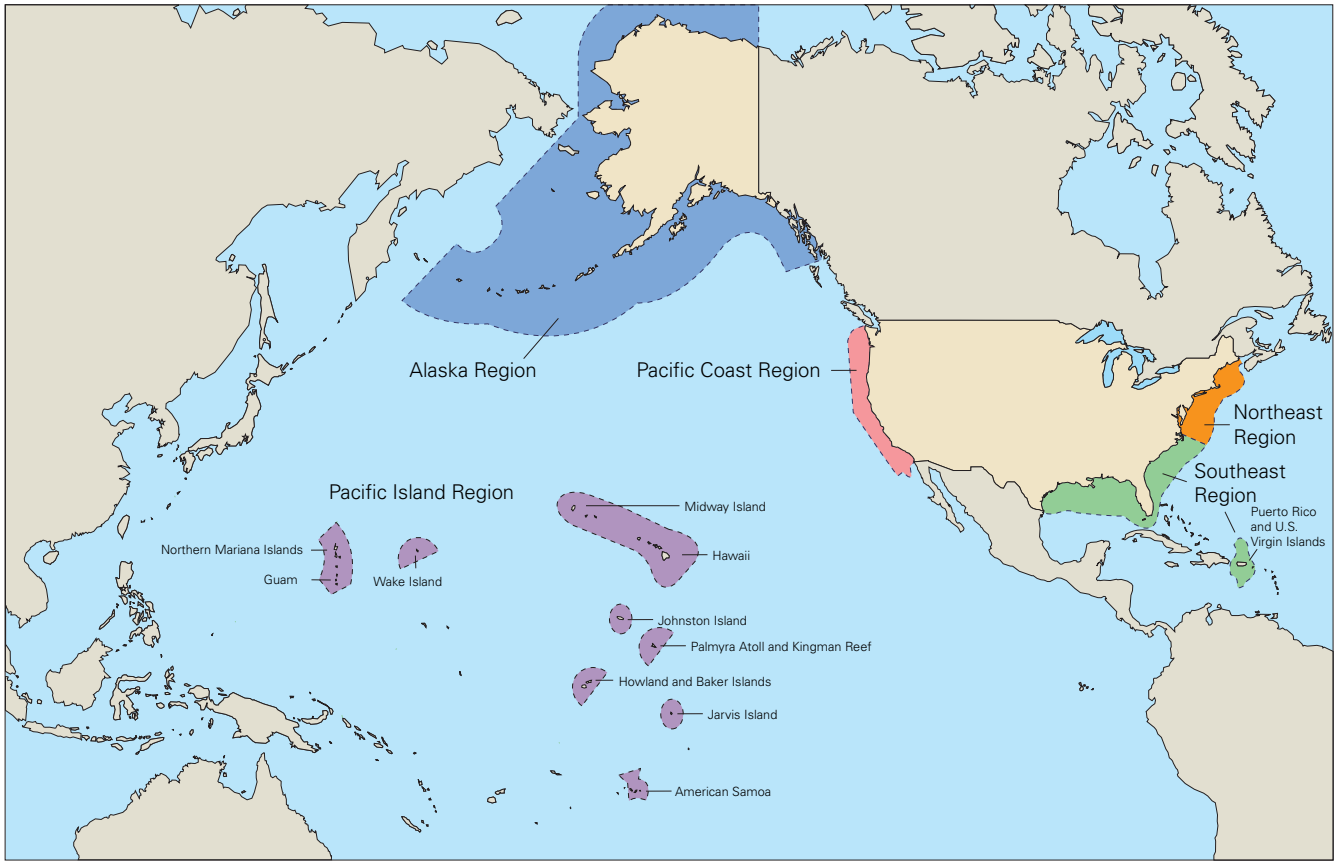


Figure 1. The U.S. Exclusive Economic Zone.

The National Marine Fisheries Service (NMFS) is responsible for the science-based management, conservation, and protection of living marine resources within the U.S. Exclusive Economic Zone (EEZ). NMFS is a subagency of the National Oceanic and Atmospheric Administration (NOAA) within the Department of Commerce.

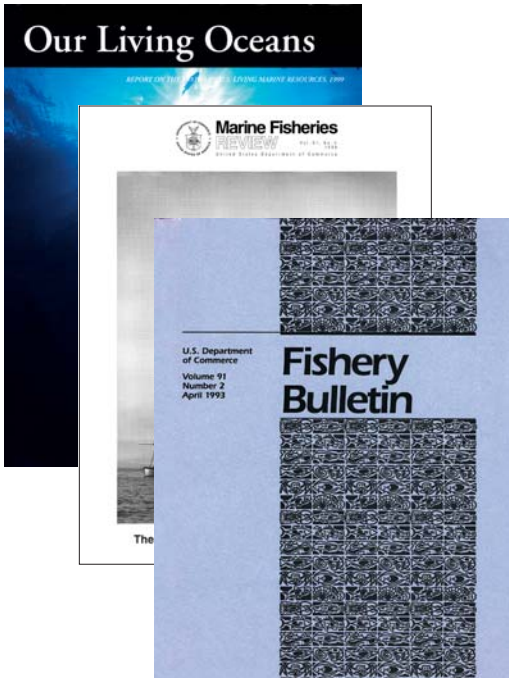
The U.S. EEZ is the largest in the world, encompassing an area 1.7 times greater than the U.S. and territorial landmass (Fig. 1). The EEZ is located from 3 to 200 nautical miles (n.mi.) seaward of the 48 contiguous states, Alaska, Hawaii, and U.S.-affiliated islands (except off Texas, the Florida Gulf Coast, and Puerto Rico, where the EEZ extends from 9 to 200 n.mi.). The EEZ is composed of at least eight Large Marine Ecosystems (Northeast and Southeast continental shelf, Caribbean Sea, Gulf of Mexico, California Current, Insular Pacific Hawaiian, Gulf of Alaska, and Eastern Bering Sea). Fisheries have developed in the United States as each area was settled, either by the aboriginal peoples or by post-Columbian arrivals. Inshore marine fisheries are managed by states, regional Marine Fisheries Commissions, and even municipalities and counties in some areas. Fisheries in the EEZ beyond state jurisdiction (3 n.mi. in most states) are the responsibility of the Federal Government, specifically NMFS, as advised by eight regional Fishery Management Councils (FMCs). Information about this system of management is available at http://www.nmfs.noaa.gov/councils.htm.

Above: The FSV *Henry B. Bigelow* making high-speed turns, without using the bowthruster, during its aceptance trials in 2006. Below: the layout of the *Bigelow*'s stern. Photos: NOAA.

In addition to its primary responsibilities within the EEZ, NMFS also plays a supportive and advisory role in the management of living marine resources in coastal areas under state jurisdiction, provides scientific and policy leadership in the international arena, and implements international conservation and management measures as appropriate.

NMFS stands at the forefront of fisheries research, both domestically and internationally. For example, the first of a new class of four 208-ft. fisheries survey vessels (FSVs), the *Oscar Dyson*, was commissioned on 28 May 2005, and began operations in Alaska waters. On 25 July 2006, NOAA took delivery of the second new FSV, the *Henry B. Bigelow*, which will be home-ported in New England. The *Bigelow* will replace the 45-year old *Albatross IV* and will support NOAA research efforts in the conservation and management of fisheries and marine ecosystems primarily in northeastern U.S. waters. Two other ships, the FSV *Pisces* and the FSV *Bell M. Shimada*, are currently under construction. These high-technology ships are among the most advanced fisheries research ships in the world. They will greatly expand the capabilities of the NOAA fleet by meeting modern NMFS data collection requirements, including the exacting quietness standards set by the International Council for Exploration of the Seas—to avoid influencing the survey results by disturbing the fish and mammals being studied.

The delivery of these vessels demonstrates the lengthy planning and construction process. The *Oscar Dyson* was put in service 7 years after the first appropriation was made by Congress, and several years of planning and justification preceded the appropriation. Although keeping the planning and budgeting responsive and coordinated was a challenge, the requirements laid out in this Plan cannot be met without continued availability of state-of-the-art ships. These ships provide scientists with the advanced research platforms required for at-sea data collections supporting stock assessments.



The NMFS Scientific Publications Office produces the noted *Fishery Bulletin*, one of the top peer-reviewed marine science publications in the world, as well as other peer-reviewed publications such as the *Marine Fisheries Review* and the *NOAA Professional Paper NMFS* series. With worldwide free distribution, in printed paper and electronic formats, these publications are vital sources for the advancement of marine science.

For more than 135 years, the agency's long-term commitment to scientific excellence via internal and external peer-reviewed scientific publications has materially advanced marine science and policy. Since 1871, Federal fisheries scientists have collected, researched, analyzed, and published peer-reviewed data on the Nation's living marine resources and marine ecosystems and on the benefits they provide. Using this peer-review process, important agency findings are published in many highly respected journals. NMFS uses its science quality assurance program to consistently monitor and review NMFS research efforts. Further, this program identifies gaps in infrastructure, facilities, and resources that may affect the productivity of NMFS scientists.

The NMFS Scientific Publications Office (SPO) and the Scientific Editor ensure the editorial and scientific integrity of the agency's research products: peer-reviewed journals, professional papers, and technical memoranda. These products and other regional NMFS publication materials serve as the basis for agency scientific reports, regulatory documents, and technical presentations for fishery scientists and managers, commercial and recreational fisheries interests, environmental groups, the information community (media), and the public. Thus, the agency's comprehensive scientific research and publishing efforts provide the foundation for developing sound policies that govern the use, protection, restoration, and conservation of living marine resources, marine habitats, and related aquatic environments.

INTRODUCTION

This Plan represents an integration of multiple perspectives on the fisheries research needs of American society. The NMFS research planning process itself includes extensive communication with our partners (e.g., Fishery Management Councils (FMCs), the states, and other governmental organizations) and our constituents (e.g., fishermen and others who are concerned about resource conservation or seafood). NMFS research programs are periodically reviewed by informal and formal program reviews, with both internal and external participation. NMFS scientists serve on FMC scientific committees, plan development teams, and boards where research inadequacies are identified firsthand. Regulatory and judicial proceedings also identify information needs that are then incorporated in the research programs. Finally, NMFS scientists work with international counterparts to identify and fill information gaps that constrain management of marine resources both domestically and on the high seas.

Planning takes place at multiple levels in government, and requires both awareness of and consistency with the goals and perspectives specific to the different levels. In response to the U.S. Commission on Ocean Policy, President Bush delivered the U.S. Ocean Action Plan to guide Federal actions to make the oceans, coasts, and Great Lakes cleaner, healthier, and more productive (CEQ 2004). This sets the parameters for the plans of all Federal agencies. At the top level within the Department of Commerce, a 5-year strategic plan addresses the varied responsibilities of the Department: to maximize U.S. competitiveness; foster science and technological leadership; and observe, protect, and manage the earth's resources (DOC 2005).

Within NOAA, a strong central Strategic Plan (NOAA 2005a) sets forth the missions, goals, and expectations of the organization. A companion Research Plan focuses the underlying research. Each NOAA line office (e.g., NMFS) has its own subordinate plan to outline the mission it serves and link with appropriate parts of the NOAA Strategic Plan.

Within the NOAA line offices, additional plans are prepared to implement specific programs, such as those programs legislated by Congress. This NMFS Strategic Plan for Fisheries Research (NSPFR) is such a document. This Plan addresses the intent of Congress as expressed in legislation while maintaining consistency with the research and management framework established within NOAA. As such, this document incorporates research planning elements across several NOAA dimensions: from the overarching NOAA Strategic Plan and the NOAA Research Plan, to the NMFS Strategic Plan (NSP), and lastly, to the six Fisheries Science Center research plans. Lying across this planning agenda is a NOAA 20-Year Research Vision, which presents a longer-term perspective of the environmental and ecological challenges our Nation faces and the technological and scientific advances we expect will help meet those challenges (NOAA 2005b). All these plans must comport

with out-year budgets; resource, staffing, and facility plans; fleet replacement and operation plans; and budget and execution plans. And all of these plans are influenced by natural and anthropogenic events and emerging technologies.

The scope of the NSPFR is specific to the requirements of the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) with respect to fisheries, habitat, and certain protected resources research. It does not include the regulatory and enforcement components of the NMFS mission, nor those research elements conducted under non-fisheries mandates, such as the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA). This Plan covers current research activities as well as strategies for improving data collection, analysis, and dissemination. Its relationship to other NOAA plans is presented in Appendix A.

LEGISLATIVE BACKGROUND

It is important to note that the recent 2006 reauthorization of the MSFCMA contains new provisions for the agency's fisheries research enterprise, and these will be incorporated into its portfolio. Details on the agency's current implementation efforts on the reauthorization are available online at http://www.nmfs.noaa.gov/msa2007/implementation.htm.

Requirements for this Plan stem from the reauthorized MSFCMA as amended by the Sustainable Fisheries Act (SFA), on 11 October 1996. Section 404 (Fisheries Research) of the MSFCMA calls for the Secretary of Commerce to develop and publish in the *Federal Register* a strategic plan for fisheries research for the 5 years immediately following such publication. The Act stipulates that the NSPFR:

- Identify and describe a comprehensive program with a limited number of priority objectives for research in each of the research areas specified below.
- Indicate goals and timetables for the program.
- Provide a role for commercial fishermen in such research, including involvement in field testing.
- Provide for collection and dissemination, in a timely manner, of complete and accurate information concerning fishing activities, catch, effort, stock assessments, and other research conducted under this section.
- Be developed in cooperation with the Fishery Management Councils and affected states, and provide for coordination with the councils, affected states, and other research entities.

The MSFCMA requires the NSPFR to address the following research areas:

- Research to support fishery conservation and management, including but not limited to:
  – Biological research concerning the abundance, trends, and life history of fish stocks.
  – Interdependence of fisheries or stocks of fish.
  – Identification of essential fish habitat.
  – Impact of pollution on fish populations.
  – Impact of wetland and estuarine degradation.
  – Other factors affecting the abundance and availability of fish.

- Conservation engineering research, including:
  – Study of fish behavior.
  – Development and testing of new gear technology and fishing techniques to minimize bycatch and any adverse effects on essential fish habitat.
  – Promotion of efficient harvest of target species.
- Research on the fisheries, including:
  Social, cultural, and economic relationships among fishing vessel owners, crew, U.S. fish processors, associated shoreside labor, seafood markets, and fishing communities.
- Information management research, including:
  Development of a fishery information base and an information management system under Section 401 that will permit the full use of information in the support of effective fishery conservation and management.

COMPREHENSIVE FISHERY RESEARCH PROGRAM

THE SCIENCE ENTERPRISE

NMFS develops scientific information needed for the stewardship of the Nation's living marine resources. The six NMFS regional Science Centers encompass 25 principal laboratories, employing more than 1,550 scientific and support personnel and another 380 full- or part-time contractors, who conduct a comprehensive, interdisciplinary science program. The scope of their work is multidisciplinary and broad in terms of space and time. The Science Centers provide the scientific knowledge base on which NMFS formulates stewardship policies in concert with its six Regional Offices. Research at NMFS laboratories supports resource management in NOAA, interstate fishery commissions, and other agencies, and the recommendations of the FMCs, to facilitate informed decision-making about marine resource management decisions for sustainable fisheries, aquaculture, protected resources, endangered species, and habitat.

The NMFS science enterprise has three primary components. In addition to the laboratories and people, the third component is fisheries survey vessels. These purpose-built, dedicated research vessels meet primary data needs, working in cooperation with chartered vessels from the academic and private industry fleets. The new vessels feature acoustic quieting to reduce behavioral responses of species targeted in surveys and to minimize noise interference to hydroacoustic signals. The ships have the speed, power, and endurance to perform acoustic and trawl surveys at the shelf edge. They support a full scientific complement, and support laboratories, computers, and multiple gears (e.g., trawl, longline, and oceanographic). Dedicated to fisheries missions throughout their 30-year service life, the continuity of service of these ships protects the integrity of long-term resource surveys. These ships are critical to the mission and are the primary method for collecting fisheries-independent data for most species.

In addition to ships, other tools and methods used to amplify and leverage the efforts and intellect of scientists include a full array of sampling equipment, observation systems, and software and analytical systems.

Because fisheries are managed on a regional basis, the focus of NMFS research programs varies across Science Centers. Each Science Center develops its own annual research priorities, based on regional and national needs. The research plans are updated as necessary

A scientist in the NMFS NWFSC Laboratory checking fish tissue samples from the Hurricane Katrina area for harmful bacteria. Photo: NMFS.

in consultation with the Regional Offices, FMCs, Program Offices in NMFS headquarters, and NOAA's constituents. The Science Center research staffs are generally organized into teams that focus on specific issues or areas of expertise.

The Office of Science and Technology coordinates the overall NMFS integrated research program. The NMFS Science Board, composed of the six Science Center Directors and chaired by the Director of the Office of Science and Technology, is responsible for ensuring the integrity and quality of scientific research. The NMFS Science Board addresses national science issues and programs and develops science policy for the agency. All components of the science enterprise provide the agency with information that is comprehensive, objective, credible, and effectively communicated.

Responsibility for the total scientific effort lies with the Director of Scientific Programs and Chief Science Advisor. This Director reports directly to the NOAA Assistant Administrator for Fisheries and supervises the Science Center Directors and the Director of the Office of Science and Technology.

The NMFS science program collaborates extensively with academia, often through cooperative agreements and grants. These partnerships enhance and extend NMFS' research capability. Many NMFS scientists serve as university adjunct professors, and this relationship enhances the ability of agency scientists to remain on the cutting edge while it expands the teaching capability of the university and brings NMFS expertise into the academic community. Academic scientists also play an important role in the periodic review and evaluation of NMFS research program quality and relevance. The Science Centers work in cooperation with other Federal and state agencies, international entities, nongovernmental organizations, and the private sector (including the recreational and commercial fishing industry).

The scale and scope of NMFS research varies. Some major research initiatives focus on the needs of the fishing industry and are performed jointly with industry. For instance, joint studies of harvesting methods and development of more effective fishing gear are under way to reduce wasteful bycatch. Other research initiatives focus on the needs of the FMCs (e.g., determination of the correct mesh size for a specific fishery or determination of the timing and area limits for a specific closure) and on the needs of the NMFS Habitat Conservation field offices to meet their scientific and management mandates under the Essential Fish Habitat provisions of the MSFCMA.

The purpose of the NMFS scientific enterprise is to ensure that the science products produced and disseminated by the agency are of the highest possible quality. These products reach the decision process in various ways, including FMC meetings, technical committee meetings, written documents published in print or on the Internet, presentations to policymakers in other fora, and workshops convened to address specific problems.

RESEARCH COMPONENTS

The MSFCMA mandates strong action to conserve and manage fishery resources that contribute to the food supply, economy, and health of the Nation's marine ecosystems. MSFCMA provisions require NMFS to end overfishing[1], rebuild all overfished stocks, and conserve essential fish habitat through research and consultations on Federal and state actions that may adversely affect such habitat. These are among our primary stewardship responsibilities.

NMFS is responsible for ensuring that management decisions are based on the highest quality scientific information on the biological, social, and economic status of the fisheries. This includes species' responses to environmental changes, species interactions, exploitation, and other human activities that affect species and their habitat. Social, cultural, and economic behaviors and incentives that influence human/marine interactions are also addressed. The information is used not just for current management decisions, but also to conserve resources and anticipate future trends, ensure future utilization opportunities, and assess the success or failure of the agency's management efforts.

NMFS is also responsible for ensuring that this information and the subsequent management decisions are understood and their validity accepted by user groups and other constituents. To accomplish this, we provide roles for commercial fishermen in our fisheries research, including operating charter surveys and participating in research program reviews. Less visible roles include providing firsthand information and knowledge about changes in species abundance and distribution, ideas and testing of bycatch reduction technology, and reviewing assessment methods and results.

The research priorities of NMFS may be grouped into the four major areas (with several subareas) defined by Congress (see Legislative Background):

I. Research to support fishery conservation and management.

II. Conservation engineering research.

III. Research on the fisheries.

IV. Information management research.

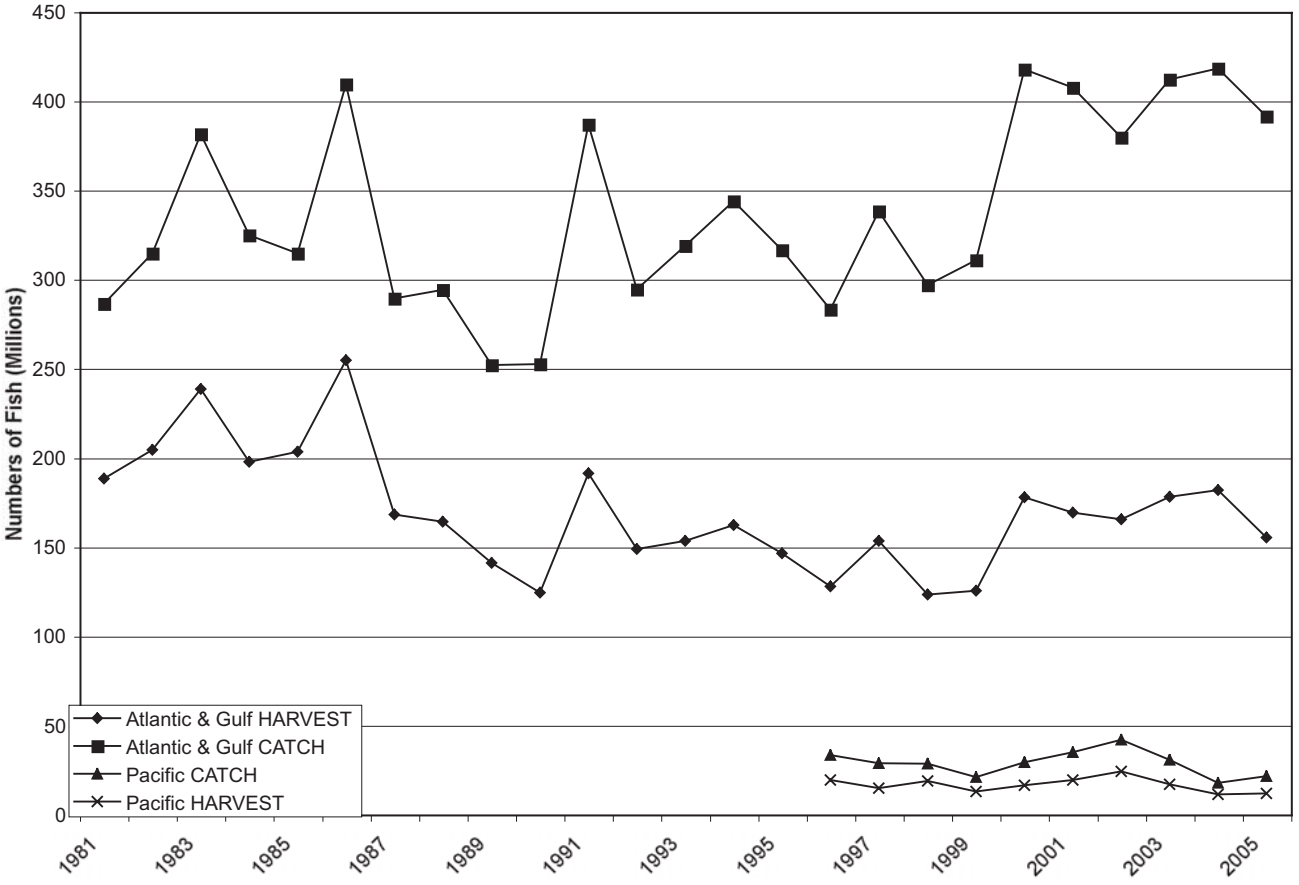
More resources are devoted to research in support of fishery conservation and management than all the other areas combined.

[1]Definitions: A stock that is subject to overfishing has a fishing mortality (harvest) rate above the level that provides for the maximum sustainable yield. A stock that is overfished has a biomass level below a biological threshold specified in its fishery management plan. This is treated at much greater depth and with respect to each of the major fisheries in the Annual Reports to Congress on the Status of U.S. Fisheries, available online at http://www.nmfs.noaa.gov/sfa/sfweb/.

I. RESEARCH TO SUPPORT FISHERY CONSERVATION AND MANAGEMENT

Living marine resources currently support extensive commercial, recreational, and subsistence uses. In 2005, commercial landings by U.S. fishermen totaled 9.6 billion pounds valued at $3.9 billion. The 2005 U.S. marine recreational fish catch was an estimated 423 million fish taken on an estimated 83 million fishing trips by about 12 million anglers (Figure 2) (NMFS 2007a). Once the value-added benefits are calculated, the commercial fishing industry contributes over $33 billion annually to our economy and about $20 billion a year is spent on recreational marine fishing activities (NMFS 2007a). U.S. consumers spent about $65.2 billion for fishery products in 2005, and based on 2001–2003 data (most recent available), the United States is the third-ranked nation in the consumption of seafood. In addition to these benefits derived from the exploitation of our living marine resources, non-consumptive uses—such as diving on coral reefs and whale-watching—provide additional benefits to many Americans.

Figure 2. U.S. Recreational Fishery Catch (includes releases) and Harvest 1981–2005 (Alaska, Hawaii, and U.S. Territories are not included; surveys in Hawaii and Puerto Rico began in 2003 and 2000, respectively; Texas harvest included for 1983–2005, but no release data collected).



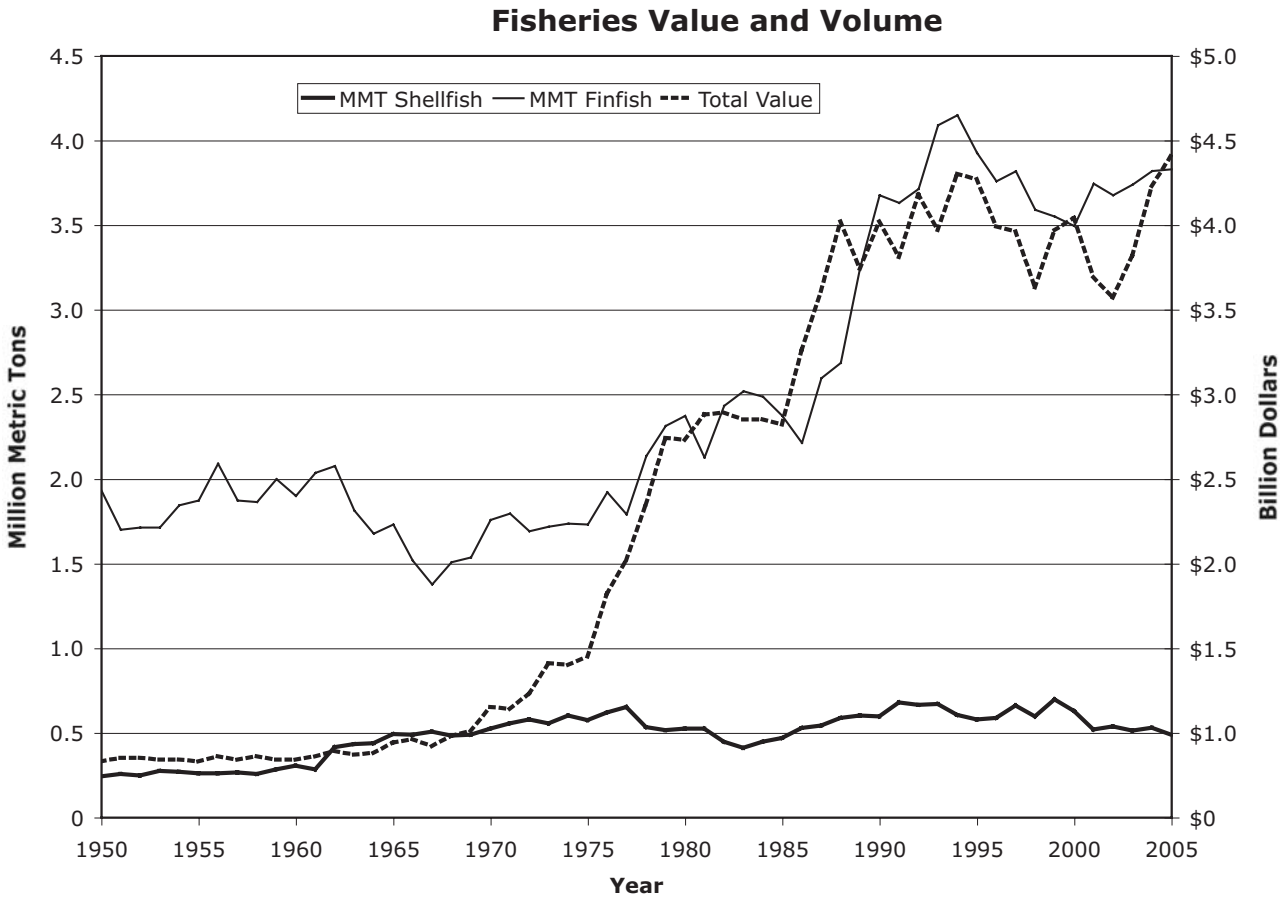


Figure 3. Commercial landings of finfish and shellfish: 1950–2005.

U.S. fisheries operate throughout the United States in all coastal waters, in and beyond the U.S. EEZ, and in many rivers and lakes. The total domestic commercial landings of finfish and shellfish increased from less than 3 million metric tons (MMT) in the early 1950s to over 4 MMT in 2005 (Figure 3). Domestic landings of all commercial fishery products reached a record high of 4.8 MMT (10.5 billion pounds) in 1993 and 1994 at a value of $3.8 billion. Alaska pollock ranked first in terms of weight and lobster ranked first in terms of total revenues in 2005 (NMFS 2007a). The resulting commercial landings combined with aquaculture production make the United States the sixth-ranked fishing nation, with 4 percent of the worldwide landings in 2004 (most recent year for which data are available) (NMFS 2007a).

NMFS has undertaken an aggressive plan of action to improve its ability to assess more of the 530 stocks and stock complexes that are identified and referenced in Federal fishery management plans. To begin implementation of this Marine Fisheries Stock Assessment Improvement Plan (SAIP) (NMFS 2001), the agency received an increase of $1.7 million in FY 2001, increasing to a total of $25.7 million in FY 2006. NMFS does not routinely assess the status of many of the 530 stocks and stock complexes identified in the 2005 Status of U.S. Fisheries report (NMFS 2007b), because generally they are not targeted in fisheries and have a low probability of becoming overfished. Based on a ranking system, the SAIP indicates that stocks with the longest history of catches, or value, rank high for having the best data collection programs and the most comprehensive assessments. This ranking system demonstrates that NMFS prioritizes its allocated research dollars to con-

Top: Pacific ocean perch caught by an AFSC survey trawl for grounfish. Right: A Pacific ocean perch in the Gulf of Alaska. Photos: NMFS.

duct status determinations for those target species most vulnerable to overfishing. The SAIP also indicates that modernization of stock assessments will require expansion of cooperative research programs with the fishing industry and other partners. The SAIP is available online at http://www.st.nmfs.noaa.gov/StockAssessment/index.html.

NMFS scientists are also working cooperatively with the interstate marine fisheries commissions, state agencies, FMCs, fishing industries, and fishing participants to improve the way data are collected and used to monitor commercial and recreational fishing impacts on fish stocks of the United States. NMFS supports a number of regional fisheries information programs that coordinate data collections, data management, and data dissemination among the state and Federal partners. NMFS is working with its partners to better integrate the data collections conducted in each region into a comprehensive regional monitoring program that more effectively supports the data and statistical needs for stock assessments and fisheries management by all of the partners. NMFS works with its partners to gather, audit, and edit data using rigorous quality control protocols, and they participate in regularly scheduled reviews of data and statistics to identify and resolve possible problems. The state and Federal agencies are working to improve the integration of final data and statistics into regional information systems that can be readily accessed by stock assessment scientists and fishery managers. The cooperative regional programs are striving to provide statistics that stock assessment scientists and fishery managers can combine geographically, temporally, and spatially as needed to support their analyses for different species or fishery segments.

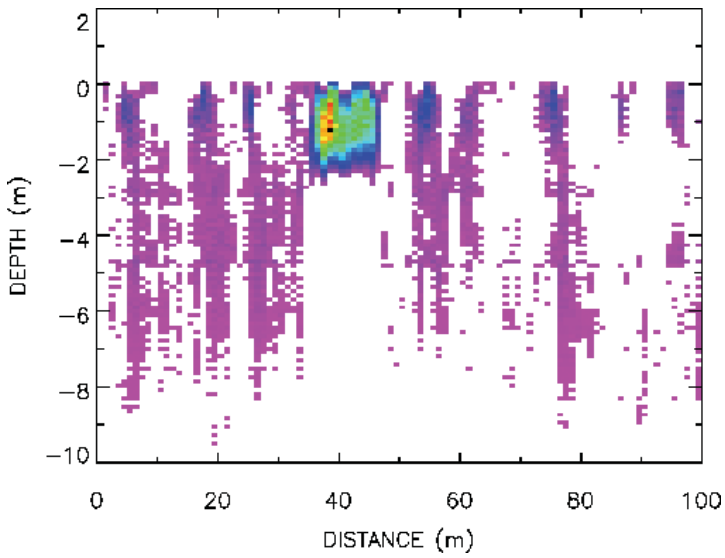
For commercial fisheries, NMFS requires participants to obtain permits and report data needed to assess fishing impacts. Permit data systems are essential for effective management of commercial fisheries, and NMFS is leading the development of an enhanced electronic database system that will improve the processing and issuing of commercial fishery permits in all regions. NMFS is designing an electronic registration system that will eliminate unnecessary redundancies in the entry and storage of data and allow implementation of operational changes that will further increase efficiency, improve data quality, and reduce the reporting burden for participants. NMFS also supports and enforces mandatory reporting programs for both commercial seafood dealers and commercial fishing vessel operators that provide the data needed to assess fishing impacts on fish stocks. Wholesale and retail dealers report the quantity and value of seafood products purchased on a trip-by-trip basis. Commercial fishing vessel operators complete and submit logbook records for each vessel trip that provide landings data along with area and effort information. NMFS is working with

its partners to implement electronic reporting systems that speed the delivery of landings data by federally permitted dealers and vessel operators. NMFS is designing these systems to use unique trip identifiers that can link each dealer trip report to the appropriate vessel trip report. More efficient matching of dealer and vessel trip reports will help reconcile differences and allow further improvements in the accuracy of commercial fishing data provided for use in stock assessments and fishery management decisions.

NMFS is also playing a lead role in developing more effective sampling survey methods for the monitoring of recreational fishing impacts. Since 1979, recreational fishing effort and catch have been monitored primarily through a combination of shoreside surveys of fishing access points and telephone surveys of coastal residential households. In recent years, NMFS has led cooperative efforts to test and implement more efficient surveys of fishing effort on for-hire vessels that are based on probability sampling of vessel lists developed from state and Federal vessel registration programs. NMFS has also been working cooperatively with some states to develop more efficient surveys of shore and private boat angler fishing effort that are based on probability sampling of angler lists developed from state licensing programs. Based on recommendations received from a 2006 National Research Council (NRC) review funded by NMFS (NRC 2006a) and from a national assessment of the information needs of fishery managers and stock assessment scientists, the agency is working with the interstate fisheries commissions to initiate a formal Federal-state collaborative process that will reassess and redesign how recreational data are collected, analyzed, and used. The redesign process has been refocused to address specific requirements and timelines for "Recreational Fisheries Information" set in the January 2007 bill that reauthorized the Magnuson Stevens Fisheries Conservation and Management Act (MSA). The reauthorized MSA requires NMFS to implement an improved survey program by January of 2009, it specifies the need for a collaborative process that addresses the NRC recommendations, it directs NMFS to work with the states to implement Federal-state registry programs for marine recreational anglers, and it directs NMFS to utilize phone/address directories developed from the registry programs in future telephone surveys.

Over the next two years, work will focus on resolving a number of potential problems with the sampling and estimation designs used in the current surveys, and on identifying changes needed to ensure that future surveys are appropriately designed to provide statistics that are readily applicable to various kinds of management decisions and that are useful for social and economic analyses. To ensure that a range of viewpoints and expertise will inform the process, NMFS will seek to establish and maintain a dialogue with those most involved and affected by the data, including anglers and various other constituent groups. Recognizing the need to implement an improved survey system in a timely fashion, NMFS will execute the plan at a pace that will ensure that redesign efforts are transparent, inclusive, and well-documented. NMFS and its partners are committed to building an improved recreational fisheries statistics program that will gain the confidence of scientists, fishery managers, and the recreational fishing community.

NMFS' research efforts focus on understanding, protecting, and restoring fishery resources and the habitats on which they depend at both ecosystem and species-specific scales. These efforts include mapping, spatial analyses, geographic information systems (GIS), and fishery and ocean habitat modeling and characterization, as well as an evaluation of ecosystem approaches to focus on spatially explicit models and further research into food web relationships. Additionally, with the increasing need to seek new management approaches to enhance and conserve essential fish habitat (EFH), NMFS is conducting



NMFS researchers flew over the school of mullet in the photo above. A subsequent aerial pass using LIDAR resulted in the graph. Photos: NMFS.

studies on adaptive management techniques through the identification and use of potential marine reserve areas or refugia (i.e., using areas closed to fishing activities for both recovery and research), and experiments on no-take and limited-take zones and time-area closures. NMFS is also exploring the research potential of Marine Protected Areas to facilitate important experiments in marine ecology and to support recommendations made by the National Research Council (NRC 2001). NMFS is conducting research on stock enhancement techniques (i.e., supplementing wild stocks with marine species raised in captivity) to help reduce rebuilding times for overfished species and recover endangered and threatened marine species. Further, NMFS is evaluating the potential impacts of artificial reef/habitat as well as commercial and recreational fishing activities on habitat and fisheries production. In combination with evaluating these impacts, public education plays a key role in increasing public awareness and support of our living marine resources.

An important aspect of NMFS' research efforts is the incorporation of innovative new technologies and techniques. For example, NMFS is cooperating with other NOAA elements to enhance survey capabilities through research and development of an omnidirectional hydroacoustic system. Airborne LIDAR (Light Detection and Ranging) technology shows promise for identifying near-surface pelagic species. Underwater laserline technology is being developed to facilitate habitat characterization and species identification. Additionally, NMFS uses manned submersibles and remotely operated vehicles to evaluate deepwater species and their habitats.

NMFS provides fishery managers with the information needed to make scientifically sound decisions. To support fishery conservation and management, NMFS scientists are actively pursuing the research described in the following sections.

I.A. Biological research concerning the abundance and life history of fish stocks

Understanding the factors affecting the abundance and life history of fish stocks requires collecting catch and effort data, measuring biological characteristics, and developing biostatistical analyses for a variety of Fishery Management Plan (FMP) and non-FMP species of exploited fish and invertebrates. Fishery-dependent and fishery-independent (i.e., resource survey) sources provide age and size samples, catch composition, and indices of relative abundance. These data are key inputs to stock assessments, fishery management regulations, and the production of status reports for living marine resources and their fisheries.

The biology and life history of species has taken on greater significance in managing the Nation's living marine resources since passage of the MSFCMA. Describing and understanding migration and distribution patterns, predator-prey relationships, habitat use, age, growth, mortality, age structure, sex ratios, reproductive biology, and responses to environmental variability are key to developing harvest strategies that produce high yields at low risk to the long-term sustainability of the resource base. A variety of scientific methods are used, including aging with the use of otoliths (ear bones), histological analyses of gonads, food studies, and observations of spawning behavior. Studies of early life history and fishery oceanography are necessary to understand recruitment dynamics, with the aim of predicting incoming year-class strength. There is also an increasing need to identify and characterize discrete stocks. The use of molecular DNA techniques, life history parameter estimates, and knowledge of ecological habits can aid in determining stock boundaries. This will enable scientists to correctly structure stock assessments and design stock-specific management measures.

The production of accurate stock assessments requires three major categories of quantitative information: 1) trends in relative abundance of the fish population, 2) total catch, and 3) life history data (growth, maturity, and natural mortality).

- The information on trends in relative abundance comes principally from highly standardized, statistically designed surveys. These surveys are conducted by NOAA's Fishery Survey Vessels and, in some cases, chartered vessels specially outfitted to conduct these surveys using a variety of case-specific methods, ranging from standardized versions of fishing gear to acoustics, plankton, submersibles, and other sampling tools. In some fisheries, the fishery catch per unit effort can be standardized to provide a relative index of the trend in stock abundance.
- The information on total catch comes from state and Federal programs to monitor the landed catch in each commercial and recreational fishery, and from the observer programs that monitor discarded bycatch.
- Life history information comes from a broad range of state, Federal, and academic sources and is often augmented through cooperative research between government agencies and the fishing industry.

These three categories of data are combined using mathematical models to derive best estimates of vital statistics, such as historical and recent trends in the numbers and biomass of the resource, recruitment levels (number of young fish entering the fishery each year), and the exploitation rate (the fraction of the stock alive at the beginning of the year that is killed by fishing). Significant gaps in any one of the three categories of information will compromise the quality of the assessment.

The SAIP defined three tiers for improving the quality of stock assessments:

Tier I: Improve stock assessments by using existing data:

a) for core species, by conducting assessments that are more comprehensive, more thorough, more timely, better quality controlled, and better communicated.

b) for species of currently unknown status, by mining existing databases of research vessel survey data and/or commercial and recreational statistics for archival information for new analyses to evaluate status determination criteria.

Tier II: Elevate stock assessments to new national standards of excellence by:

a) upgrading assessments for core species to at least an adequate level (today the list of core stocks matches the list of 230 stocks included in the Fish Stock Sustainability Index [FSSI]). This requires improvements in all aspects of the assessment enterprise, including ships, surveys, fishery monitoring, observers, analysis, and related components.

b) conducting baseline monitoring for all federally managed species (about 900 stocks are included in fishery management plans).

Tier III: Next generation assessments will:

a) assess all federally managed species or species groups at an adequate level and improve the accuracy and timeliness of forecasts for core stocks by including more detailed biological information.

b) explicitly incorporate ecosystem considerations such as multispecies interactions and environmental effects.

Shortly after publication of the SAIP, NOAA set a performance measure to reduce the number of stocks with unknown status. Between 2000 and 2006, the status of 25 major stocks changed from "unknown" to "known." For 2007, this performance measure is being replaced by a measure designed to increase the percentage of living marine resource stocks with adequate assessments. This measure is tracked for the 230 core stocks also tracked with the FSSI. Details and updates on the FSSI performance measure are available online at http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm. For these 230 stocks, an adequate assessment is considered to be an assessment that has enough information to make status determinations and track trends in stock abundance and mortality, and has been updated within the past 5 years. In FY 2006, 52 percent of the FSSI stocks have adequate assessments. Many of these assessments are required to be updated more frequently than every 5 years to support implementation of fishery management plans.

Although adequate assessments can generally support the implementation of fishery management plans, improvements can be made by elevating more assessments to the Tier III level. For example, inclusion of environmental information can help explain and forecast fluctuations in the growth and recruitment to improve the accuracy of short-term potential yield and longer-term rebuilding times. Stock assessment models are being expanded to include interactions among species in the ecosystem, and models of ecosystem-wide food webs are being developed to guide fishery managers.

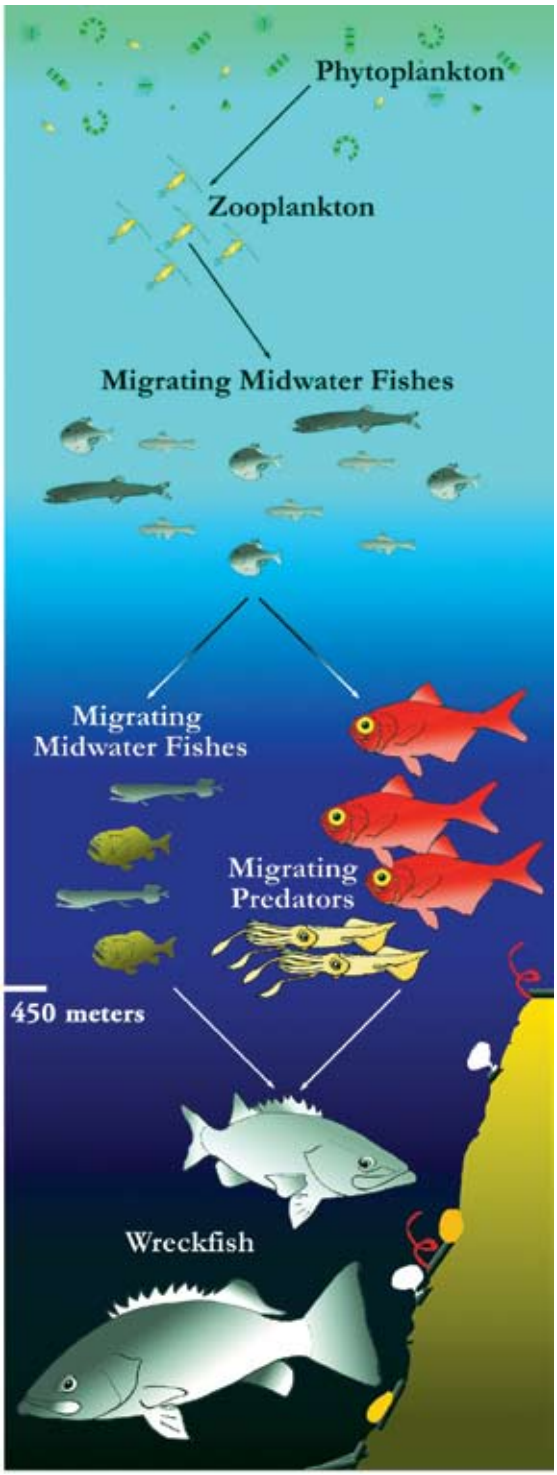
By quantifying the status of assessments for each of the important species and the amount of resources required to raise the assessment status to the next tier, NMFS has been able to determine the budgetary and associated resources that are needed to improve stock assessments.

I.B. Interdependence of fisheries or stocks of fish

Living and nonliving components of an ecosystem are linked through physical and biological relationships—e.g., by food chains or shared habitat use. Understanding these relationships is important if we are to successfully manage our living marine resources in a holistic manner. The status of a fish stock and the merits of alternative harvest strategies cannot be determined in isolation; an ecosystem-based approach is needed to take into account the various factors that affect the status of a stock and the importance of a stock to other components of the ecosystem, as recommended in the Ecosystems Principles Advisory Panel's Report to Congress (EPAP 1999). The abundance, productivity, and spatial distribution of a fish stock depend on a number of factors, including environmental conditions; habitat quantity and quality; the abundance and status of its competitors, predators, and prey; and possible symbiotic relationships.

The objective of biological studies on ecosystem interdependence is to understand the functional relationships among ecosystem components. To do so requires that we determine consumption rates and the functional form of feeding interrelationships involving resources, as well as spatial and temporal variability in abundance and habitat use. NMFS is developing recruitment and multispecies models that incorporate food web and environmental information. The models can be used to help predict long-term impacts of various harvest strategies and environmental trends on yield potential and species composition, as well as to investigate effects of predation and compensating biological changes on long-term stability, production, and structure of fish communities under different harvest strategies and environmental regimes. Research activities include:

- Marine food web research through field and laboratory studies of fish consumption rates, feeding selectivity patterns, food preference, and nutritional values of various foods.
- Stock size, food availability, and predator-prey dynamics.
- Fisheries oceanography to determine how changing environmental conditions cause changes in biological components of ecosystems.
- Food-web-based dynamic mathematical models that are used to examine how abundance of fish stocks, marine mammals, and other ecosystem components react to changes in environmental conditions and alternative fishery management measures.



An example of a food web that involves marine species. Illustration: South Atlantic Fishery Management Council Internet site.

Different fishing methods, whether by commercial or recreational fishermen, affect ecosystems differently and also have different consequences for non-consumptive user groups (e.g., in the availability of fish or mammals for tourists to view). These

different impacts, and the different values of various ecosystem attributes by different user groups, are important to ecosystem management. Some critical research areas include:

- The suite of fishing and non-fishing activities available to commercial and recreational fishermen.
- The geographic range within which various consumptive and non-consumptive user groups operate.
- The identification of all user groups, including consumptive and non-consumptive users, as well as those that value, from afar, the continued existence of the resource.
- The effect of point and non-point specific sources of pollution on the ecosystem (e.g., hypoxia in the Gulf of Mexico).
- Identification of the impact of coastal development on ecosystems and stocks of fish.
- Identification of the role of ecosystems and stocks of fish on coastal development.
- Determination of the interactions and links between user groups and fish stocks.
- Establishment of a national bioeconomic panel of experts to advise NOAA and NMFS on ecosystems, habitat, fish stocks, and their interdependence with all affected user groups.
- The amount and value of subsistence, recreational, and part-time fishing.

I.C. Identifying, conserving, and mapping of essential fish habitat (EFH)

The long-term viability of living marine resources depends on conservation and protection of their habitat. The effects of habitat degradation are often insidious, and some losses are not well understood. Other impacts are obvious. For example, we know that dams for hydroelectric power generation and water diversion for agriculture have restricted some valuable anadromous fish runs, and chemical contaminants cause tumors and reproductive dysfunction in fish (e.g., winter flounder in Boston Harbor and English sole in Puget Sound). We also know that habitat changes in Florida Bay and Chesapeake Bay have resulted in changes in fish communities, and that environmental perturbations, such as El Niño, change the latitudinal distribution, abundance, and recruitment dynamics of several species on the West Coast. Many habitat changes are not only the result of natural processes, but are also the direct result of human interactions with the environment.

The Sustainable Fisheries Act of 1996 requires FMCs to describe and identify EFH in Fishery Management Plans, to minimize to the extent practicable adverse effects of fishing activities on such habitat, and to identify other actions to encourage the conservation and enhancement of such habitat. The Act also requires that Federal agencies consult with NMFS if their actions may adversely affect habitat, and requires that the Secretary of Commerce initiate and maintain related research. MSFMCA defines EFH as

> ... those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity. For the purpose of interpreting the definition of EFH: "waters" include aquatic areas and their associated physical, chemical, and biological properties that are used by fish, and may include aquatic areas historically used by fish where appropriate; "substrate" includes sediment, hard bottom, structures underlying the waters, and associated biological communities; "necessary" means the habitat required to support a sustainable fishery

and the managed species' contribution to a healthy ecosystem; and "spawning, breeding, feeding, or growth to maturity" covers a species' full life cycle. (*Federal Register* 2002).

NMFS will continue to conduct research and analyze data necessary to:

1. Identify freshwater, estuarine, coastal, and oceanic habitats necessary to various life stages of federally managed fish species.
2. Document the life history of managed fish and assess the degree to which fishing is adversely affecting the sensitivity and resiliency of EFH.
3. Increase NMFS' understanding of the role of the benthic community in the overall ecosystem, the interaction of target fish with benthic communities, and effects of fishing on benthic communities.
4. Assess and quantify the impacts of non-fishing activities on EFH, and determine the best methods for conserving EFH injured by human impacts (including harmful spills, vessel groundings, material disposal, and fishing).
5. Develop population and habitat recovery models.
6. Describe seasonal changes in the character of the water column and seabed, mega-invertebrates, and benthic infaunal communities in estuaries and nearshore waters.
7. Map EFH using remote sensing platforms (satellite, aerial, and acoustic) along with ground truth and algorithm development to assess habitat type and quality and environmental parameters such as temperature, turbidity, and salinity.
8. Work cooperatively with fishermen to gain information on existing fishery habitats.
9. Determine the social, cultural, and economic needs of fishing communities with respect to EFH designations.

Fishery managers will use the information resulting from these activities to identify, describe, conserve, and enhance EFH.

NMFS Science Centers work closely with the regional offices, FMCs, National Ocean Service (NOS) research facilities, the NOAA Damage Assessment and Restoration Program, other Federal and state agencies, and academic and other partners to provide timely habitat information. NMFS works with the NOAA line offices and other agencies to develop the Coastal Change Analysis Program and Coastwatch to apply satellite imagery and aerial photography to habitat mapping, analysis of change in coastal land cover, and assessment of water temperature, color (for information on its content), and circulation.

These research areas and the specific EFH research described for each Science Center will provide information to be used by NMFS and the FMCs to:

- Develop a comprehensive and coordinated habitat research program in NMFS that interacts with and provides information to habitat managers, the FMCs, and the NMFS Offices of Science and Technology, Sustainable Fisheries, Habitat Conservation, and Protected Resources.
- Improve understanding of the distribution and habitat requirements of early life stages of managed species and their prey and predator species.
- Improve stock assessment capabilities and reduce uncertainty.

- Improve habitat conservation, protection, and enhancement capabilities and improve assessment of threats to EFH and managed fish stocks.
- Evaluate and predict how environment and climate signals change the distribution and amount of EFH for important stocks.
- Synthesize research information needs nationally and prioritize habitat research and funding across regions to refine EFH identification, assess and minimize adverse effects of fishing activities, and identify actions to encourage the conservation and enhancement of such habitats as required by the MSFCMA.
- Develop a national database on habitat restoration measures and designs to enhance recovery of biodiversity and value to fisheries.
- Make EFH maps available to the public via the Internet, and develop a national GIS database that will connect existing habitat information located in the Regions, Science Centers, and elsewhere.
- Provide GIS identification and mapping of habitat subject to adverse impacts from fishing gear and determine whether habitat conservation actions have been implemented.
- Restore degraded habitat using restoration options that have a scientific basis.
- Cooperate with fishermen in gathering information on habitat.
- Study incentives for habitat protection, including literature reviews of incentives for non-fishery activities (e.g., control of land-based non-point source pollution).

I.D. Impact of anthropogenic factors and environmental changes on fish populations

Changing conditions of the biotic and physical environment occupied by fish, whether natural or anthropogenic, affect population productivity through mechanisms that vary greatly in severity. Detecting such changes is an important task, but determining causal relationships is complex. Anthropogenic effects may be confounded by natural environmental changes or cycles. NMFS is conducting research to unravel these complex relationships to better understand their role in the sustainability of marine fish populations.

Toxic contaminant discharges to the coastal oceans can have a significant impact on the viability of important fish populations. For example, contaminants can disrupt an organism's early life stage development and growth, which in turn can affect its reproductive potential as an adult. Such nonlethal effects are not easily identified or characterized, and are therefore difficult to relate to the sustainability of the fish populations. The quantification and identification of deleterious changes is further complicated by natural and uncontrollable variability within and between fish populations and their supporting food webs.

NMFS will continue to study the potential effects of contaminants on important fish species as well as the sources of these contaminants. To assess the risk to fish populations from different combinations of stressors, a link must be made between understanding toxic effects of contaminants to individual organisms and the factors, both anthropogenic and natural, that influence fish populations. There has been growing recognition that marine pollution can disrupt the development and function of the reproductive, endocrine, immune, and nervous systems of marine animals, including fishes, which affects reproductive and growth processes critical to population stability. Because the effects are not always

immediately visible, it is difficult to establish the impact on fish populations. Environmental variation at different temporal and spatial scales further complicates the picture.

NMFS is also studying social and economic causes of habitat degradation, from fishery and non-fishery sources. This research includes coordination with researchers studying land-based activities such as non-point source pollution and urban development. NMFS also engages in research to determine the effects of long-term changes in the ocean climate on living marine resources. This information helps assess the true impact of human-induced factors.

A degraded wetland on Staten Island, NY. Photo: NOAA.

Habitat loss and degradation affect riverine, estuarine, and coastal ecosystems. The primary threats come from physical destruction of wetland and other habitats, or access to these habitats, such as blockage by dams, alteration of freshwater flows, eutrophication, and destructive fishing methods. For example, logging contributes to siltation and can destroy salmon spawning habitat and impede migratory paths. Construction of marinas and docking facilities, as well as dredging and disposal of dredged material in estuaries and bays, also cause significant habitat impacts. Loss of aquatic habitat (e.g., coastal wetlands or seagrass and kelp beds) resulting from development adversely affects a variety of food webs important to adults and juveniles of many marine and anadromous species. Propeller damage to shallow vegetated and nonvegetated habitats not only causes a direct loss of habitat, but results in destabilization of these areas, resulting in increased habitat loss and increased sediment resuspension and turbidity. Changes in freshwater volume and flow rates impact nearshore ecosystems adapted to seasonal discharges of freshwater. Destructive fishing methods can damage EFH and live bottom, such as coral reefs.

Nutrient enrichment and eutrophication have a major impact on fish populations in estuarine and coastal waters. This impact is manifested by hypoxia/anoxia accompanying the death of phytoplankton blooms (e.g., in the Gulf of Mexico dead zone off the Mississippi River and the western portion of Long Island Sound) and loss of inshore habitat (e.g., replacement of eelgrass beds by macroalgae or loss of eelgrass beds due to shading by epiphytes or phytoplankton in Chesapeake Bay, Waquoit Bay, and Lake Pontchartrain). In addition, changes in nutrient dynamics can create conditions that facilitate harmful algal bloom events that may lead to shellfish harvest closures and mass mortalities of farmed salmon and wild fish in the Northwest. Fishing activities could also change the population dynamics of harmful algal species. A change in trophic webs that decreases grazing on phytoplankton is a major factor in many blooms, leading to more or longer-lasting bloom events. The potential effect of climate change or environmental variability on harmful algal blooms events is also poorly known.

NMFS is engaging in a variety of research initiatives to study the effects of natural and

man-made environmental changes on living marine resources and the related ecosystem, social, and economic causes and effects. Some of the initiatives are exploratory or at early stages of development. Among the initiatives are:

- Examining the effects of mobile fishing gears, such as bottom trawls, which disturb the sea bottom and damage fragile corals and other bottom-dwelling species.
- Determining the cumulative effects of changes in watershed and regional land cover on EFH and associated living marine resources.
- Monitoring the ecosystem for habitat degradation and conducting resource surveys by satellite remote sensing and shipboard and moored instrumentation.
- Developing methodologies to detect and quantify habitat loss and gain.
- Establishing GIS databases to document and track habitat changes.
- Determining natural environmental variability at temporal and spatial scales relevant to marine fish populations.
- Developing methodologies to detect and quantify the effects of habitat alterations on fishery populations.
- Conducting laboratory and field research to identify the probable results of contaminant inputs and habitat alterations that significantly affect important fishery species.
- Developing molecular techniques to assess the genetic fitness of fishery organisms.
- Developing models (descriptive and predictive) to assess the risk posed by contaminants and habitat alterations to fishery populations.
- Analyzing and synthesizing available environmental and fishery data on fishery habitat types and fishery populations.
- Separating the effects on fish populations of natural versus human-induced climate change.
- Developing methods to identify, map, and forecast harmful algal blooms.
- Determining the effects of fishing on ecosystem trophic structure and population dynamics.
- Assessing, through cooperation with fishermen, habitat changes over time.
- Assessing current economic and social incentives for habitat protection or degradation.

II. CONSERVATION ENGINEERING RESEARCH

Conservation engineering research is intended to make fishing gear more efficient and to reduce fishing costs, bycatch mortality, and habitat destruction. It is also intended to improve the data provided by scientific surveys of fish populations. This research area includes studies related to gear performance and fish behavior to be used in the development of selective fishing gear to reduce bycatch. Bycatch mortality decreases the sustainability of a fishery and the net benefits provided by that fishery in four ways (NMFS 2004):

1. If bycatch mortality is not monitored adequately, the uncertainty concerning total fishing-related mortality increases.
2. The discards themselves can have adverse effects on other species.

3. Bycatch mortality precludes some other uses of living marine resources; for example, juvenile fish subject to bycatch mortality will not contribute directly to the growth of that stock and to future catch.
4. The absence of management measures to reduce bycatch typically results in too much bycatch; i.e., the overall net benefit to the Nation from that fishery can be increased by decreasing bycatch.

Commercial discards are a significant source of fishing mortality worldwide. The United Nations Food and Agriculture Organization (FAO) estimates that, from 1992 to 2001, yearly discards worldwide averaged 7.3 million metric tons. Trawl fisheries for shrimp and demersal finfish account for over 50 percent of the total estimated discards while representing approximately 22 percent of total landings recorded in the study (FAO 2004).

Recreational discards are another source of fishing mortality. Information is needed to determine proportions of discards in different recreational fisheries and assess associated release mortality. Additionally, NMFS is encouraging research on ways to increase the survival of recreational releases.

Bycatch reduction is particularly critical when the bycatch includes protected species. NMFS conducts research at several of its laboratories regarding fishing gear interactions with populations of species protected under the ESA and MMPA, including sea turtles, seabirds, and marine mammals. Such species interact with species managed under the MSFCMA through, for example, competition for prey species and fishing gear interactions. As such, research conducted to support requirements of the MSFCMA also makes an important contribution to the conservation and management requirements of the ESA and the MMPA. Along with incentives and other management strategies, one way to reduce bycatch is to design and operate selective fishing gears, using knowledge of species behavior, gear hydrodynamics, and fishing practices.

An important data collection method used by NMFS to conduct research on fishing gear and its impact on fish stocks, protected species, and habitat is the deployment of marine resource observers on commercial and recreational fishing vessels. Observers collect information on all aspects of fishing gear operations, including what kind of gear is used, how it is set, how long it is set, and how it is retrieved, as well as information on fish catch and bycatch and incidental takes of protected species. Observers also collect life history data on species of concern, collect biological samples, and support research through tagging of released animals and other activities. Observer data provide information for stock assessment research, for the assessment of gear efficiency, and for monitoring the relative impacts of various types of gear and fishing methods on fish and protected species and marine habitats. Currently, observers are deployed in only a fraction of the U.S. commercial and recreational fisheries managed by NMFS or required to be monitored under the MMPA, but initiatives are under way to expand the observer program into more fisheries and to more fully integrate observers into fisheries research activities.

Bycatch levels and control measures continue to occupy the attention of most fishery management actions of the regional FMCs. Even when apparent solutions are found, the dynamics and abundance of marine species change in time and area, and this can shift the character of the problems and require continuous adjustments to their solutions. NMFS will continue to conduct studies to determine the magnitude of bycatch of overfished stocks and options to reduce it. The options may require the design of new types of fishing gear that

are more selective for the targeted species, and NMFS is working in cooperation with the commercial and recreational fishing industry, tribes, states, international and environmental organizations, academia, and gear manufacturers to find designs that meet conservation needs while recognizing the financial constraints of fishermen.

To determine when gear modifications are the most appropriate response to bycatch problems, NMFS is studying a variety of gear technologies and fish behaviors, including:

A circle hook. Offset circle hooks have the point bent off to the side. Photo: South Carolina Department of Natural Resources.

- Flatfish behavior around bottom trawls.
- Fish traps with narrow entrances designed to exclude rockfish.
- Sea turtle interactions with scallop dredges.
- Gear modifications for the herring midwater trawl fishery to minimize haddock bycatch.
- Escape vent selectivity in the Northeast fishery for deep-water red crab.
- A topless shrimp trawl to reduce finfish bycatch in the pink shrimp fishery.
- Hook size and shape regarding the catch of sublegal cod and haddock in the recreational fishery.
- Turtle excluder dredges for the sea scallop fishery.
- Squid mesh selectivity to reduce bycatch of juvenile squid and other species.
- Longline turtle bycatch using offset circle hooks.

By understanding the successes and setbacks in these and other settings, NMFS will be better able to coordinate gear research with the social, economic, and institutional constraints of specific fisheries.

Experimental work with selective fishing gear involves considerable fieldwork on board fishing vessels working under actual fishing conditions. Most trawl gear evaluation includes an alternative tow approach, varying which net is fishing with the experimental gear and comparing the catch results using statistical tests. Underwater cameras and advanced sonars allow for examination of the behavioral mechanisms and gear variations that would account for the catch differences.

The MSFCMA's EFH provisions have created a need to evaluate the impacts of fishing gear on EFH. Effects from fishing may include physical disturbance of the substrate and loss of and injury to benthic organisms, prey species and their habitat, and other components of the ecosystem. Recent research to evaluate fishing impacts on habitat have included:

- Development of a habitat impacts model that enables quantitative evaluation of the effects of fishing on benthic habitat.
- Acoustic seabed mapping.
- Remotely operated vehicle video census of habitat to determine recovery rates from bottom-contact fishing gear.
- Trawl sweep and footrope modifications to reduce seafloor effects.
- Quantification of bottom trawl effects on soft-bottom habitats in naturally disturbed areas.

- The effects of fishing on tilefish habitats.
- Habitat resilience and recovery following cessation of bottom trawling activity.
- Distribution of trap fishing and effects on habitats on coral reef ecosystems.
- Pre-closure evaluation of habitats and fish in proposed South Atlantic marine protected areas.

Growing concern over the impacts of bycatch on stocks resulted in the development of a NMFS Bycatch Plan (NMFS 1998a). Agency experts with experience in fishery management, stock assessment, and social sciences compiled the plan, which included national bycatch objectives; specific recommendations concerning data collection, evaluation, and management actions necessary to attain the objectives; and a comprehensive assessment of the state of bycatch in the Nation's marine fisheries. NMFS increased its commitment to addressing bycatch by issuing its National Bycatch Strategy on 11 March 2003. This strategy comprised six components (Benaka and Dobrzynski 2004):

1. Assess progress toward meeting the goal, objectives, and strategies of the NMFS Bycatch Plan.
2. Develop a national approach to a standardized bycatch reporting methodology (NMFS 2004).
3. Implement regional bycatch implementation plans.
4. Undertake education and outreach efforts to develop effective and efficient methods to reduce bycatch.
5. Use existing partnerships and develop new international approaches to reduce bycatch.
6. Identify new funding requirements to support the NMFS National Bycatch Strategy on an ongoing basis.

NMFS is committed to maximizing the research contribution of the commercial and recreational fishing industry and the other above-mentioned partners in fisheries management. Across the NMFS regions, the commercial and recreational industry and other important partners are providing advice in research planning, formal reviews of research programs, and, where possible, research operations. Examples of research involvement include:

- Providing expertise, ideas, chartered vessels, and crew for surveys and bycatch gear development.
- Keeping logbooks of species catches, including bycatch.
- Developing gear, gear modifications, and fishing practices to reduce bycatch.

Since its inception decades ago, the Saltonstall-Kennedy Grant Program has had a history of direct industry involvement and investment. Industry members submit proposals, usually with significant cost sharing, to conduct research in conservation engineering, to develop fisheries for underutilized species to relieve pressure on traditional species, and to improve the after-catch utilization of captured species. Regional programs such as the Marine Fisheries Initiative MARFIN Program and the Northeast Cooperative Research Partners Program often fund bycatch reduction research with various partners from industry,

academia, states, and other nongovernmental organizations. In addition, "Research Set Aside" programs administered by NMFS' Northeast Fisheries Science Center allow fishermen to harvest fish and shellfish they normally would be unable to harvest in exchange for the use of their vessels and other services to conduct bycatch reduction research.

III. RESEARCH ON THE FISHERIES

New management measures, based on the Sustainable Fisheries Act (Public Law 104-297), have been successfully implemented to halt the decline in stock levels in many U.S. fisheries.

The 2006 annual report to Congress on the status of the U.S. fisheries identifies 530 marine fish stocks and stock complexes in the EEZ, an area that extends from 3 to 200 miles offshore and covers more than 2 million square miles, including those stocks that straddle international boundaries and highly migratory stocks. NMFS reviewed 530 individual stocks and stock complexes. Of those, 242 have known overfishing determinations: 194 (80 percent) are not subject to overfishing and 48 (20 percent) are subject to overfishing; 187 stocks have known overfished determinations: 140 (75 percent) are not overfished and 47 (25 percent) are overfished (NMFS 2007b).

III. A. Social and economic research

Many of the principal threats to marine ecosystems (overfishing, habitat degradation, water quality degradation, etc.) are economic and social in origin. Rebuilding and maintaining marine ecosystems requires understanding the economic and social drivers at the root of human impacts, in addition to understanding the biological and ecological functions and constraints of marine ecosystems. The NMFS Economics and Social Sciences Program is tasked with understanding the economic and social motivations that generate impacts to marine ecosystems, as well as assessing stakeholders' and the general public's preferred status of marine ecosystems (e.g., abundance of fish stocks, marine protected species, etc.) and determining the outcomes that achieve the greatest benefits to society.

To meet these mandates, the NMFS Economics and Social Sciences Program encompasses three core functions: 1) collecting information on resource users; 2) conducting economic and social analyses of fishery management issues; and 3) providing scientific advice to fishery managers.

This emerging program has targeted its data collection efforts on meeting current management needs and building the information base to meet future challenges. For example, although NMFS' goal is to establish high-quality, long-term continuous economic data collection programs on commercial harvesters in all federally managed fisheries, NMFS is currently collecting the full suite of economic data (landings revenue, trip expenditures, and fixed costs) only in key fisheries, with the intention of expanding these efforts to other fisheries in the future. However, in 2006 NMFS conducted its first national recreational survey of angler trip expenditures, and out-year plans call for increased use of surveys that directly ask anglers their preferences for proposed management options.

Furthermore, NMFS is currently completing its initial assessment of fishing communities that includes baseline information on demographics and an inventory of marine-related businesses and social and cultural institutions. In the long term, continued phased growth

of economic information collections on fishing-related industries and expanded social assessments are planned in order to provide a richer characterization of coastal economies, fishing communities, and fishing participants and for use in predictive modeling.

These information collections underpin the second core function of the program—conducting economic and social analyses of fishery management issues. In particular, these data enable NMFS to perform rigorous economic and social assessments, including:

- Developing economic and social indicators that describe the status and trends of fishery participants, marine-related businesses, and fishing communities, and that may be used as signals for identifying economic and social hardship in its early stages.
- Determining the benefits and the cost-effectiveness of current fisheries rebuilding programs and habitat and protected species recovery programs in an integrated ecosystem framework.
- Assessing the economic and social impacts and cumulative impacts of proposed management measures and existing policies on fishery participants, shoreside firms, and coastal communities.
- Developing predictive models of harvest, bycatch, and entry/exit, which are critical elements in understanding fishery capacity.

Fisheries management is undergoing two major changes, both of which suggest an expanded role for using socioeconomic research in decision-making. NMFS' move toward an ecosystem approach to marine fisheries management represents a major regime shift in fisheries management and the science requirements underpinning management decisions. Fisheries economists' ability to support ecosystem approaches has been significantly enhanced by recent advances in spatial econometric modeling, which provides an integrated framework for overlaying commercial harvesters' production decisions (e.g., where to fish, target species choices, and whether to stay in fishing) and recreational anglers' decisions (coincidentally, also location and target species decisions) against the physical, biological, and ecological condition on which those decisions are made. These models are already being used to assess the short-run costs and benefits associated with fishing ground closures. Future extensions of these models include incorporating additional biological and ecological information, including stock and habitat effects, that would enable scientists to assess the effects of localized habitat protection measures on the larger ecosystem as well as estimating the short- and long-run damages from environmental events (e.g., hurricanes, harmful algal blooms, and tsunamis), oil spills, and other exogenous factors.

The other phenomenon transforming fisheries management is the recognition of the importance of using market-based approaches to solving fishery management issues. The U.S. Ocean Action Plan and the 2005 and 2006 Economic Report of the President all advocate identifying market-based solutions to fishery management issues. For example, dedicated access privilege (DAP) programs—which include individual fishing quotas, community quotas, fishing cooperatives, and area-based quotas—are often cited as a market-based solution for reducing overcapacity and improving the economic and environmental performance of commercial fisheries, as well as the long-term sustainability of the fishing communities that depend on these resources. Accordingly, the Administration has set a goal of doubling the number of Federal fisheries managed by DAPs. Increased economic and social monitoring and research will help ensure that the economic and social goals of each DAP are achieved.

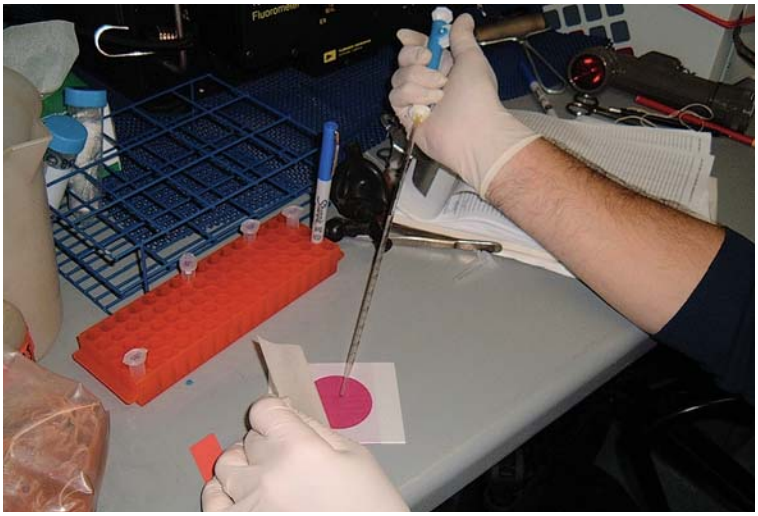
The data collection and research functions support the third core function of the NMFS economics and sociocultural program—providing scientific advice to fishery managers. Fisheries management is complex because decisions must reflect the values and the often-competing needs of many different groups, including commercial and recreational fishermen, subsistence fishing communities, non-consumptive users (e.g., non-harvest divers, whale watchers, etc.), Pacific Islanders, and Native American tribes, many of whom have treaties with the United States guaranteeing certain fishing rights. To understand the importance of economic and sociocultural information to fisheries management, one need only consider that a key feature of the Federal regulatory process is that it is not possible to simply implement a regulation to achieve a conservation goal, but instead fishery managers must consider a suite of management alternatives for achieving that outcome. Fishery managers' evaluations of these options not only include weighing the trade-offs associated with alternative management measures at an aggregate or societal level; they also include evaluating the distributional effects of proposed options on various stakeholder groups.

III.B. Seafood safety research

The Product Quality and Seafood Safety Research (PQ&S) program is the foundation of NMFS' capabilities to proactively address seafood safety issues on multiple levels from specific shellfish or fish to human health and the broader marine environment. PQ&S has provided, in part, the necessary capability to respond quickly to environmental disasters that can affect seafood quality. The value of this capability was evident in NOAA's rapid response to possible human health threats in the aftermath of Hurricane Katrina. Without this component of the PQ&S Program, NOAA's rapid response to Katrina would not have been possible because the needed expertise would not have existed. The availability of trained and experienced staff is a critical prerequisite for a rapid, timely, and effective response to all seafood safety issues, which is essential to providing the public with the science-based assessments they need to have confidence in the quality of their seafood and to understand any potential risks. The program, and the NOAA Katrina response enabled by it, ensured public confidence in the $7 billion Gulf of Mexico fishery, demonstrating a sound return on NOAA's investment in the PQ&S program. Other examples of public health and economic benefits involving regional fishery resources can be cited. Tangible benefits from NOAA's response capabilities also occurred following the Exxon Valdez, North Cape, and other oil spills, as well as from surveys of mercury in Gulf of Mexico fishery resources and Pacific Island region resources, as well as addressing other seafood safety concerns.

Intra- and extramural seafood safety research and monitoring provides for the continued integration of trophic web research relative to fishery resource health and disease threats, and differential trophic-level risk evaluation effects resulting from such threats, be they to other fishery resources, marine mammals, or human consumers. Studies focus on identifying and determining the characteristics of marine pathogens; improving methods to detect, forecast, and evaluate the ecological significance of harmful algal blooms; and developing and applying biological and chemical analytical methods to measure toxic contaminants to restore living marine resources and their habitats. Additionally, when needed, specific highly focused research is rapidly directed to address crisis situations dealing with animal and human health concerns (e.g., research needed to perform a risk assessment to wild shrimp stocks resulting from imported aquaculture shrimp products being infected with various shrimp viruses, reevaluating the human exposure rate from mercury in seafood, or investigating the mitigating effects of selenium on mercury toxicology). Personnel associ-

ated with the program represent the agency in all significant national and international food safety forums, including those dealing with food safety regulatory policy development, to ensure that national and international food policy development incorporates the nuances associated with fishery resources being used as a food source. These research efforts are conducted primarily at the National Seafood Inspection Laboratory in Pascagoula, Mississippi, as well as at the Northwest, Southeast, and Pacific Island Fisheries Science Centers and Regional Offices.



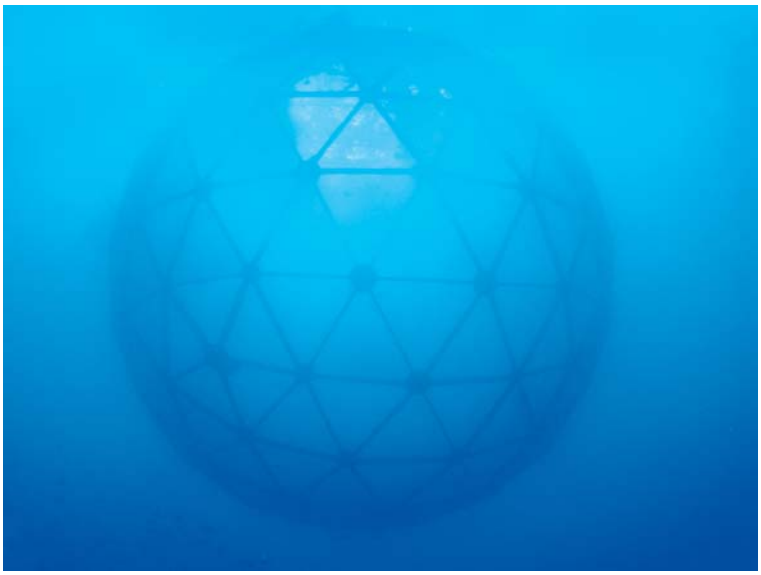
NMFS researcher testing for harmful bacteria in fish sampled from the Hurricane Katrina area. Photo: NMFS.

III.C. Marine aquaculture

Aquaculture is defined as the propagation and rearing of aquatic organisms in controlled or selected aquatic environments for any commercial, recreational, or public purpose. NMFS has a long history in aquaculture research and development, stretching back more than 100 years, and has made major contributions to the progress of aquaculture both domestically and internationally. Research efforts span the full range of issues associated with the ability to culture marine species for both commercial production and as a tool in stock enhancement and habitat restoration. Expanded marine aquaculture production in the United States has the potential to reduce the pressure on wild stock harvest and help in the rebuilding efforts for those stocks. Research efforts include the evaluation of the impacts of aquaculture production and stock enhancement on marine ecosystems and, in particular, on wild stocks and their habitats, which is the focus of regional FMCs and NMFS under MSFCMA. In particular, there is a need for models, mapping tools, guidelines, protocols, and other research products to support NMFS and the FMCs in the review of aquaculture projects under MSFCMA and other authorities.

With the recent expansion of aquaculture production worldwide, and increasing interest in the expansion of aquaculture in the United States, NMFS laboratories can make significant contributions to public understanding of the scientific issues surrounding marine aquaculture and stock enhancement. Many of the issues raised in public forums are based on outdated or questionable studies that do not accurately reflect current industry practices, so it is critical for NMFS to provide up-to-date assessments based on sound science. If the Administration's proposed National Offshore Aquaculture Act is enacted by Congress, NOAA will become the lead permitting agency for aquaculture in Federal waters of the EEZ, and the need will increase for science activities to support the rulemaking process, evaluation of aquaculture permit applications, monitoring of offshore aquaculture operations in the EEZ, and assessment of the cumulative impacts on marine ecosystems.

National policies stated in the National Aquaculture Act of 1980, as amended, and in the aquaculture policies adopted by NOAA and the Department of Commerce in the late 1990s, support the development of sustainable aquaculture production in the United States. The more recent recommendations issued by the U.S. Commission on Ocean Policy in 2004, and in particular the support for aquaculture stated in the U.S. Ocean Action Plan, reaffirm the national interest in expanding aquaculture production in the United States. There are multiple reasons for this interest in domestic aquaculture production,



Facing pages: An underwater aquaculture cage, called the Aquapod, below the surface (left) and at the surface (right) is shown in tests for raising a fish species called cobia, *Rachycentron canadum*, near Puerto Rico. Photo credits: NOAA.

including the increasing demand for seafood which, coupled with limited ability to increase harvests from wild fisheries, has resulted in a growing U.S. trade deficit in edible fishery products that currently is approaching $8 billion. Most of the increased global production of fisheries products during the past decade has come from aquaculture, so the choice for the United States is clear: increase seafood imports, which will increasingly consist of aquaculture products, or increase domestic aquaculture production.

U.S. aquaculture production in 2003 was about 926,000 pounds (420,000 metric tons), with a value of $961 million (about 20 percent from marine species). Aquaculture accounts for about 25 percent of the total U.S. landings value, and there is significant potential to increase U.S. marine aquaculture production. NMFS can support the expansion of marine aquaculture by providing sound scientific information and analyses to answer the range of technical, environmental, and socioeconomic questions that have been raised about aquaculture. These questions relate to the appropriate siting of aquaculture facilities, aquatic animal health, alternatives to the use of fishmeal and fish oil in feeds, potential genetic and ecological impacts of escapes, potential marketplace competition with wild products, and other issues. NMFS' scientific expertise can be applied to all of these issues, as well as to the development of sustainable culturing techniques, design of cages and other types of grow-out systems, and establishment of protocols for the release of cultured stock for purposes of stock enhancement.

In addition to food production and stock enhancement, aquaculture can also assist in recovery plans for protected species, and can be used to produce nonfood products such as ornamental fish, baitfish, and pharmaceuticals.

Finally, an enabling policy and regulatory framework is needed in support of aquaculture development. Regulatory complexity and uncertainty are generally recognized as the major reasons why domestic marine aquaculture production has not increased in recent years. The NOAA Aquaculture Program is addressing this barrier to domestic production by working within NOAA and with other Federal agencies to clarify and simplify how aquaculture is regulated under current law, and by working with NOAA's Office of Legislative Affairs to obtain congressional authorization to establish and implement a regulatory framework for offshore aquaculture in Federal waters of the EEZ. Enactment of the National Offshore Aquaculture Act or similar legislation would establish NOAA as the lead agency for offshore aquaculture, authorize NOAA to develop regulations and issue permits to support a sustainable marine aquaculture industry in Federal waters, and pave the way for a productive offshore aquaculture industry in the United States.

To ensure that marine aquaculture progresses in an environmentally sound manner, NMFS will concentrate its aquaculture research activities in the following broad areas, in partnership with the broader research and aquaculture communities:

- Develop and evaluate commercially viable husbandry technologies for new candidate species.
- Investigate the effects of marine aquaculture on habitat and ecosystems.
- Evaluate the risk to wild stocks from the introduction of cultured stocks, including determining genetic baselines of wild populations as part of the introduction decision process.
- Develop integrated and effective enhancement research and management strategies for aquatic species to help in the rebuilding and recovery of wild fish stocks, endangered species, and habitat.
- Develop and foster the adoption of protocols for aquatic animal health in the aquaculture industry.
- Assess the effectiveness of aquaculture as an alternative employment source for fishermen working in overexploited fisheries.
- Encourage coordination and collaboration of stakeholders to achieve regional and national goals by establishing frameworks for regional cooperation among the private and public sectors.
- Assist associations of producers to prepare best management practices for their respective industries based on scientific analysis and risk assessments.
- Conduct studies of the environmental, ecological, social, and economic impacts of aquaculture and stock enhancement, and develop science-based strategies and guidelines for avoiding, minimizing, and mitigating negative impacts.
- Develop data collection and analysis tools to monitor and assess aquaculture production trends.

IV. INFORMATION MANAGEMENT RESEARCH

To address important data shortcomings, MSFCMA requires the Secretary of Commerce to "develop recommendations for implementation of a standardized fishing vessel registration and fisheries information management system." In December 1998, NMFS completed and delivered a report to Congress that outlined an approach to integrate the collection and management of all fisheries information required under all applicable NMFS statutory and regulatory requirements, including but not limited to MSFCMA, the Marine Mammal Protection Act, the Endangered Species Act, and the Atlantic Coastal Fisheries Cooperative Management Act (NMFS 1998b). It also includes all data collected and statistics compiled under state authority for those states willing to participate. This report was developed in consultation with the U.S. Coast Guard, the states, the interstate marine fisheries commissions, the FMCs, other key governmental and nongovernmental organizations, and interested stakeholders.

Marine fisheries management organizations have long understood that the quantity and quality of fisheries information relate directly to the quality of the scientific analysis supporting resource management and allocation decisions. In its 1998 Report to Congress, NMFS made the case that significant long-term investment would be required to ensure that the right information of the right quality is readily available to form the basis of these management decisions. In that report, NOAA and its partners delivered a high-level strategy and an estimate of investments needed to realize a national Fisheries Information System (FIS). Congress began funding the agency in 2003 to initiate an FIS program that will improve the existing framework for partnership and collaboration with NOAA partners who collect, manage, and disseminate fisheries information.

A governance structure has been developed for the program that includes an Executive Sponsorship Team, a Program Management Team (PMT), and several Professional Specialty Groups (PSGs). The Executive Team is composed of the agency's Chief Science Advisor and Deputy Assistant Administrator for Regulatory Programs; it provides high-level guidance and advice on national and cross-regional issues and ensures that the FIS program operates in a manner consistent with fundamental policies and general principles of the agency. The PMT is composed of representatives of two headquarters offices (Office of Science and Technology and Office of Sustainable Fisheries), the six NMFS Regions, and the three interstate commissions responsible for coordinating the major cooperative state-Federal fisheries information network programs on the Atlantic coast, Pacific coast, and Gulf of Mexico. The regional state-Federal programs for which representation is provided include the Atlantic Coastal Cooperative Statistics Program (ACCSP), the Gulf of Mexico Fisheries Information Network (Gulf FIN), the Alaska Fisheries Information Network (AKFIN), the Pacific Fisheries Information Network (PacFIN), the Pacific Recreational Fisheries Information Network (Pacific RecFIN), and the Western Pacific Fisheries Information Network (WPacFIN). The PMT is responsible for achieving the mission, vision, goals, and objectives for the program and for providing the tactical and operational governance needed to ensure effective planning and execution of all projects.

PSGs have been formed as needed to support the FIS program's business and technical needs. Each PSG consists of experts from multiple disciplines brought together to address a specific goal, objective, or subcomponent of the FIS program. Each PSG receives approval and direction from the PMT for functions, tasks, and projects.

The FIS program vision of "a comprehensive, continuously updated time-series of well-documented, high-quality, easily-accessible information on the nation's fisheries that supports living marine resource stewardship" guides the PMT in executing the FIS program mission: NOAA's FIS program delivers fisheries information collection, management, and dissemination solutions to improve accuracy, completeness, timeliness, and accessibility. The program leverages Federal-state partnerships and investments to provide the information needed to help understand the effects of fishing on living marine resources, and to improve the quality of resource management decisions.

The current development of the FIS program is based on linking and integrating existing regional state-Federal fisheries information collection and management programs around the country with national programs to create a "system of systems" that will satisfy information needs of Federal and state agencies, the fishing industry, and the general public.

The FIS program is working toward realizing its vision and mission by striving to achieve the following four goals:

1. Expand and adapt data collection to meet current and future needs for resource stewardship.
2. Build, link, and integrate information management systems within and across regions.
3. Establish regional and national standards (including minimum guidelines) for information collection, management, and dissemination to ensure high quality, completeness, timeliness, and accessibility.
4. Implement and maintain effective partnerships to support collaboration among stakeholders and to leverage investments across regions and throughout the Nation.

In addition, the FIS program has established certain design principles to:

- Avoid unnecessary costs by reducing duplicative efforts and leveraging current and projected investments.
- Establish an overall FIS program architecture that includes business and technology perspectives, standards of measurement, and standards of quality.
- Reduce industry and reporting burdens.

These design principles represent guiding elements for FIS program execution.

Recent initiatives within NOAA and with its domestic and international partners also illustrate the importance of an ecosystem approach to resource management. This will require tight integration of FIS and its products with the agency's fishery-independent data collection and management programs, as well as major NOAA programs such as the Integrated Ocean Observing System (IOOS) and the Global Earth Observing System of Systems (GEOSS).

The regional fisheries data collection and information management programs—developed by NMFS in cooperation with state agencies and interstate commissions—have progressed considerably during the past decade. The concept of a "one-stop shop" for fisheries information at state, regional, and national levels is achievable if funding and executive sponsorship continues during the next 5 to 10 years.

Initial investments have established an FIS program management plan, as well as governance processes for project selection and resource allocation. The PMT has also been developing plans for communications and outreach, program architecture, and risk management. The PMT is implementing program management best practices by:

- Establishing clear roles and responsibilities for the participants.
- Developing a portfolio management approach to the array of diverse projects to be executed.
- Ensuring that project management expectation is standardized and well-documented.
- Establishing the expectation and means to monitor and evaluate progress and performance.

The PMT has organized, funded, and planned projects into eight FIS program portfolios that represent the core areas for initial, current, and future investments:

1. **FIS One-Stop Shop:** Make fisheries data and statistics readily available at a regional or national level in a form that is easily used by fisheries managers, stock assessment scientists, other stakeholders, and the general public. Make all information accessible through a single regional or national web-enabled information portal.
2. **FIS Information Catalog:** Provide a metadata catalog of all critical fisheries data holdings.
3. **Information Quality:** Ensure the quality of fisheries information needed to support stock assessments, as well as timely monitoring of FMP compliance and related fishing quotas.
4. **Common Identifiers:** Provide a unique key or identifier that can be used to link permits and fishing performance data for individual owners, vessels, dealers, and/or anglers for the purpose of effective tracking of individuals and their performance histories.
5. **Establish and Meet Minimum Information Requirements:** Ensure collection of minimum information needed to fulfill the stewardship responsibilities of NOAA, the FMCs, interstate fisheries commissions, and states.
6. **Electronic Reporting and Registration Systems:** Develop electronic systems for purchasing permits; processing and sharing permits information; and collecting, reporting, processing, and sharing fisheries performance information for all major fisheries.
7. **Program Management Support:** Maintain a well-managed program that delivers value to FIS program partners and customers, and is a model for program management in NMFS.
8. **FIS Program Architecture:** Develop a roadmap that describes the current state of business and systems elements and their use in a new FIS program state.

The PMT has developed initial high-level work plans and identified the desired outcomes for each portfolio. Additional analyses are establishing critical paths, interrelationships, and dependencies between and among these portfolios.

Development of FIS is being coordinated with the Integrated Ocean Observing System (IOOS), a developing, multi-agency system to routinely and continuously provide quality controlled data and information on current and future states of the oceans and Great Lakes. The IOOS will operate from the global scale of ocean basins to local scales of coastal ecosystems. It is a multidisciplinary system designed to provide data in forms and at rates required by decision makers to address seven societal goals. Three of these goals are directly relevant to fisheries research and management: reduce public health risks; protect and restore healthy coastal ecosystems more effectively; and enable the sustained use of ocean and coastal resources. The IOOS has three major components to form an end-to-end system: observations, data management and communication, and data analysis and modeling.

Although development of FIS predates development of the IOOS, FIS can provide the mechanism for bringing fishery-dependent data into the larger IOOS. For example, FIS can be brought into compliance with IOOS standards for data access, metadata, and data stewardship (e.g., quality control and archiving).

MAJOR FISHERY RESEARCH GOALS AND OBJECTIVES

The major fishery research goals of NMFS have a one-to-one relationship with the program areas identified in the MSFCMA, except that a sixth element has been added to help focus efforts on building partnerships. The objectives under each goal have been developed through many discussions with agency managers and staff and with stakeholders and reviewers. They generally correspond to the principal functions necessary to develop and disseminate information and advice for use by fisheries managers.

GOAL 1—PROVIDE SCIENTIFICALLY SOUND INFORMATION AND DATA SUFFICIENT TO SUPPORT ECOSYSTEM-BASED FISHERY CONSERVATION AND MANAGEMENT.

Objective 1.1: Periodically assess stocks to ascertain whether changes in their status due to natural or human-related causes have occurred. These stock assessments require adequate fishery monitoring and resource surveys and knowledge of the physical environment.

Objective 1.2: Provide stock assessments that include current and forecast abundance levels and trends, based on a comprehensive suite of ecosystem variables such as biological productivity, climatic and oceanographic information, ecological interactions, and economic and other social forces that will affect levels of fishing effort.

Objective 1.3: Determine and reduce the level of uncertainty associated with stock assessments through improved data collection and advanced analytical techniques.

Objective 1.4: Develop implementation strategy and annual operational plans for executing the days-at-sea requirements identified in the NMFS Data Acquisition Plan (NMFS 1998c).

Objective 1.5: Use stock assessment workshops, peer reviews, and other fora to ensure that NMFS' information and advice are developed through an open and collaborative process.

Objective 1.6: Communicate NMFS' scientific information and advice, along with the associated uncertainties, to the Councils, other management authorities, and the public.

Objective 1.7: Collaborate with other management authorities and the Councils to explore and develop fishery management regimes and alternative governance systems that will effectively control exploitation and promote sustainability.

Objective 1.8: Provide guidelines to assist the Councils in assessing and specifying Maximum Sustainable Yield (MSY) for managed fisheries.

Objective 1.9: Work with the Councils to develop objective and measurable criteria for each managed stock to determine if the stock is overfished or approaching an overfished condition.

Objective 1.10: For each stock that is overfished or approaching an overfished condition, develop, with the advice and recommendations of the Councils, measures to eliminate or prevent overfishing.

Objective 1.11: Conduct additional research to provide needed information to refine EFH designations (for example, to better differentiate between spawning habitats and habitats used occasionally) and to help the Councils minimize the adverse effects of fishing, aquaculture, and other activities on EFH, as mandated by the MSCFMA.

Objective 1.12: Establish a continuing review of living marine resource habitats (as part of the Our Living Oceans series and implement measures to monitor the trends in habitat availability. (NMFS, in prep.).

Objective 1.13: Support recommendations provided by the NRC (NRC 1999) and the Report to Congress (EPAP 1999) by establishing criteria to define and delineate marine, estuarine, and riverine ecosystems for management purposes, and identify indicators for assessing the status and detecting changes in the health of such ecosystems.

Objective 1.14: Define the key aspects of vital habitat functions and increase our understanding of how they affect marine and anadromous species and how they are affected by human activities. This will involve the development of new methods of quantifying fishing and non-fishing impacts on habitat and evaluating the quality and productivity of restored habitats, as well as improved restoration and creation technologies, including contaminant remediation, to ensure that restored and created habitats are beneficial to fish populations.

Objective 1.15: Incorporate assessments or indices of climate variability into stock assessments.

Objective 1.16: Monitor climate change on interannual, decadal, and centennial scales and its impact on currently sustainable fisheries.

Objective 1.17: Use economic and sociocultural research to predict future trends (e.g., entry and exit behavior from industry or community, organizational structure, cultural changes, etc.) of shoreside fishing-related households and firms in fishing communities.

Objective 1.18: Use economic and sociocultural research to predict future trends in entry and exit of fishermen to the fishery and to assess fishing capacity.

GOAL 2—THROUGH CONSERVATION ENGINEERING RESEARCH CONTRIBUTE TO EFFORTS TO REDUCE BYCATCH AND ADVERSE EFFECTS ON EFH, PROMOTE EFFICIENT HARVEST OF TARGET SPECIES, AND IMPROVE THE DATA FROM FISHERY SURVEYS.

Objective 2.1: Improve NMFS' ability to identify and assess the magnitude of incidental takes of protected marine species.

Objective 2.2: Establish sustainable levels of takes for all protected marine species and continue to improve the estimates of these levels through ecological research.

Objective 2.3: Work through domestic and international cooperative relationships with industry and environmental groups, including take reduction teams, special task forces, and other needed scientific collaborations.

Objective 2.4: Explore, develop, and implement new technologies and practices for reducing detrimental interactions. When such technologies could reduce detrimental effects both to and from protected species in other nations, these technologies will be made available to those nations.

Objective 2.5: Establish a standardized reporting methodology to assess the amount and type of bycatch occurring in each fishery covered by an FMP.

Objective 2.6: Work in cooperation with the fishing industry and gear manufacturers to improve gear selectivity, design and field test new gear designs and modifications, and evaluate gear regulations.

Objective 2.7: Assess and quantify the degree of impact of existing and new gears on EFH and research new gear types that can reduce those impacts.

GOAL 3—THROUGH ECONOMIC AND ECOLOGICAL RESEARCH ON MARINE COMMUNITIES AND ECOSYSTEMS, PROVIDE SCIENTIFIC DATA AND INFORMATION TO INCREASE LONG-TERM ECONOMIC AND SOCIAL BENEFITS TO THE NATION FROM LIVING MARINE RESOURCES. (THE SCOPE CENTERS ON INFORMATION ABOUT HOW THE RESOURCES ARE USED AND ITS INTEGRATION WITH INFORMATION ABOUT THE RESOURCES ADDRESSED IN GOAL 1.)

Objective 3.1: For each fishery management plan, collect the complete suite of economic data for commercial harvesters (variable cost, annual operating cost, and revenue) and recreational anglers (expenditures on fishing boat, tackle, and other trip-related expenses).

Objective 3.2: For each coastal state and territory, collect economic and sociocultural data needed for analyzing and understanding fishing, fishing-related industries, and fishing communities.

Objective 3.3: Establish an inventory of non-market values for protected species, essential fish habitats, and ecosystems.

Objective 3.4: Determine the costs and benefits as well as the economic and sociocultural impacts to fishery participants, shoreside firms, and fishing communities from proposed management options prior to the management decision.

Objective 3.5: Collect data and develop integrated bioeconomic models to assess the net benefits to the Nation derived from living marine resources accruing to those actively en-

gaging in fishing-related activities, e.g., commercial harvesters, recreational users, fishing communities, and seafood consumers.

Objective 3.6: Assist the Councils in reviewing optimum yield (OY) levels for consistency with economic theory and with the revised definition in the Sustainable Fisheries Act.

Objective 3.7: Evaluate the impacts of climate change on biological, social, and economic conditions in fishing communities and commercial and recreational sectors.

GOAL 4—PROVIDE SCIENTIFIC INFORMATION AND ASSESSMENTS TO GUIDE THE DEVELOPMENT OF A SUSTAINABLE AND ENVIRONMENTALLY SOUND MARINE AQUACULTURE, INCLUDING RESEARCH ON ENVIRONMENTAL IMPACTS, SOCIAL AND ECONOMIC IMPACTS, AND TECHNOLOGIES TO IMPROVE MARINE AQUACULTURE OPERATIONS.

Objective 4.1: Monitor and assess potential impacts from escapes from marine aquaculture facilities, including impacts on the genetics of wild stocks and competition from escapees.

Objective 4.2: Monitor and assess potential impacts from disease and parasite transmission to wild stocks.

Objective 4.3: Monitor and assess potential impacts to water quality and benthic habitats.

Objective 4.4: Provide research into developing alternative feeds for aquaculture operations (e.g., from plant-based proteins) to reduce reliance on fish meal and fish oil.

Objective 4.5: Study new candidate species for culture through their complete life cycle to determine which are economically and biologically suitable for commercial culture or wild stock enhancement.

Objective 4.6: Work with the aquaculture industry to develop, identify, evaluate, and transfer technologies that are appropriate to both economically efficient aquaculture production and environmental protection and sustainability.

Objective 4.7: Conduct research to evaluate local and regional economic and social impacts that may be expected by the introduction or expansion of marine aquaculture.

GOAL 5—IMPROVE THE FISHERY INFORMATION SYSTEM.

Objective 5.1: Integrate and link existing regional and national fisheries information systems so that fisheries data and statistics are readily available at a regional or national level in a form that is easily utilized by fisheries managers, stock assessment scientists, other stakeholders, and the general public. Make all information accessible through a single regional or national web-enabled information portal.

Objective 5.2: Utilize a standard FIS web-enabled system (InPort) to compile and provide a metadata catalog of all critical fisheries data holdings.

Objective 5.3: Establish regional and national standards for information collection, management, and dissemination to ensure high quality, completeness, timeliness and accessibility. Implement improvements in quality control and assurance procedures for existing fisheries information collection, processing, and management activities as needed to assure the quality of fisheries information needed to support stock assessments, as well as timely monitoring of FMP compliance and related fishing quotas.

Objective 5.4: Develop a unique key or identifier that can be used to link permits and fishing performance data for individual owners, vessels, dealers, and/or anglers for the purpose of effective tracking of individuals and their performance histories.

Objective 5.5: Determine minimum fisheries information needs, perform gap analyses of current data collection programs, and assure collection of information needed to fulfill the stewardship responsibilities of NOAA, the Fishery Management Councils, interstate fisheries commissions, and states.

Objective 5.6: Develop electronic transaction systems to support "one-stop shopping" for fishery permits and to facilitate the processing and sharing of permits information within and among regions as needed.

Objective 5.7: Develop electronic systems for the collection, reporting, processing, and sharing of fisheries performance information for all major fisheries.

Objective 5.8: Coordinate development of the fisheries information system with the developing Integrated Ocean Observing System.

GOAL 6—IMPROVE THE EFFECTIVENESS OF EXTERNAL PARTNERSHIPS WITH FISHERS, MANAGERS, SCIENTISTS, CONSERVATIONISTS, AND OTHER INTERESTED GROUPS

Objective 6.1: Promote a cooperative network of partners in the coordination of fisheries research.

Objective 6.2: Develop infrastructure for long-term, continuous working relationships with partners to address fisheries research issues.

Objective 6.3: Sponsor symposia and conferences for partners to exchange information and identify major fisheries research initiatives.

Objective 6.4: Solicit partners' views on fisheries research needs.

All Federal agencies operate in an environment of increasing demands competing for limited resources. To meet this challenge, NMFS is collaborating with other NOAA line offices and their programs (e.g., Sea Grant, National Undersea Research Program, Center for Sponsored Coastal Ocean Research); other Federal, state and local agencies; universities; Native American tribes; Pacific Islanders; the commercial and recreational fishing industries; environmental groups; and international organizations. NMFS is committed to strengthening existing relationships and building new ones.

Strategic planning usually includes the use of timetables for performance of the various activities associated with each goal. Fisheries research has been developing for well over a century. Initially, it was mostly studies of fundamental life history and exploratory fishing. Routine surveys accelerated with the advent of international conservation treaties and became nationwide with the passage of the MSFCMA. Much of the research is operational in nature and will continue into the future. Issues are ever-changing, as natural and human-induced changes to ecosystems modify species distributions and abundance, unforeseen ecological relationships become suspected or known, marketplace preferences change, and harvesting technology evolves. For example, stock assessment surveys, the analysis of the obtained data, and the projections of future abundance, are done according to a schedule (when there is sufficient funding). Other parts of this plan involve improvements to the science or the provision of new facilities.

Several lines of NMFS research have gained importance in recent years, reflecting increased levels of interest in developing management areas. One example is marine aquaculture. The United States has a long history in marine aquaculture, but domestic production has lagged behind as foreign production has substantially increased, resulting in a large and growing seafood trade deficit. There is growing recognition that the U.S. needs to increase marine aquaculture production, particularly offshore,[2] and more research needs to be targeted toward supporting a sustainable and productive domestic industry (e.g., research on new feeds, cage designs, and genetic and disease issues). NMFS is working with industry to increase the level of research required to support domestic marine aquaculture. Another developing line of research involves the relatively new paradigm of Ecosystem Area Management. In this research, all areas of an ecosystem are considered, from climate variability, to predator-prey relationships and changes, and multiple uses of the habitat areas and the resources.

[2]In July 2006, the Marine Fisheries Advisory Committee unanimously approved the draft 10-Year Plan for the NOAA Aquaculture Program; recent statements from President Bush and Commerce Secretary Gutierrez strongly endorse using marine aquaculture, and offshore aquaculture in particular, to provide economic opportunities and augment commercial fishing operations.

NMFS FISHERIES SCIENCE CENTERS

NMFS is a world leader in fisheries research. Each year the agency uses harvest and survey data to assess the status and trends of more than 200 major commercially valuable fish and shellfish stocks. The NMFS Science Centers provide annual stock assessment information and management advice to support the NOAA stewardship mission for the living marine resources in their regions. Increasingly, as more data and more sophisticated models are developed, the information and advice become better able to support ecosystem-based resource management. These cross-disciplinary efforts are undertaken in cooperation with other Federal and state agencies, international organizations, the fishing industry, and academia, and are based on long-standing cooperative research agreements. In addition to these basic responsibilities, each regional Science Center has unique capabilities to focus on special research needs. The following is an overview of each of the NMFS Science Centers.

A survey from a small boat in an icy fjord in Alaska. Photo: NOAA.

ALASKA FISHERIES SCIENCE CENTER

The Alaska Fisheries Science Center (AFSC) has research facilities in Alaska (Auke Bay, Kodiak Island, Anchorage, and Dutch Harbor), Washington (Seattle), and Oregon (Newport). Beginning in 2006, the Ted Stevens Marine Research Institute becomes the AFSC's new home for much of the current Auke Bay Laboratory operations. Organizationally, the AFSC consists of the Resource Assessment and Conservation Engineering Division (RACE), the Resource Ecology and Fisheries Management Division (REFM), the National Marine Mammal Laboratory (NMML), the Auke Bay Laboratory, Fisheries Monitoring and Analysis Division, and other administrative units. The major shipboard platforms supporting the AFSC include the NOAA fishery survey vessels *Oscar Dyson*, *Miller Freeman* (built in 1967), and *John N. Cobb* (built in 1950), as well as chartered vessels from the fishing industry. The new fishery survey vessel, the NOAA Ship *Oscar Dyson*, was commissioned in May 2005 at her homeport of Kodiak. The AFSC has numerous on-going relationships with external cooperators, including state and other Federal agencies, academic institutions, foreign research institutions, the fishing industry, and resource conservation organizations.

The AFSC has a permanent staff of about 365 employees in support of fisheries and marine mammal research in the coastal and offshore waters of Alaska. This marine region of nearly 3 million square miles includes over 50 percent of the U.S. coastline and over 70 percent of the U.S. continental shelf. The region supports some of the most important commercial fisheries in the world, particularly groundfish and Pacific salmon species, and is a popular destination for recreational fishing. It also hosts some of the world's largest populations of marine mammals and seabirds.

The AFSC focuses research on the following fishery resources that support major commercial fisheries off Alaska:

- Groundfish in the Bering Sea-Aleutian Islands (BSAI) region, including separate catch quotas for 14 individual species or stocks and four species complexes. These management complexes include shortraker/rougheye rockfish, other flatfish (15 species), other rockfish (eight species, including thornyheads), and squid.
- Groundfish in the Gulf of Alaska (GOA) region including separate catch quotas for 12 individual species or stocks and five species complexes. The management complexes include deep water flatfish, shallow water flatfish, other slope rockfish, pelagic shelf rockfish, and demersal shelf rockfish.
- The remaining groundfish species are managed as separate "other species" groups in the BSAI and GOA regions. These management groups include species of sculpin, skate, shark, and octopus. Eight species of skate, over 50 species of sculpins, three species of sharks, and four species of octopus are occasionally caught in groundfish fisheries. Commercial and scientific interest in these species continues to grow, while research efforts are under way to improve our knowledge of their life history, abundance, and interactions with commercial fisheries.
- The shellfish species include king, tanner, snow, and hybrid crabs; several species of shrimps; and sea snails.
- The five major Pacific salmon species (Chinook, chum, sockeye, pink, and coho) and steelhead have supported strong traditional salmon fisheries along the entire Alaskan coastline.

In addition to research on fishery resources, the AFSC is continuing to develop studies that will help predict how marine resources respond to climate change, the nature and location of habitat resources required by commercially valuable fish species, and habitat interactions between fish and marine mammals. Direct research on marine mammals includes stock assessments for most marine mammal species of Alaska, as required by the Marine Mammal Protection Act (MMPA) and for those species also listed under the Endangered Species Act (ESA). This information, in turn, is used to assess anthropogenic impacts, including direct (e.g., incidental take) and indirect effects (e.g., competition) of fisheries on those populations.

The Fisheries Monitoring and Analysis Division monitors groundfish fishing activities in the U.S. EEZ off Alaska and conducts research associated with sampling commercial fishery catches, estimation of catch and bycatch mortality, and other aspects of fishery-dependent data. The Division is responsible for training, briefing, debriefing, and oversight of observers who collect catch data onboard fishing vessels and at onshore processing plants and for quality control/quality assurance of the data provided by these observers. Division staff process data and make it available to the Sustainable Fisheries Division of the Alaska Regional Office for quota monitoring and to scientists in other AFSC divisions for stock assessment, ecosystem investigations, and a broad range of research investigations.

The AFSC also conducts research on habitat use by FMP-managed fish and invertebrates, alterations in habitat quality through human and environmental change, and an understanding of threats to habitat in Alaska. Studies involve diverse fish habitats that range from eelgrass beds to benthic substrates, and wetlands to coral and sponge communities which

A sculpin that was collected by trawl during a survey. Photo: NMFS.

serve as refugia, forage grounds, or nursery areas for managed species. Perturbations include fishing, oil transportation, logging, and development, plus natural effects on fish habitat such as climate, prey distribution, and nutritional quality.

The National Marine Mammal Laboratory (NMML) is responsible for conducting research on all marine mammals of the coast of Alaska, and pinnipeds occurring in Washington, Oregon, and California. Information is provided to various U.S. governmental and international organizations to assist in developing rational and appropriate management regimes for marine resources under NOAA's jurisdiction. Research programs are carried out cooperatively with other Federal, state, and private sector agencies. Priorities over the next several years include:

- Assessing abundance, distribution, and stock structure, and estimating direct and indirect anthropogenic impacts on all marine mammal stocks off the coasts of Alaska, Washington, Oregon, and California.
- Collecting information on the four species of ice seals, which are very likely to be highly sensitive to projected decreases in sea ice in the Arctic.
- Investigating the causes of the decline of pinnipeds in the Bering Sea and of the Cook Inlet beluga whale stock.
- Determining the abundance, distribution and habitat requirements of North Pacific right whales in the Bering Sea and Gulf of Alaska.

RECENT ACCOMPLISHMENTS AND RESEARCH PRIORITIES FOR FY 2007–2012

I. Research to Support Fishery Conservation and Management

Recent Accomplishments:

- Major research cruises conducted by the AFSC included:
  - The annual winter fishery acoustic surveys aboard the NOAA Ship *Miller Freeman* to estimate the biomass and distribution of pollock in the Shumagin Islands and Sanak Trough region of the western Gulf of Alaska, southeastern Bering Sea (including the Bogoslof Island area), Shelikof Straits, and along the eastern side of Kodiak Island.
  - A summer longline charter vessel survey to assess the distribution and abundance of sablefish, rockfish, and other commercially important groundfish resources in the Gulf of Alaska.
  - A biennial summer bottom trawl survey in 2005 of the Gulf of Alaska shelf and continental slope groundfish, with three chartered fishing vessels, to estimate the biomass and distribution of groundfish and to collect other biological data.

– A biennial bottom trawl survey in 2006 of Aleutian Islands groundfish.
– A summer fishery acoustic survey aboard the NOAA Ship *Oscar Dyson* of the western and central Gulf of Alaska to further determine the feasibility of conducting a biennial summer Gulf of Alaska survey to estimate the distribution and abundance of pollock off bottom over the shelf.
– A biennial summer acoustic survey of eastern Bering Sea pollock in 2006.
– An annual summer bottom trawl survey of eastern Bering Sea shelf, with two chartered fishing vessels, to estimate distribution and abundance of crab and groundfish stocks.
– Support to the Alaska Department of Fish and Game to continue the annual bottom trawl survey for shrimp in Pavlof Bay.
– Spring, summer, and fall surface trawl surveys by the NOAA Ship *John N. Cobb* to determine abundance, migration patterns, ecology, bioenergetics, and carrying capacity for juvenile salmon in Southeast Alaska waters.
– Fall surface trawl surveys of the eastern Bering Sea shelf and basin with chartered vessels to determine distribution, relative biomass, habitat, and ecology of western Alaskan salmonids.

- The AFSC's Fisheries Monitoring and Analysis Division runs an observer program to collect information from the federally regulated fisheries of Alaska. The observer program collected valuable data on the target fishery resource for the purpose of stock assessment and fishery management. In addition, the observer program provided the information used to estimate the levels of direct, incidental takes of all protected species in Alaska's federally regulated fisheries, including seabirds, prohibited species of fish, and marine mammals. The scope of this program is extensive. For example, in 2005, 366 individual observers collected over 35,000 data collection days from 304 vessels and 24 shoreplants.

- The AFSC had the lead responsibility for analyzing the population dynamics and status of most of the groundfish species managed by FMPs in the Bering Sea-Aleutians and the Gulf of Alaska regions. For effective management, hypotheses on different complex population dynamics (including environmental and inter-species interactions) are being tested relative to current harvest guidelines. For example, management strategy evaluations are currently being conducted for Gulf of Alaska Pollock. Extensive data analyses from observer data are continuing. Specifically, for the eastern Bering Sea Pollock fishery the salmon bycatch levels have increased in recent years. Studies on causes for these increased levels are under way and advice revisions to the FMP have been provided.

- The AFSC's Recruitment Processes Program, in cooperation with the Pacific Marine Environmental Laboratory (PMEL), conducted a number of research cruises to support studies of environmental and biological factors affecting the spatial distribution and relative abundance of larval and juvenile pollock in the Gulf of Alaska and the Bering Sea, particularly with respect to their role in the ecosystem and importance as prey for Steller sea lions. These studies were supported by the Steller sea lion research program, the North Pacific Research Board, and appropriated funding for the North Pacific Climate Regime and Ecosystem Productivity studies.

- The AFSC conducted studies on salmon ocean ecology, species life histories, and historical data patterns to increase our understanding of how marine and anadromous species are affected by natural and human activities.

- The AFSC, in cooperation with the North Pacific Anadromous Fish Commission

(NPAFC), will continue its role in the Bering Aleutian Salmon International Survey (BASIS), an international research program encompassing the entire Bering Sea epipelagic ecosystem, to understand the mechanisms underlying the effects of climate change, environmental variation, and density-dependence on salmon carrying capacity in the Bering Sea for sustainable conservation of salmon stocks.

- After the 2002 discovery of dense aggregations of deepwater corals and sponge in the Aleutian Islands, AFSC scientists conducted further mapping and Remotely Operated Vehicle (ROV) and submarine work in 2003 and 2004. Data are currently being processed to better understand coral and sponge distributions and biology.
- In 2005, the AFSC conducted a 10-day survey in the Bering Sea with university partners to develop methods for assessing forage species. Methods included adaptive sampling with midwater trawls, acoustics, LIDAR, as well as nearshore sampling and assessment of energy content.
- Cooperating with the International Pacific Halibut Commission and industry, the AFSC expanded the collection of sablefish logbook data and included them within the annual sablefish stock assessment.
- The AFSC added several new age-structured stock assessments, including rougheye and dusky rockfish, raising these assessments to Tier III.
- The AFSC continues restoration studies stemming from the *Exxon Valdez* oil spill in Prince William Sound, particularly those relating to the abundance and biological availability of lingering oil.
- The AFSC has conducted synthesis studies on the effects of the *Exxon Valdez* oil spill, either from the initial impacts or lingering oil, on various species ranging from marine mammals to herring (long-term population depressed state).
- AFSC scientists, in cooperation with the State of Alaska and others, participated in technical fora under auspices for implementation of the Pacific Salmon Treaty to help sustain fisheries among healthy stocks while rebuilding weaker stocks within jurisdictional regions of the treaty.
- The AFSC, in collaboration with the Bering Sea Fisheries Research Foundation, conducted a number of studies in 2004–2006. The collaborative efforts included expansion of the standard eastern Bering Sea annual survey effort to the north to examine abundance of snow crab in the northern areas of the Bering Sea and, in 2005, included a pilot survey of Bristol Bay red king crab using an alternative trawl and survey station design. Cooperative research was conducted with a number of segments of the Alaska fishing industry to reduce the bycatch of salmon and halibut in trawl fisheries. The research focused on the development of fishing gear modifications and modification of fishing practices to reduce bycatch.
- AFSC scientists have made the data provided by the atlas of ichthyoplankton abundance and distribution patterns in the northeast Pacific Ocean and the Bering Sea ecosystems available to the public through the web. The Ichthyoplankton Information System (IIS) provides data on the early life history of fishes from the northeast Pacific Ocean and Bering Sea to identify unknown fish eggs and larvae by using known data such as meristics, distribution, and illustrations of developmental stages or as a source of original data on the early life history stages of fishes of the Northeast Pacific Ocean and Bering Sea.

- The NMML conducted research to determine the status, conservation needs, and potential impacts of fishing activities on marine mammals of Alaska. Based on data collected by the AFSC's observer program, federally regulated fisheries are not considered to have a direct, incidental take level of marine mammals high enough to warrant management action. However, indirect interactions between some commercial fisheries and some species of marine mammals (e.g., Steller sea lions and northern fur seals) may potentially occur. Research to resolve whether and to what extent these interactions occur has included surveys of marine mammal forage fish and the collection of detailed foraging information. The NMML worked closely with the Alaska Scientific Review Group (ASRG) to determine the status of marine mammal stocks in Alaska. The ASRG includes representatives from Alaskan universities, the Alaska Native community, and the commercial fishing industry.
- The AFSC's Auke Bay Laboratory completed radio-tagging studies on Yukon River Chinook and fall chum salmon that documented spawning location, migration rates, and estimated numbers crossing the border into Canada. Genetic baseline information on salmonids was assembled to identify stocks or country of origin. AFSC scientists are key partners in Coastal Fish Habitat Restoration design, application of new aquatic habitat restoration technologies, and in developing the database needed to test the effectiveness of those restoration designs.

Research Priorities, FY 2007–2012:

I.A. Biological research concerning the abundance and life history of fish stocks

The following surveys are planned by the AFSC:

- Conduct an annual summer bottom trawl survey on groundfish and crabs in the eastern Bering Sea shelf with chartered fishing vessels.
- Conduct summer midwater trawl-acoustic surveys to assess the off-bottom component of pollock stock in the Bering Sea every 2 years (2008, 2010, 2012) and the Gulf of Alaska (2007, 2009) from the NOAA Ship *Miller Freeman* and the new NOAA Ship *Oscar Dyson*.
- Reinstate the biennial eastern Bering Sea slope survey for groundfish (2008, 2010, 2012) with a chartered fishing vessel that was discontinued in 2006 due to lack of funding.
- Conduct the annual winter surveys on spawning pollock stocks in the southeastern Bering Sea, Bogoslof Island area (biennial schedule), Shumagin Islands, Shelikof Straits, and along the east side of Kodiak Island using the NOAA Ship *Miller Freeman* and/or the new NOAA Ship *Oscar Dyson*.
- Conduct the biennial summer bottom trawl survey on groundfish in the Gulf of Alaska with chartered fishing vessels every 2 years (2007, 2009, 2011).
- Conduct the biennial summer bottom trawl survey on groundfish in the Aleutian Islands region with chartered fishing vessels every 2 years (2008, 2010, 2012).
- Conduct annual summer longline surveys on sablefish and other fishery resources in the Gulf of Alaska by a chartered vessel and in the Bering Sea and Aleutian Islands on alternate years.

An adult male Steller sea lion on a rocky shoreline. Photo: NMFS.

- Conduct annual Recruitment Processes (FOCI) research cruises for larval pollock, plankton productivity and ecosystem status, and juvenile pollock ecology from the NOAA Ship *Miller Freeman* and/or the new NOAA Ship *Oscar Dyson* and chartered UNLOS (University-National Oceanographic Laboratory System) vessels.
- Conduct seasonal acoustic and biological sampling of pre-spawning eulachon in southeast Alaska and observe associated Steller sea lion feeding aggregations.
- Surveys of seasonal, temporal, and habitat related variation in nutritional quality of prey consumed by Steller sea lions and other apex predators.
- Complete three estuarine surveys in southeast Alaska to delineate habitats and fish associations.
- Conduct annual fall surface trawl surveys (BASIS) on Pacific salmon ecology and associated marine fish species (e.g., age-0 pollock) in the Bering Sea using the NOAA research vessel *Oscar Dyson* and chartered fishing vessels (2007–2012).
- Conduct annual summer surface trawl surveys on Pacific salmon in the Gulf of Alaska using a chartered fishing vessel (2007–2012).
- Conduct annual Southeast Coastal Monitoring (SECM) surface trawl cruises with the NOAA research vessel *John N. Cobb* to study the habitat use and early marine ecology of juvenile Pacific salmon.

In addition to the above traditional baseline surveys, the AFSC has a Fishery Interaction Team that develops and implements surveys to study the interactions among the component species of the ecosystem, the environment, and fisheries. The research includes:

- Tag release and recovery cruise for Atka mackerel in the Aleutian Islands to assess the impact of commercial fishing on the local distribution and abundance of Atka mackerel inside and outside Steller sea lion critical habitat.
- Map the distribution and size of Pollock aggregations in the Aleutian Islands with acoustic data collected on commercial vessels.
- Develop a statistical model for estimating Pacific cod movement rates from tagging data.
- Verify visual keys of Pacific cod maturity stages with histological data and calibrate gross maturity data collected by observers.
- Examine spatial and temporal patterns in Pacific cod reproduction.
- Relate large-scale patterns in Atka mackerel food habits to growth and use food habits data to assess small-scale habitat utilization.

The AFSC is conducting research cruises in 2006 and 2007 to inter-calibrate the scientific acoustic survey systems between the NOAA Ship *Miller Freeman* and the new NOAA Ship *Oscar Dyson* 1) to ensure the standardization of the surveys over time series; 2) to estimate the selectivity and catchability of standard mid-water and bottom trawl survey nets; 3) to conduct experiments with trawling procedures in order to confirm or revise AFSC trawl survey standards relative to ensuring that the national trawl protocols are met; and 4) to continue research on essential fish habitat determination and to measure the effects of fishing on it. The inter-calibration work may need to be continued beyond 2007 depending on the results of research completed in 2006 and 2007. During all standard surveys, biological specimens of fish and invertebrates will be collected to identify new species, estimate biological rates, and study prey-predator relationships and genetic stock structure.

Each year, observers will be deployed on commercial fishing vessels and at shoreside processing plants to meet the following coverage requirements (as specified in the groundfish FMPs for the Gulf of Alaska and Bering Sea/Aleutian Islands regions):

- 100 percent observer coverage of fishing and processing vessels longer than 125 feet.
- 100 percent observer coverage of most fish shoreside processing plants.
- 30 percent observer coverage of fishing vessels 65–125 feet long.
- 100 percent observer coverage (with multiple observers) of special category vessels that engage in community development quota (CDQ) and American Fisheries Act (AFA) fishing operations.

The AFSC will assess trends in Alaskan salmon populations and the environment through:

- Operation of a two-way fish weir to relate climatic changes with long-term variability in freshwater and marine survivals for seven anadromous salmonids.
- Retrospective analyses and monitoring programs focusing on the covariance between climate, ocean conditions, and Alaskan salmon populations at various time and spatial scales.

- Process-oriented studies on inter-annual variations in marine carrying capacity and bioenergetics of juvenile salmon, including trophic interactions with predators and competitors.
- Cooperative operation of the Fish, Energetics, Diets, and Zooplankton (FEDZ) Laboratory to analyze, maintain, and correlate biophysical databases for food habits, zooplankton prey densities and composition, condition assessed as energy density, and associated oceanographic data.
- Determination of the stock origin of the salmon bycatch in the Bering Sea groundfish fishery using new DNA-based genetic methods.
- Use of the new DNA-based genetic methods to determine the numbers of Canadian-origin sockeye salmon harvested in the southeast Alaska fishery.

The AFSC will assess the status of Alaskan groundfish and Bering Sea crab stocks and document their management requirements in annual Stock Assessment and Fishery Evaluation (SAFE) documents. The SAFE documents will define estimates of stock biological production potential (Maximum Sustainable Yield (MSY) or proxy thereof), recommend levels of acceptable biological catch (ABC), overfishing levels, bycatch requirements, and other harvest control rules for the setting of fishery regulations. The stocks covered are:

- All Bering Sea-Aleutian Islands groundfish stocks or stock complexes, including EBS pollock, AI pollock, Bogoslof pollock, Pacific cod, yellowfin sole, rock sole, arrowtooth flounder, flathead sole, Greenland turbot, Alaska plaice, other flatfish, Pacific ocean perch, other rockfish, other red rockfish (including shortraker, rougheye, and northern rockfish), Atka mackerel, and sablefish.
- All GOA groundfish stocks or stock complexes, including western central pollock, southeast pollock, Pacific cod, arrowtooth flounder, flathead sole, other flatfish (including rex sole, deepwater flatfish, and shallow water flatfish), Pacific ocean perch, northern rockfish, other slope rockfish (including shortraker, rougheye rockfish), pelagic shelf rockfish, Atka mackerel, and sablefish. The Alaska Department of Fish and Game will assess the demersal shelf rockfish complex.
- The AFSC will work cooperatively with the Alaska Department of Fish and Game to assess the status of king, Tanner, and snow (*opilio*) crab stocks in the eastern Bering Sea.
- Concerns for Steller sea lion recovery continues. In addition to direct monitoring of populations, fishery and ecosystem interaction research continues.
- Fish bones will be used to reconstruct Steller sea lion diets and identify seasonal changes in their principal sources of energy by combining diet data with seasonally adjusted energetic equivalents.
- Forage fish species collected seasonally in southeast Alaska will be compared with those from Kodiak, the Aleutian Islands, and Bering Sea to understand basin-wide processes that affect their nutritional value.
- Results of the comparative surveys of forage fish abundance and distribution off Kodiak Island and Southeast Alaska will be analyzed.

I.B. Interdependence of fisheries or stocks of fish

- Collect and analyze stomach contents of groundfish to determine ecological linkages between species.

- Develop and maintain multispecies and ecosystem models that quantify predator-prey interactions between species. Models will be developed into a predictive framework for management policy, climate, and cumulative effects analysis and used in ecosystem-level projections presented in the Ecosystem Assessment section of the annual SAFE report. Analysis will include indices of foraging habitat for key groundfish as it changes with time, space, and season, and indices of forage fish abundance for augmentation of assessments.
- Empirically derive bioenergetic models describing the life histories of forage fish species to better understand energetic limitations on their survival and reproduction.
- Collect biological specimens of pre-spawning eulachon throughout its range for DNA-based genetic marker.
- Analyze survey and observer data to determine spatial distributions of different species clusters that would indicate separation or interdependence of stocks.
- Develop DNA-based genetic baseline information on salmonids to identify stocks or area of origin.
- Develop DNA-based genetic baseline data for selected species of groundfish and forage fish to establish stock structure and stock boundaries.
- Continue the development of a new movement model for Alaska sablefish based on time series of tag returns.
- Determine incidence of coded-wire tagged salmonids in commercial and research catches in the North Pacific Ocean and Bering Sea and report annually to Pacific States Marine Fish Commission and North Pacific Anadromous Fish Commission.
- Evaluate the importance of resident rainbow trout for use in protected species recovery programs for a large number of ESA-listed salmonids.
- Determine genetic, domestication, and behavioral effects from multiple generations of hatchery culture in two stocks of Chinook salmon compared with their pristine founder populations.

I.C. Identifying, restoring, and mapping of essential fish habitat (EFH)

- Conduct studies on the impacts of logging, urbanization, and mining on coastal habitats; information will provide a basis for mitigation or restoration strategies
- Conduct restoration studies related to the Exxon Valdez oil spill in Prince William Sound. Studies will focus on long-term persistence and long-term effects.
- Conduct bottom typing and mapping surveys using acoustic techniques (side scan sonar and multibeam) to characterize and identify bottom type and map the habitats of the continental shelf and slope off Alaska.
- Conduct pilot mapping of fishing grounds and essential fish habitat associated with those grounds; describe benthic habitats, community structure of the habitats, and the basic life histories of corals, sponges, and other benthic invertebrates.
- Expand geospatial habitat data for the Alaska coastline through continued ShoreZone videography, habitat classification, and ground-truthing.
- Establish eelgrass monitoring sites in various parts of coastal Alaska to track long-term

and large-scale changes in fish communities and habitat that may result from shoreline development or global climate change.

- Use fish bioenergetics and biochemical indicators of growth to develop metrics for quantifying fish habitat quality; emphasis will be on seasonal changes, particularly on habitats that support critical life stage bottlenecks for survival and growth.
- Develop models describing basic metabolic requirements of forage fish to combine with empirical observations of energy allocation to understand how climate change will affect forage fish distributions.
- Map seasonal and temporal shifts in the use of kelp and eelgrass habitat by nearshore fish assemblages in Southeast Alaska.
- Expand models of fishing impacts and improve input such as growth, reproduction, and recovery rates of sessile invertebrates.

I.D. Impact of anthropogenic factors and environmental changes on fish populations

- Investigate the role of pathogens and parasites in vitality of marine fish and shellfish populations and as biomarkers of anthropogenic and environmental change on stock health.
- Conduct Recruitment Processes (Fisheries Oceanography Coordinated Investigations (FOCI)) studies, a cooperative research program with the Pacific Marine Environmental Laboratory of NOAA's Oceanic and Atmospheric Research Office to investigate the causes of variation in annual recruitment in fish stocks and investigate the ecological interactions and relationships relevant to the productivity of the ecosystem and ecosystem-based management.
- Assess effects of fishing on EFH and develop ways to minimize adverse impacts.
- Assess impacts of natural and anthropogenic factors on the production, distribution, and abundance of Alaskan groundfish stocks. Products are included in contributions to the ecosystem considerations chapter of the SAFE documents, peer-reviewed publications, and stock assessment advice.
- Analyze the response of fish populations to changes in climate and the ecosystem.
- Develop, evaluate, and update indicators of climate effects on North Pacific stocks and ecosystems and incorporate these into predictive assessments. This will take the form of an enhanced ecosystem assessment section of the SAFE report.
- Evaluate hatchery/wild stock interactions of juvenile chum salmon in inshore and coastal marine habitats of Southeast Alaska to rebuild and maintain sustainable, economically viable fisheries.
- Conduct Ocean Carrying Capacity (OCC) investigations—a cooperative ecosystem research program with the North Pacific Anadromous Fish Commission and other Federal, state, and university partners to investigate the factors affecting distribution and survival of Pacific salmon and associated marine species in the Gulf of Alaska and Bering Sea.
- Conduct restoration studies related to the *Exxon Valdez* oil spill in Prince William Sound. The research will focus on the long-term effects of lingering oil on intertidal organisms. This is part of an interagency study examining transfer of oil from intertidal organisms to bird and otter predators.

- Develop models describing basic metabolic requirements of forage fish to combine with empirical observations of energy allocation to understand how climate change will affect forage fish distributions.
- Monitor organochlorine levels in forage fish species to understand spatial and temporal patterns to food web contamination in Alaskan waters.
- Use satellite and other oceanographic data within groundfish stock assessments.

Sorting groundfish from a research trawl in Alaskan waters. Photo: NMFS.

II. Conservation Engineering Research

Recent Accomplishments:

- The AFSC continues to conduct research cruises and to analyze results of recent surveys to measure the direct effects of bottom trawling on seafloor habitat in the eastern and central Gulf of Alaska, eastern Bering Sea, and the Aleutian Islands. Some of the major accomplishments were:
  - Assessment of changes to the seafloor caused by chronic long-term trawling in soft-bottom areas in the Gulf of Alaska.
  - Examination of possible adverse effects of bottom trawls on soft-bottom benthos in the eastern Bering Sea.
  - Evaluation of acoustic technology for seabed classification.
  - Assessment of impacts to habitat areas of particular concern (HAPC), such as gorgonian corals.
  - Documentation of the effects of trawling on hard bottom habitat in the Aleutian Islands and Gulf of Alaska.
  - Mapping of the areas by sediment types.
- The AFSC worked cooperatively with the pollock midwater fishing vessels to design and evaluate a bycatch reduction device to reduce the bycatch of salmon in their midwater trawls. Prior work supported by the North Pacific Research Board provided the first observations of the capture behavior of salmon in a midwater trawl targeting on pollock. Based on these results, fishermen working with AFSC scientists developed and evaluated a number of possible salmon excluder designs. Testing of these designs with industry cooperation is continuing. A similar project working with Alaskan fishermen and funded by Cooperative Research and Reducing Bycatch funding is designed to reduce the bycatch of Pacific halibut in trawl fisheries in the Gulf of Alaska for Pacific cod and flatfishes. Current excluder designs being tested look promising for reducing bycatch in these fisheries.
- AFSC scientists carried out laboratory experiments on live fish at the Hatfield Marine Science Center in Newport, Oregon, to determine the impact of stress from capture processes on the behavior and survival of important bycatch species in trawl and longline fisheries. This research has provided insights on the key principles that control bycatch fish mortality by integrating analysis of behavioral and physiological assays and observed mortality. Recent published research on the measurement of bycatch mortal-

ity has shown the value of the use of the measurement of easily observable behavioral reactions in predicting bycatch mortality.

- The AFSC responded to a critical need to conduct research on methods to reduce seabird incidental take on groundfish trawl vessels. Three types of seabird deterrent devices were chosen by industry as having potential for large catcher processor vessels, including paired streamer lines, side-boom arrays, and third wire control devices. Seabirds interact with the trawl warp cables and third wire sonar cables, sometimes resulting in mortalities. The experimental deterrent devices were designed to keep seabirds away from these cables. Additional research is being conducted to examine the risk of interactions between groundfish trawl components and the endangered short-tailed albatross and to characterize the trawl fleet regarding seabird interactions.
- At the request of Alaska longliners, the AFSC developed sampling plans for a developmental "shrimpfly" rockfish fishery that will experiment with fishing gear capable of catching rockfish without bycatch of salmon, halibut, and other valuable groundfish.

Research Priorities, FY 2007–2012:

- Continue to conduct research to measure direct effects of bottom trawling on seafloor habitat according to a 5-year research plan.
- Conduct fishing gear performance and fish behavioral studies to reduce bycatch and bycatch mortality of prohibited, undersized, or unmarketable species, and to understand performance of survey gear.
- Work with industry and the Council to develop bycatch reduction techniques.
- Continue work to characterize the trawl groundfish fleet's interactions with seabirds.
- Continue research to develop appropriate mitigation gear, using experience from recent work. Identify which component of the trawl fleet is the most likely to have seabird interaction issues and develop directed research to take place during the fishing season.
- Analyze vessel-specific effects of seabird incidental take in the longline fishery and develop means to work with those individual companies and vessels to further reduce seabird takes.

III. Research on the Fisheries

Recent Accomplishments:

The AFSC conducted economic and social research to support fishery conservation and management actions, particularly those recommended by the North Pacific Fishery Management Council. In terms of that research and data programs to support such research, the principal accomplishments included the following:

- Collaborated with the National Overcapacity Working Group to develop a methodology to estimate overcapacity in all federally managed fisheries in order to satisfy an obligation in the National Plan of Action on Overcapacity in Fisheries.
- Completed this year's Economic Status chapter for the groundfish SAFE report. The SAFE report was expanded to include a broad range of research topics, in response to the Council's Scientific and Statistical Committee requests.

- Published (or submitted for publication) several papers in various areas, including recreational demand modeling, regional economic modeling, fisher behavior, productivity and fishing capacity measurement, quantitative methods for evaluating knowledge, and community profiling.
- Developing a joint ecological and regional economic model with researchers at the University of Wyoming.
- Completed and disseminated a large community profiling document that summarizes the cultural and economic relationships between the fishing industry and over 100 Alaskan communities. The profile of each individual community will be available soon on the web.
- Conducted a study that analyzes the effects of Individual Transferable Quotas (ITQ) programs on emigration from remote Alaska fishing communities.
- Developed new methods for evaluating spatially complex area closures using an improved discrete location choice model for the Bering Sea pollock fishery. This model measures the impacts on profits of boats traveling to more distant locations and/or experiencing lower levels of catch in alternative fishing areas. The model also provides ex-ante and ex-post welfare estimates of the economic impacts of the Steller sea lion Conservation Area (SCA). Extensions of the model will allow the prediction of the economic impact of future closures, such as marine reserves.
- Developed a survey to estimate the economic value of sport halibut fishing in Alaska and the public's value for Steller sea lion protection measures, and contributed to a national survey on the public's value for over 20 protected species.
- Worked with North Pacific Fishery Management Council economists to develop a new economic data collection program for freezer-longliner head and gut fleet (as part of Amendment 80). Developed a draft economic survey, and the Council recently voted to have this data collected as part of mandatory regulations for the fleet.
- Led in the development, implementation, and management of the BSAI Crab Rationalization Data Collection Program. This collection is the most detailed economic data collected in Alaska fisheries and will be used to assess the effects of this novel program.
- Implemented two projects to collect primary data on seafood industry expenditures in the Gulf and Southwest Regions of Alaska for our regional economic model. Collaborating with the Alaska Department of Labor to have them compile additional information for use in the regional economic model.
- Performed an analysis of multispecies Individual Fishing Quota (IFQ) systems that looks at multispecies IFQ fisheries in Iceland, New Zealand, Australia, and Canada. The AFSC assessed the design and use of catch-quota balancing mechanisms, with an eye on applications to the West Coast and Alaska.
- Developed a cap-and-trade system for regulating habitat impacts of fisheries with the goal of developing a cost-effective approach for protecting habitat. This work proposes and explores a rights-based system to manage fishery impacts on habitat using individual habitat quotas (IHQ). Also compared the performance of the IHQ system with more conventional fixed or rotating Marine Protected Areas (MPA).
- Examined commercial fishing crew demographics and trends using the commercial crew license database of the Alaska Department of Fish and Game. This database in-

cludes information on age, gender, citizenship, and residency and covers 272,000 crew licenses (1993 to 2003). The crew demographics were discussed and analyzed in terms of crew population, license tenure, age and gender distribution, and geographic distribution.

- Published research documenting dramatic size changes in salmon in relation to climate change and population density.
- Published research on northward migration of fish in the Bering Sea in response to changing ocean conditions.
- Identified single nucleotide polymorphisms (SNP) useful for stock identification of salmon and forage fish bycatch in the GOA and BSAI.

Research Priorities, FY 2007–2012:

III.A. Social and economic research

- Assist in implementing and improving data collection programs that support economic and social research.
- Develop and continue to maintain social and economic information databases on the fisheries and fisheries-dependent communities of GOA and BSAI in order to evaluate the impacts of Council actions intended to improve the long-term net benefits derived from fisheries. This information is required for establishing a baseline for use in 1) identifying stakeholders to be included in the distribution of dedicated access privileges (e.g., harvesting quotas and processing quotas), 2) projecting the likely consequences of alternative management measures, and 3) conducting retrospective analysis of management actions that have been taken.
- Prepare the economic status report of Alaska's groundfish fisheries as part of the annual Groundfish SAFE reports.
- Analyze current determinants of ex-vessel, wholesale, international, and retail demands for principal seafood products from the GOA and BSAI.
- Estimate the pre- and post-implementation benefits and costs, and distribution of benefits and costs, associated with changes in management regimes (e.g., changes in product markets, characteristics of quota share markets, changes in distribution of ownership, and changes in crew compensation as a consequence of the introduction of dedicated access privileges in the halibut/sablefish, pollock, and crab fisheries).
- Analyze the robustness and resilience of alternative management strategies under varying environmental and ecological conditions.
- Analyze changes in the spatial and temporal distribution of fishing effort in response to management actions (e.g., time/area closures, marine reserves, bycatch restrictions, co-ops, IFQs).
- Evaluate the evolution of community social and economic structure in response to alternative management actions; the benefits and costs, and the distribution of benefits and costs, associated with consumptive and non-consumptive uses of resources supported by the North Pacific and Eastern Bering Sea ecosystems; and evolving seafood markets.
- Develop longitudinal data sets of ex-vessel, wholesale, and retail prices; daily or weekly,

firm-scale data on production by species and product form; trip-scale data on variable costs for catcher vessels, catcher-processors, and sportfishing charters; daily or weekly plant-scale data on variable processing costs for shore-based and floating processors; annual vessel- or plant-level data on fixed costs; trip-scale information about the location and duration of fishing; weekly or monthly data on patterns of expenditures associated with harvesting, processing, and sportfishing charters; pay-period scale, vessel- and plant-level data on employment and income of fishery participants; socioeconomic and demographic data for fishery-dependent communities; and community- and regional-scale annual data on the distribution and magnitude of tax receipts and transfer payments associated with commercial and sport fishing.

- Expand sociological and economic research and incorporate results into the fishery management process. The process will include the acquisition of data, and development and analysis of socioeconomic models that are compatible with, and can be integrated with, ecosystem models.
- Conduct research on vessel overcapitalization and impacts of their fishing effort levels on fisheries.
- Compile and analyze data on harvesting and processing sector behavior.

III.B. Seafood safety research

This item is not applicable.

III.C. Marine aquaculture

- Conduct stock-enhancement aquaculture research on Chinook salmon at the AFSC's Little Port Walter Marine Station to determine strategies that result in increased contribution of Alaska-origin fish in Alaska fisheries to help achieve an improved harvest balance under Pacific Salmon Treaty oversight.
- Conduct parentage analysis of multi-generational hatchery Chinook salmon and wild stock cohorts using DNA micro-satellites to determine relative biological and fishery contribution performance measures.
- Measure the effects of 70 years of freshwater sequestration on genetic variability, growth, survival, maturation, juvenile behavior, and adult spawning behavior on normally anadromous steelhead trout with protected species implications for successful restoration of ESA-listed stocks.
- Determine effects of different founder regimes on genetic variation in hatchery brood stocks of salmon.

IV. Information Management Research

Recent Accomplishments:

The AFSC communicates its scientific information and advice, along with the associated uncertainties, to NMFS staff, other management authorities, the Councils, and the public. For example, survey results of the AFSC were disseminated to the user groups through the participation of experts at meetings and submission of technical reports and published papers. On a yearly basis, the AFSC publishes roughly 100 scientific papers as well as over a dozen NOAA Technical Memorandums and Center Processed Reports.

The NOAA vessel *John N. Cobb* on a research cruise in Alaskan waters.

The AFSC's Auke Bay Laboratory is developing protocols and formats to comply with Federal Geospatial Data Committee (FGDC) requirements for web-accessible metadata sets of fisheries-related biophysical and oceanographic information. A full FGDC-compliant metadata record has been constructed for a large data set (Southeast Coastal Monitoring [SECM]) consisting of fish catches and associated biological and physical oceanographic data. In addition, a data dictionary has been constructed for the entire data set. The complexity of the SECM data set makes it likely that its metadata record and data dictionary can serve as the example for most other data sets within the AFSC. When all active Auke Bay Lab data sets are FGDC-compliant (by the end of FY 2007), the information will be ready for access via the Internet.

- The AFSC has been proactive in providing public access to research information via the web. Projects include:
  - AFSC scientists have conducted ichthyoplankton cruises in 1972 and yearly from 1977 until the present. The results are now in a web-enabled database, the Ichthyplankton Information System, that allows users to search for information and data on the early life history of fishes from the northeast Pacific Ocean and Bering Sea.
  - AFSC scientists and researchers gather thousands of digital images on the various scientific cruises. The AFSC has web-enabled access to nearly 10,000 images through the deployment of an image management database system.
  - Geographic Information Systems (GIS) play a key role in the analysis of data. The AFSC annually conducts training programs for AFSC scientists and researchers on how to use the various GIS tools available to them.
  - A GIS habitat and fish use database was established in 2006 for nearshore habitats. Nearshore surveys of habitat and fish species use was combined with a ShoreZone GIS database, and includes data from 1998 to present over thousands of kilometers of Alaska shoreline. Data can be accessed online and queried by location or species, and will give managers and researchers quick access to information. Periodic updates are conducted as new information is gathered.
  - The AFSC is the host for the NMFS publication *FishNews*—an automated e-mail newsletter that provides electronic notification of important actions, rules, policies, and programs that may be of interest to the public.
  - The AFSC hosts the scientific editor position for 2005-2008 for the NMFS publication *Fishery Bulletin*, publishing peer-reviewed scientific manuscripts of the highest caliber.
  - The AFSC is developing a Internet-accessible longline survey database.
- The AFSC and other research units of NMFS used stock assessment workshops, peer reviews, and other forums to ensure that our information and advice are developed through an open and collaborative process. The stock assessment process of the AFSC undergoes periodic review internally and externally throughout the years.

- AFSC scientists participated as scientific advisors to bilateral panels and bilateral technical committees in various international salmon forums, including the U.S.-Canada Pacific Salmon and Yukon Treaty accords and NPAFC.
- The AFSC database for bottom trawl surveys is undergoing a major restructuring to include all the catch, haul, specimen, and effort data that are routinely collected. The design is complete and populating the new database is continuing.
- The AFSC provided guidelines to assist the Councils in assessing and recommending MSY for managed fisheries. The AFSC's Resource Ecology and Fisheries Management Division (REFM) has the lead role for defining and estimating the MSY levels for all the groundfish stocks managed in the BSAI and GOA area. The information helps the NPFMC determine the relative status of the stocks to historical levels. The AFSC also has the lead role in defining and estimating the overfishing levels for each of the groundfish stocks managed in the BSAI and GOA area. These maximum fishing levels guide the NPFMC to recommend management measures to maintain the exploitation of the stocks within biologically safe levels.
- REFM provided the technical lead role to develop objective and measurable criteria for stocks that are overfished or approaching an overfished condition. The definitions were used as uniform applications throughout NMFS. These definitions would standardize the criteria for determining depleted stocks due to fishing and other causes throughout the Nation.
- The AFSC provided technical expertise and analysis in environmental impact statements involving Alaska groundfish fisheries. Most notably, AFSC scientists contributed substantially to the successful completion of two key Environmental Impact Statements (EISs): 1) the Alaska Groundfish Fisheries Final Programmatic Supplemental Environmental Impact Statement, and 2) the Final Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska.
- The AFSC is developing ecosystem-based indicators and assessments. This information is being integrated into documents provided to fishery managers in support of ecosystem-based management. Time-series data on climate, fishing, and status and trends of species and ecosystem-level characteristics are being collected from diverse sources and consolidated into a central place to facilitate integrated ecosystem assessments.
- The AFSC provided the technical lead role for developing the Marine Fisheries Stock Assessment Improvement Plan for Alaska groundfish. Research activities include a broad spectrum of field research and data analyses that involves other divisions within the AFSC and partnerships with three universities.
- The AFSC (REFM) continues to provide the technical lead to further define overfishing for uniform applications throughout NMFS. The role also extends into a National Committee tasking to establish new for listing under ESA.
- The AFSC has worked cooperatively with staff from the other NMFS Science Centers and NOAA's Office of Marine and Aviation Operations in the design, development, and implementation of the Fisheries Scientific Computer System on NMFS research vessels. This system provides for improved collection and recording of data collected at sea through the use of improved data collection and computer technology. Work is now continuing to extend these same advances for use on vessels chartered by NMFS to conduct stock assessment surveys.

Research Priorities, FY 2007–2012:

- Develop processes and procedures to enhance the communication of scientific information generated by the AFSC, with emphasis on web-enabled access to its data.
- Continue to build data infrastructure and resources for easy access and data processing. The AFSC's key databases are its survey data bases from the 1950s (or earlier) and the scientific observer database that extends back to the foreign fishing days of the 1960s.
- Continue to provide information products based on experts and technical data that support NMFS, the Regional Office, the Councils, international scientific commissions, and the overall research and management community.

An adult male killer whale breaches the surface. Photo: NMFS.

NORTHWEST FISHERIES SCIENCE CENTER

The Northwest Fisheries Science Center (NWFSC) conducts research to support the management, conservation, and sustainable use of the Pacific Northwest region's anadromous and marine fishery resources and their habitats. The NWFSC carries out its research from its Montlake Laboratory headquarters in Seattle, Washington, and from five research stations in Manchester, Mukilteo, and Pasco, Washington, and in Newport and Pt. Adams, Oregon. The NWFSC's more than 320 Federal employees and 200 non-Federal employees conduct both field and laboratory research in coastal, ocean, and estuarine environments, as well as in inland freshwater habitat used by anadromous species, such as salmon.

The NWFSC has several small vessels for conducting studies. The R/V *Harold Streeter* serves Puget Sound, and the R/V *Murrelet*, R/V *Siliqua*, and R/V *Quinnat* serve Columbia River Basin projects. The Center does not have a dedicated research vessel, but one is currently being planned. Center scientists currently rely on the NOAA FSV *Miller Freeman* and the NOAA vessel *McArthur II*, as well as on privately chartered vessels and academic research ships to supplement the Center's research capability and to conduct critical surveys.

The NWFSC's research brings together a number of disciplines, including fisheries science, marine biology and ecology, genetics, biochemistry, molecular biology, oceanography, mathematics, and physiology. Organizationally, the Center consists of the Conservation Biology Division, the Environmental Conservation Division, the Fish Ecology Division, the Fishery Resource Analysis and Monitoring Division, and the Resource Enhancement and Utilization Technologies Division. In addition, the Center has Socioeconomics, and Science Synthesis and Coordination programs. Across these five divisions and programs, NWFSC scientists and staff conduct research in several primary areas:

- Status of stocks—Center scientists conduct and coordinate stock assessments for West Coast groundfish and salmon stocks in the Pacific Northwest by conducting surveys to monitor trends in stock abundance and biological characteristics, and analyzing these data with mathematical models of the populations. These assessments are the primary tool used by managers to set biologically sustainable harvest levels for healthy stocks and to identify and guide the monitoring and rebuilding of overfished and threatened stocks.
- Human-Caused Stress/Risks—Center scientists conduct research to better understand how salmon, marine fish, and marine mammals react to anthropogenic stresses and to quantify, assess, and minimize associated risks. The Center's research provides the underpinning for management decisions.
- Ecosystem and Climate Characteristics—Center scientists conduct research on physical and biological processes that influence aquatic, marine, and estuarine ecosystems in the Pacific Northwest, as well as the effects of invasive species, toxic phytoplankton, pathogenic bacteria, climate change, and natural environmental fluctuations.
- Recover and Rebuild Species—Center scientists study genetic variation and conduct research on the population structure of salmon, marine fish, and killer whales. The Center also develops innovative recovery tools like captive broodstock programs to propagate salmon species, new techniques for rearing hatchery fish, and culture techniques to rear marine fish. In addition, Center scientists provide scientific leadership for salmon recovery planning efforts on the West Coast.
- Innovation and Technology—Center scientists are taking a lead role in developing and applying technologies, techniques, and tools to support conservation and recovery of the Pacific Northwest's living marine resources. Over the years, the Center's innovative and original research has helped establish new aquaculture endeavors, seafood processing techniques, dam passage equipment and techniques, methods to detect and evaluate harmful algal blooms, and technology to integrate and track important fisheries dependent data, as well as to identify and monitor marine and anadromous fish populations.
- Product Quality and Seafood Safety—Center scientists conduct research on seafood to reduce risks and demonstrate benefits from the Nation's seafood supply. The primary objectives are improving our understanding of, monitoring for, and mitigating the possible adverse human health effects of pathogens (bacteria and viruses), algal toxins, and chemical contaminants in fish and shellfish; understanding human health benefits; and supporting environmentally sound production of marine aquaculture species.

NWFSC research supports critical management decisions. The Center has lead responsibility in the region to study and provide state-of-the-art scientific information on the following primary living marine resources.

- Pacific Salmon—Fifty-two groups of populations (evolutionarily significant units [ESUs]) of salmon and steelhead exist on the West Coast, 26 of which are listed as endangered or threatened under the Endangered Species Act.
- West Coast Groundfish—The West Coast groundfish fishery includes some 80 commercially fished stocks and supports millions of dollars in economic activity and many livelihoods. The Center coordinates the NMFS' Groundfish Program on the West Coast.
- Killer Whales—The Southern Resident killer whale population was recently listed as

endangered under the ESA and depleted under the Marine Mammal Protection Act. The Center has developed a research plan to address possible causes for the killer whale decline and gain a better understanding of the physiology, ecology, and behavior of these whales.

The NWFSC develops and maintains strong collaborative partnerships with state and Federal agencies, industry, environmental groups, Native American tribes, individual fishermen, universities, and other research and academic institutions. The Center also provides opportunities for students in marine research, technology, and library science through cooperative research agreements with regional universities and councils.

RECENT ACCOMPLISHMENTS AND RESEARCH PRIORITIES FOR FY 2007–2012

I. Research to Support Fishery Conservation and Management

Recent Accomplishments:

- Major survey cruises conducted by the NWFSC included:
  - The biennial acoustic survey aboard the NOAA Ship *Miller Freeman* to estimate the biomass and distribution of hake off the coasts of California, Oregon, and Washington.
  - A summer bottom trawl survey on board chartered commercial fishing vessels to assess the distribution and abundance of commercially important groundfish resources off the coasts of Washington, Oregon, and California and to collect other biological data.
  - In collaboration with the Pacific Whiting Conservation Cooperative, a juvenile groundfish survey that extends from the Washington border to central California.
  - In collaboration with fishing industry, a pilot acoustic survey of widow rockfish off the coast of Oregon.
  - A pilot survey to assess abundance and distribution of groundfish in untrawlable areas using autonomous underwater vehicle (AUV) technology.
  - A pilot survey of vermillion and bocaccio rockfish in the southern California Bight.
- The NWFSC conducted two observer programs to collect information from the federally regulated groundfish fisheries off the West Coast, including limited entry trawl and fixed gear fleets, the at-sea hake fleet, and the open access fleet. The observer programs collect valuable data on the bycatch and discard of groundfish. In addition, the observer program data are used to estimate the levels of direct, incidental takes of all protected species, including seabirds, prohibited species of fish, and marine mammals. The observer program is also testing the application of electronic monitoring systems to cut costs while still collecting essential at-sea data. The systems are being tested on the entire hake fleet that processes their catch shoreside—the first full fleet in the Nation to be monitored with this method.
- The Center had lead responsibility for analyzing the population dynamics and status of most of the groundfish species managed by the Pacific Fishery Management Council. It coordinated the groundfish stock assessment and review process for the Council and conducted 12 of the 23 stock assessments during the last biennial management cycle. In 2005 Stock Assessment team members completed assessments of Pacific hake, sablefish, darkblotched rockfish, canary rockfish, Pacific ocean perch, longspine thornyhead,

Yellowtail rockfish. Photo: Timothy Nesseth, NOAA.

shortspine thornyhead, English sole, petrale sole, cabezon, blackgill rockfish, and yellowtail rockfish. Rebuilding analyses were conducted for canary rockfish, darkblotched rockfish, and Pacific ocean perch. Details on these and other West Coast groundfish assessments conducted in 2005 are available online at www.pcouncil.org. These assessments form the basis for Council recommendations for Allowable Biological Catches and Optimum Yields for these species for 2007–2008, which were finalized at the June 2006 Council meeting.

- The NWFSC coordinated the peer review process (STAR panels) for these assessments and also organized several pre-assessment workshops, including one on data issues, one on modeling methods (including introduction of the new Stock Synthesis 2 modeling platform), and another on the use of recreational catch per unit effort (CPUE) data, which was co-sponsored with the Southwest Fisheries Science Center.
- Through a cooperative agreement between NMFS and the Pacific States Marine Fisheries Commission, the NWFSC hosted the cooperative Ageing Lab based at Hatfield Marine Science Center. The Ageing Lab produced ages to support assessments on Pacific hake, Pacific ocean perch, sablefish, Dover sole, canary rockfish, darkblotched rockfish, and English sole.
- The NWFSC has also expanded its stock assessments by incorporating environmental indices. Key oceanographic variables have been identified and correlated with annual variations in sablefish recruitment success. This work was formally incorporated into the 2005 sablefish stock assessment.
- In cooperation with Oregon Sea Grant, Center staff designed a project to compensate fishermen who participate in research planning and data collection. As part of this project, port liaisons—local leaders in West Coast communities—have been selected to help match fishermen with research projects, and the fishermen are then compensated for their time spent assisting in research and research planning.

Other accomplishments by the NWFSC include:

- Statistically evaluated the relationship of climate with recruitment of bocaccio and the interaction of fishing and climate impacts on groundfish and on rebuilding of overfished groundfish.
- Updated models and data inputs used for estimating discards in directed groundfish fisheries off Washington, Oregon, and California.
- Conducted studies in groundfish ecology, species life histories, and historical data patterns. This included the development of a new program to collect information on trophic dynamics of key groundfish during the bottom trawl surveys.

- Developed a coupled biological-oceanographic fisheries model of the California Current that can be used to test sensitivity of ecosystem indicators to natural and human-induced environmental perturbations, to evaluate the effects of management strategies on ecosystem attributes, and to forecast changes in the California Current LME as a result of climate oscillations or climate change.
- Used active and passive ultrasonic telemetry to characterize the daily and seasonal movements of groundfish and apex predators. These data have been used to parameterize models of movement that allow us to evaluate habitat preferences, movement rates, and responses to fishing. Such models also allow us to estimate the number, size, and location of marine reserves necessary to achieve specific fisheries or conservation goals.
- Developed species-area relationships for West Coast groundfish. The relationships allow us to evaluate trade-offs between fisheries yield and conservation goals, the value of a few large Marine Protected Areas versus several small ones, and mechanisms maintaining fish biodiversity in the California Current.
- Authored the West Coast cold water coral chapter for the national report on cold water corals, and provided a summary of cold water coral information off Washington, Oregon, and California to be used during analyses and discussion of areas to be proposed for EFH designations.
- Applied inductively coupled mass spectrometry and laser ablation to characterize the chemical composition of water masses as well as the otoliths of juveniles to identify essential nursery habits for English sole. Examined the juvenile portion of adult otoliths to determine whether different habitats contributed disproportionately to the adult population. Results indicate that fish from regions within 10 km of urban centers grow slower and die at a greater rate than in areas distant from urban centers, even when habitat structure is identical.
- Developed frameworks to provide management options specific to community protection and community quota to include as alternatives for the Trawl Individual Quota System. The Pacific Fishery Management Council was able to select specific community options for future impact analysis in an environmental impact statement process.
- Conducted and published an ESA status review for Cherry Point (Puget Sound) Pacific herring.
- Conducted research on prespawn mortality in adult coho salmon from urban streams. The Center documented rates of 60 to 90 percent pre-spawn mortality over the past 3 years and developed population models based on these results.
- Conducted research to estimate growth condition of juvenile salmon during early phases of ocean entry. Physiological indicators of growth status (plasma insulin-like growth factor I) of juvenile coho salmon off the coast of Washington were related to long-term survival.
- Continued research designed to estimate the relative reproductive success of naturally spawning hatchery salmon and initiated a new long-term research project to study the genetic effects of hatchery rearing on the fitness of wild salmon populations.
- Continued to chair three salmon Technical Recovery Teams (TRTs)—Puget Sound, Lower Columbia River and Willamette River, and Interior Columbia River Basin—and co-chaired the Oregon and Northern California Coast TRT. These teams are describing the biological conditions necessary for recovery of listed populations and are

providing technical support to policymakers to help evaluate alternative strategies for meeting recovery goals. In conjunction with the Northwest Regional Office, Southwest Regional Office, and Southwest Fisheries Science Center, the NWFSC developed the original TRT concept, purpose, and goals.

- Developed a framework for analyzing the economic impacts of critical habitat designation under the ESA. This framework was successfully applied to critical habitat designations for 12 West Coast salmon and steelhead ESUs, and to Southern Resident killer whales.
- Developed an understanding of the role of estuaries as critical habitat to enhance population productivity and resilience needed to support recovery of endangered salmon stocks.
- Developed an understanding of the role of river plumes as they interact with the California Current as critical habitat for salmon and coastal pelagic species.
- Developed economic guidance for estimation of costs of recovery actions for West Coast salmon and steelhead recovery planning.
- Developed final or draft biological viability criteria for listed salmon ESUs in Puget Sound, the Lower Columbia River, Interior Columbia River, and Oregon Coast.
- Developed methods for assessing human impacts on stream habitats in tributaries to the Columbia and Snake Rivers, and completed analyses of habitat change in the Columbia River basin. These analyses helped identify populations where habitat restoration is likely to improve salmon populations, and also where there are few opportunities to increase salmon abundance through habitat restoration.
- Initiated model development to quantify the population and genetic effects of conservation-type hatcheries for rockfish stocks.
- Initiated research to estimate the early marine survival of steelhead and identify nearshore habitats important for survival.
- Led a multi-agency project that created a standardized genetic dataset for Chinook salmon sampled from California to Alaska. The dataset is being used for estimating fishery impacts, and for understanding the ocean distribution of salmon stocks.
- Organized and sponsored a Symposium/Workshop (March 2005 in Seattle) on designation of conservation units of Pacific salmon and steelhead, with special emphasis on complex units that might include both resident and anadromous populations and/or both hatchery and natural populations. The objective was to review the state of the science underlying complex legal and policy issues that NMFS must address under the ESA. The symposium was attended by over 150 people, and the report of the Science Panel outlines scientifically defensible options for NMFS to consider in listing determinations.
- Produced a final guidance document for developing monitoring and evaluation plans for ESA-listed salmon stocks.
- Published a book sponsored by the American Fisheries Society entitled *Monitoring Stream and Watershed Restoration*. The book, consisting of 12 chapters authored primarily by NWFSC scientists, provides comprehensive guidance on how to monitor and evaluate habitat restoration projects for salmon and other fish species that are important in the Pacific Northwest. The book synthesizes much of the important innovations in

monitoring and restoration science made by Center scientists in the past several years. Additionally, this publication provides guidance on the cost-effectiveness (i.e., hundreds of millions of dollars being spent annually on habitat restoration for salmon) of habitat restoration on improvements in habitat conditions as well increases in salmon abundance. The book is being used extensively by local watershed groups, scientists, and restoration practitioners to quantify physical and biological response to various stream restoration techniques at various scales.

A chinook salmon in spawning colors. Photo: USGS.

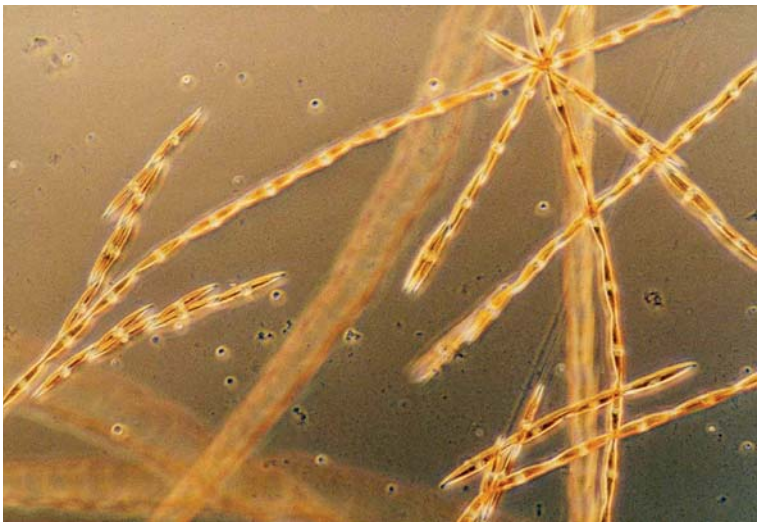
- Developed recovery plans for 17 listed salmon and steelhead populations in four geographic domains under the Center's jurisdiction.
- Led the Interior Columbia TRT's effort to develop a draft population viability document. This document describes key parameters related to population viability (abundance, productivity, spatial structure, and diversity) and is a critical step for developing biological recovery goals. These goals are also useful in determining when listed salmon populations will no longer be considered threatened or endangered.
- Conducted cooperative sampling effort in Puget Sound nearshore environments to better understand life history patterns of six Skagit River Chinook populations. The sampling program filled important life history data gaps and greatly improved our ability to model potential effects of restoration on various life history patterns. The findings of this study have led to an expanded Puget Sound-wide sampling program being conducted by scientists with the NWFSC, U.S. Geological Survey, and local tribes, with monetary support from Seattle City Light, U.S. Army Corps of Engineers, and the Port of Bellingham.
- Hosted an international conference on Bacterial Kidney Disease (BKD), with presentations on the history, current research, and future needs and directions in the study of *Renibacterium salmoninarum*. The *R. salmoninarum* Genome Project was also publicly unveiled during the conference. Microbiologists, fisheries biologists, and resource managers from the United States, Canada, Iceland, Norway, and the United Kingdom attended the conference. A conference website with most of the scientific presentations and future needs summaries is hosted by the NWFSC.
- Hosted a workshop to identify needs and future directions for a West Coast program using marine mammals as sentinels of ocean change impacting human health. Veterinarians, biologists, and epidemiologists working with marine mammals attended, a West Coast network is proposed, and website for communication among attendees will be hosted by the NWFSC.
- Sampled California sea lions on the Channel Islands (San Miguel Island and San Nicolas Island) and in Seattle for the incidence of different zoonotic fecal bacteria. A high prevalence of *Salmonella* spp. and *Campylobacter* spp. was identified on the islands; *Salmonella* decreased northwards, and *Salmonella* isolates from the islands showed no

antibiotic resistance. Presence of both these bacteria in gulls suggests these birds may be important vectors of these enteric bacteria.

- Investigated the prevalence of different zoonotic fecal bacteria in elephant seals, and areas of high *Salmonella* and *Campylobacter* spp. prevalence were identified.
- Chaired a Biological Review Team to review the status of the Southern Resident killer whale population. The team evaluated whether these whales were a distinct population of the global killer whale species, examined why the whale population has been declining, and estimated the risk of extinction of this stock. The report led to a listing as endangered.
- Co-hosted, with the Washington Department of Fish and Wildlife and the Canadian Department of Fisheries and Oceans, a killer whale research symposium to review recent research accomplishments and identify future priorities.
- Conducted research on Southern Resident killer whales, including studies to determine what species and stocks of fish they prey upon.
- Sampled eight adult California sea lions with documented urogenital cancer, five non-cancerous sea lions for DNA adduct analyses, and 14 fresh dead late-term sea lions for additional analyses.
- Established a detailed postmortem sampling protocol (i.e., urogenital tract, other parenchymal tissues) for both cancerous and non-cancerous sea lions. Tissue samples for both DNA adduct analysis and future caricinogenesis studies were obtained.
- Determined the antimicrobial resistance in *Escherichia coli* isolated from rectal swabs using broth microdilution from free-ranging elephant seals on their natal beaches and stranded seals at admission and release from the Marine Mammal Center. These results indicate antibiotic resistant *E. coli* are acquired by elephant seals in coastal waters rather than on the beach from other seals.
- Measured chemical signals—fatty acid profiles, carbon and nitrogen stable isotope ratios, and persistent organic pollutants (POPs) concentrations, patterns, and ratios—in blubber biopsy samples and used this data to provide information about prey species of killer whale groups called "ecotypes." In North Pacific waters, two ecotypes have been identified—the "transients" (thought to prey solely on marine mammals) and the "residents" (believed to principally consume marine fish). Because of possible predation by Alaskan transients on protected Alaskan marine mammal populations, more information is needed about the specific diet of this ecotype. In the current study, carbon and nitrogen stable isotope ratios, supported by field observations of the transient diet, found that it is unlikely that Steller sea lion pups represent a substantial proportion the overall diet for Alaska transients. In addition, Alaskan resident killer whales were found to be consuming a fish diet, based on both field observations and their chemical signatures compared to those of other resident populations. A third ecotype—the "offshores"—had fatty acid profiles in the blubber most similar to those of the fish-eating resident ecotype. POP concentrations and ratios suggested these whales are consuming contaminated, predatory species that are distinctly different from those of sympatric resident and transient killer whales.
- Developed a status report on the state of the California Current to be used by fisheries managers.
- Initiated a multi-agency collaborative process to develop a scientific framework for an

ecosystem approach to management in Puget Sound.

- Initiated projects to study the effects of climate change on salmon population viability.
- Led an inter-institutional effort to develop new tools for ecosystem-based management, including efforts with University of Washington to include climate cycles and climate change scenarios in rebuilding models.
- Became a NOAA Oceans and Human Health Initiative Center of Excellence to investigate linkages between ocean processes and human health—specifically the impacts of pathogens, marine biotoxins, and toxic chemicals on both seafood and sentinel species.



Microscopic view of *Pseudo nitzschia* plankton, prominent in harmful algal blooms (HABs) and which accumulate in shellfish and are potentially lethal to humans. Photo: NMFS.

- With collaborators at the National Research Council, Canada, University of Washington, and University of Maine, determined the molecular basis for resistance to paralytic shellfish toxins in clams. Determined that a mutation in the sodium channel of nerves in clams from areas that have records of paralytic shellfish poisoning (PSP) results in a single amino acid change in these channels, conferring over 1000x resistance of clams to saxitoxins. This is the first demonstration of a harmful algal bloom (HAB) as a natural selection agent in the marine environment, resulting in greater rates of toxin accumulation in exposed clams, thereby increasing the risk of PSP to humans. This understanding of shellfish adaptation to toxins will serve as a model for improved characterization of the effects of oceans on human health.
- Led a multi-institutional study of the ecology of harmful algal blooms along the West Coast of the United States. Scientists successfully identified a potential "bloom initiation site" and correlated storm activity with the arrival of toxic blooms on the coast. The use of drifter buoys to track blooms also has provided insight into the conditions that favor the movement of HABs toward shore, where shellfish beds may be contaminated. In addition, the biophysical models resulting from this project will be applicable to other coastal regions around the world that are affected by similar toxic events.
- Participated in two HAB sampling cruises to collect bacterial samples from phytoplankton bloom areas off the Washington coast in order to begin studies on the relationship of *Vibrio parahaemolyticus* with algal blooms. These samples will be analyzed for *V. parahaemolyticus* by qPCR, and the presence/absence compared to sample data already available, including species of phytoplankton and salinity/temperature/depth data for each sample and sample site.
- Identified key factors expressed by pathogenic *Vibrios* that contribute to shellfish colonization and ability to cause disease in human hosts. Understanding the mechanisms used by the bacteria to persist in the environment holds promise toward development of methods to eliminate them from shellfish prior to market.
- Analyzed the risk of zoonotic disease, integrating landscape ecology, community theory, and epidemiology in Bayesian relational models.

- Characterized the impact of polycylic aromatic hydrocarbons (PAH) exposure on the kinetic expression of both innate and adaptive immune system genes in rainbow trout.
- Established a zebrafish model system as a new experimental system for investigating the impacts of chemical contaminants on fish development. Studies showed that the developing heart is the most likely target of PAH toxicity, and that deformities in PAH-exposed embryos can be attributed to cardiac arrhythmia and circulatory failure. These findings hold considerable promise for developing new cardiovascular biomarkers that can be used to monitor the health of at-risk fish species in the coastal waters of the United States.
- Implemented a series of innovative improvements to the methods used to analyze for persistent organic pollutants in environmental samples. The new procedures have improved quality assurance results significantly, so that now more than 90 percent of analyses in standard reference material agree with certified values (70 percent is the minimum allowable). Furthermore, costs for the analyses have been lowered by 43 percent. Finally, safety has been improved considerably by reducing solvent consumption by 60 percent and hazardous waste by 40 percent.
- Monitored contaminant concentrations in water, sediments, and juvenile Chinook salmon from five sites along the Columbia from Bonneville to the mouth of the estuary, and from local hatcheries, and are using the data to model potential impacts on salmon health and survival. Results indicate toxicants are widespread in the system, with particularly high concentrations in the Portland area. In addition, salmon are being exposed to other environmental stressors (i.e., estrogenic compounds and brominated fire retardants [PBDE]). These data were used to develop a population dynamic model to assess the incidence and corresponding significance of delayed disease-induced mortality in outmigrant salmon populations associated with environmental stressors.
- Deployed several databases to support research involved with ESA-listed salmon species for abundance, artificial propagation release and spawner, age structure, harvest fraction, bird predation, and habitat data tied to ArcInfo IMS mapping software available online. These efforts are aimed at bringing together disparate data sources, integrating where feasible, and providing a centralized corporate repository that will be managed over the data and application life cycle tied to geospatial locations for query and analysis.
- Deployed a centralized GIS repository with over 89 corporate geospatial layers and 204 individual project layers and serving over 30 GIS users within the Center. Efforts are expanding to share the NWFSC GIS infrastructure and technical support with the Northwest Regional Office users for ESA-listed salmon recovery efforts.
- Worked closely with the Northwest Regional Office to develop a centralized web-enabled database to track funds from the Pacific Coastal Salmon Recovery Fund (PCSRF) with five states and 10 tribal groups. This database is tracking $462 million in funding for over 5,857 projects and has been used to generate data needed for the PCSRF Annual Report to Congress.
- In collaboration with Oregon State University, created a Geologic and Geophysical Bottom Character Database and GIS for U.S. West Coast groundfish. The database and GIS project for West Coast Essential Fish Habitat is a joint effort between the NWFSC and the Active Tectonics and Seafloor Mapping Laboratory at Oregon State University.
- Developed an access database of habitat utilization of groundfish to support analysis of Essential Fish Habitat information.

- Merged the North Pacific Marine Science Organization (PICES) Harmful Algal Bloom (HAB) Section harmful algal event database (HAE-DAT) with the ICES/IOC database. The goal is to enroll countries in the creation of worldwide maps that will document harmful algae events on a yearly basis. This marked the first year of PICES member country HAB data submission to HAE-DAT.
- Applied innovative technologies such as the use of AUVs to survey rockfish and the use of biopsy hooks to assess groundfish abundance of rockfish by genetic identification on individuals for "tag recapture" assessments.
- Conducted an integrated study using radio telemetry and PIT-tag technology to evaluate total project survival, route-specific survival, and fish passage behavior at Ice Harbor and Lower Monumental Dams for yearling and sub-yearling Chinook salmon.
- Conducted analyses in support of the Columbia River Federal Hydropower System Biological Opinion, including analyses of the survival changes necessary to reach the population viability goals set by the Technical Recovery Teams.

Research Priorities, FY 2007–2012

I.A. Biological research concerning the abundance and life history of fish stocks

The following surveys are planned:

- Conduct an annual bottom trawl survey on groundfish across the entire California Current LME with chartered fishing vessels.
- Conduct the biennial midwater trawl acoustic surveys to assess the abundance of hake off the West Coast using the NOAA FSV *Miller Freeman*. This survey will be conducted in collaboration with the Department of Fisheries and Oceans Canada.
- Conduct the annual groundfish juvenile/prerecruit survey from the Canadian border to central California.

  In addition, in response to GAO recommendations, the Center will continue to develop new surveys for groundfish to address needs for additional information on species not surveyed by traditional bottom trawl surveys. These surveys include:
  - An annual survey using AUV platforms developed by Woods Hole Oceanographic to survey species in untrawlable areas
  - An annual survey of widow rockfish in cooperation with the fishing industry.
  - An annual hook and line survey of vermillion and bocaccio rockfish in the Southern California bight.
- The following observer programs are planned for the groundfish fisheries that occur off California, Washington and Oregon:
  - 25 percent observer coverage of permitted trawl fleet.
  - 25 percent observer coverage of permitted fixed-gear fleet.
  - 100 percent observer coverage of fishing vessels at-sea processor fleet.
  - 5 percent observer coverage of the open-access groundfish fleet.
- The NWFSC will coordinate the assessment and review of the status of West Coast groundfish stocks. The NWFSC will coordinate and organize pre-assessment workshops, including workshops on modeling, data, and trawl survey data use and standards.

- Stock assessment scientists will 1) assess the status of Pacific ocean perch, sablefish, Pacific hake, darkblotched rockfish, canary rockfish, English sole, arrowtooth flounder, and longnose skate; and 2) test and improve the capability of assessment software to use available ecological indicators and correctly estimate pertinent fishery parameters.
- The NWFSC cooperative ageing laboratory will produce age information to support assessments of Pacific hake, Pacific ocean perch, sablefish, Dover sole, canary rockfish, darkblotched rockfish, arrowtooth flounder, and English sole.
- The NWFSC staff will improve the reliability of fish ages used in assessments through further age validation research.
- The NWFSC will continue to provide analyses to support biologically based delisting goals for listed salmon and steelhead. This work will be carried out by the Puget Sound, Willamette/Lower Columbia River, Columbia River Basin, and Oregon and Northern California Coast Technical Recovery Teams (TRTs). TRTs will apply extinction risk estimates to salmonid populations to establish rationally based priorities for recovery goals.
- Center staff will conduct research to evaluate newly developed methods for the analysis of population genetic data and their applicability to real-world problems in natural resource management (these methods and evaluations are applicable to all species under NMFS' jurisdiction). Genetic Stock Identification studies will be continued to determine stock allocation under the Pacific Salmon Treaty, help elucidate the ocean migration patterns of listed salmon stocks, and compare different methods of stock identification.

The NWFSC will also:

- Initiate research projects to measure the long-term effects of hatchery supplementation on the abundance, productivity, and diversity of wild salmon populations.
- Continue and initiate new research on the predicted effects of climate change on Northwest ecosystems, particularly with regard to ESA-listed Pacific salmon.
- Assess condition of juvenile salmon during early ocean entry in Puget Sound and Washington coast.
- Assess the distribution and relative abundance of resident (rainbow trout) and anadromous (steelhead) *Oncorhynchus mykiss* to help determine population status.
- Develop an ocean condition index of the California Current ecosystem.
- Develop more efficacious vaccines or chemotherapeutants to treat Bacterial Kidney Disease in salmon.

I.B. Interdependence of fisheries or stocks of fish

NWFSC staff will:

- Develop bioenergetics models for *Sebastes* species, and use these models to examine various issues, such as per capita prey demand of different species, the influence of temperature anomalies (e.g., PDO shifts, El Niño) on fish growth and reproductive potential, and habitat-specific prey allocation across different life history stages of rockfish.
- Collect and analyze stomach contents of groundfish to determine ecological linkages between species.

- Develop and maintain an ecosystem management model for the California Current LME.
- Analyze survey and observer data to determine spatial distributions of different species.
- Develop genetic baseline data for selected species of groundfish to establish stock structure and stock boundaries.
- Determine incidence of coded-wire tagged salmonids in commercial and research groundfish catches.
- Conduct field observations on home ranges of rockfish and lingcod, and develop model to link these data to Marine Protected Area design.
- Develop biophysical models to quantify the ecological linkages of juvenile salmon distribution, growth, and survival in Pacific Northwest estuarine and coastal marine waters.
- Improve understanding of the impact of future climate change on ocean conditions of the California Current ecosystem.
- In partnership with the Marine Mammal Center, develop tools to measure the presence of and effects of domoic acid and chemical contaminants in California sea lions, which serve as a model for human heath impacts and a proxy for ecosystem condition.

I.C. Identifying, restoring, and mapping of essential fish habitat (EFH)

The NWFSC will:

- Conduct acoustic surveys of ocean floor to characterize and identify bottom type and map groundfish habitats off the West Coast.
- Conduct pilot mapping of areas closed as groundfish essential fish habitat.
- Describe benthic habitats, community structure of the habitats, and the basic life histories and distributions of corals, sponges, and other benthic invertebrates in the California Current LME.
- Develop tools for recovery planning that meld economic costs with biological benefits to ensure that conservation planning is responsive to both economic considerations and biological needs

I.D. Impact of anthropogenic factors and environmental changes on fish populations

The NWFSC will:

- Assess effects of fishing on EFH and develop ways to minimize adverse impacts.
- Analyze the response of groundfish populations to changes in climate and the ecosystem.
- Assess the evolutionary consequences of anthropogenic changes on salmon populations (previous assessments have focused almost entirely on demographic effects).
- Develop bioenergetic models and a photographic key for larval rockfish.

- Evaluate potential long-term effects of short-term exposure of juvenile salmon to endocrine disrupting contaminants that are present in sewage waste water effluent.
- Evaluate potential endocrine disrupting activity of flame retardant chemicals—Polybrominated diphenyl ethers (PBDEs)—in fish.
- Analyze effects of multiple stressors on salmon and marine fish populations through use of next generation population dynamic models.
- Determine relationships between land use, stormwater flows, water quality, fish health/survival/reproduction, and population viability for Pacific salmon in urbanizing areas.
- Develop methods for assessing developmental processes in wild salmon and marine fishes.
- Implement a forecasting capability for detecting and responding to harmful algal bloom events on the Northwest coast.
- Using chemical signatures, evaluate the life history and feeding ecology ecotypes for killer whale populations on a global scale.
- Link habitat characteristics to salmon productivity in a quantitative manner for freshwater and estuarine systems of the West Coast.
- Describe the relationship between impaired reproductive processes and contamination of urban bays for marine groundfish species.
- Evaluate the long-term effects of supplementation hatcheries on the abundance, genetic, and demographic characteristics of salmon populations in the Pacific Northwest.
- Determine impact of environmental change (temperature, salinity, zooplankton quality/quantity, etc.) on growth and development of larval marine fish. Develop a predictive model based on results.

II. Conservation Engineering Research

Recent Accomplishments:

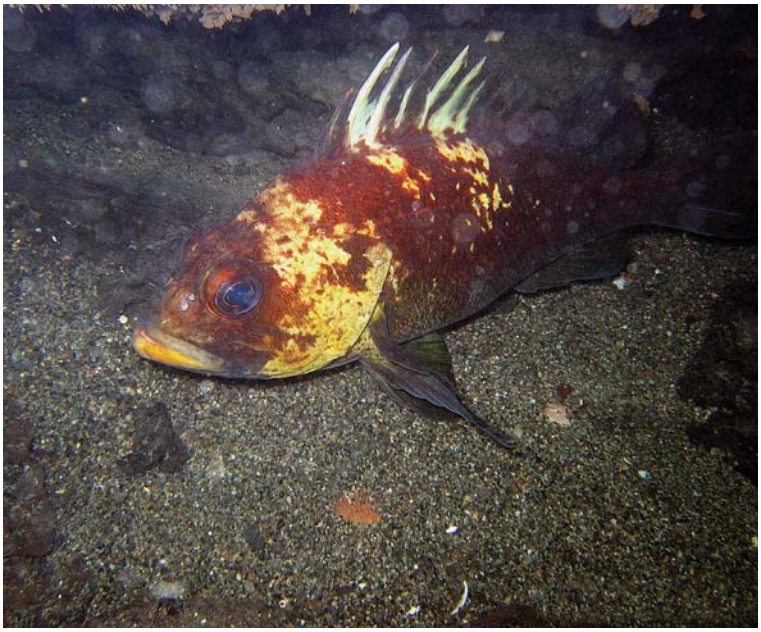
- NWFSC staff continued to work with the State of Oregon to test and develop gear to reduce the capture of overfished groundfish. Initiated in 2004, this project used a state-of-the-art ultrasonic camera (DIDSON, or dual frequency identification sonar) in conjunction with conventional in situ video to document and categorize fish behavior during the sequence of capture in bottom trawls with an emphasis on a selective flatfish trawl—an experimental net being used in West Coast groundfish fisheries.
- The NWFSC conducted research to produce Chinook salmon from artificial propagation programs with age of maturity similar to that of fish rearing in their native habitat. Juvenile salmon rearing conditions and growth regimes that reduce proportions of males maturing at age 2 have been developed. This information is being used to control age of maturity in fish reared in captive broodstock programs to aid recovery of ESA-listed stocks of Pacific salmon. Spawning locations for hatchery and wild spring Chinook salmon in the Yakima River were characterized and the efficacy of acclimation ponds for improving homing fidelity of hatchery fish determined. Center staff initiated a large-scale, long-term experiment to quantify the demographic and genetic effects of supplementation-type hatcheries, and developed a method of detecting natural spawning of salmon by implanting electromyogram transmitters and monitoring muscle activity.

- Center staff developed biofilm and chitin binding assays for *V. parahaemolyticus* and *V. vulnificus*. These assays will be used to assess the role of the type IV adhesins in environmental persistence. Center staff also demonstrated that the *V. vulnificus* type IV fimbrial adhesin encoded by PilA is required for biofilm formation, epithelial cell adherence, virulence, and persistence in oysters, confirming that the PilA adhesin is an important colonization factor. This is the first study to show that a specific bacterial protein structure contributes to colonization of shellfish. They also confirmed that PilA and MshA are highly conserved among all strains of *V. parahaemolyticus* isolated from many geographical areas (like *V. vulnificus*). This suggests that adherence and colonization factors identified for one strain will be applicable to all, an important consideration for development of a universal colonization inhibitory factor.
- Center staff also constructed in-frame deletion mutants in the PilA gene in both *V. parahaemolyticus* and *V. vulnificus*. In order to study the role of the PilA and MshA adhesins, it is necessary to construct mutants unable to express these proteins without affecting expression of adjacent genes. This was a significant hurdle requiring considerable empirical experimentation. Development of the method will now allow us to construct similar mutants deficient in expression of MshA, as well as strains defective in expression of both adhesins.
- NWFSC staff developed cytometric criteria for tracking HABs. Identification of functional phytoplankton groups is now possible. A single cell immunofluorescent assay for domoic acid was developed through a jointly sponsored study between the University of Washington's Pacific Northwest Center for Human Health and Ocean Studies and NOAA's West Coast Center for Oceans and Human Health.
- The NWFSC developed methods to characterize the diversity of V, D, and J regions within salmon lymphocytes that will be used to assess the potential impact of contaminants on antibody diversity, and thereby provide a fundamental underpinning for observed population level effects.
- Initial immunohistochemistry was completed on various tissues from six sea lions to determine whether antibodies to p53, estrogen receptor, progesterone receptor, Ki67, and E-cadherin will cross-react with formalin fixed paraffin embedded sea lion tissue. Initial results indicate good cross reactivity between sea lion tissues and all the antibodies except anti p53. Interestingly, an estrogen receptor was identified in genital epithelium in males and females.
- NWFSC staff continued developing and testing acoustic technologies designed to measure survival and behavior of anadromous salmonid juveniles at Columbia River hydroelectric projects and in the river's estuary and plume environment.

Research Priorities, FY 2007–2012:

NWFSC staff will:

- Conduct surveys of habitat to measure direct effects of bottom trawling on seafloor habitat.
- Conduct fish behavioral studies in field to assist in development of gear to reduce bycatch and bycatch mortality of prohibited, undersized, or unmarketable species.
- Work with industry and the Council to develop bycatch reduction techniques.



Quillback rockfish. Photo: Timothy Nesseth, NOAA.

- Develop groundfish information for national reports on bycatch.
- Continue to fund industry cooperative research projects that propose the development of bycatch reduction methods.
- Continue to develop an acoustic telemetry receiver array in Puget Sound and Hood Canal to track the movements and estimate survival of numerous marine species, monitor species interactions, and identify important habitats.
- Continue to develop understanding of how and why pathogenic *Vibrio* bacteria persist in the environment and develop methods to remove them from harvested shellfish prior to market.
- Continue to study *V. parahaemolyticus* association with marine phytoplankton, zoo plankton, and various climatic and ocean conditions in order to develop and refine risk assessment models for the shellfish industry and public health agencies.
- Use radiotelemetry and PIT-tag technology to evaluate the performance of removable spillway weirs as a surface-oriented passage route for yearling and sub-yearling Chinook salmon at Ice Harbor and Lower Monumental Dams.
- Continue advancing PIT-tag and acoustic technologies to promote safe and efficient fish passage through hydropower systems and other unnatural barriers, and to gain understanding of migration patterns.

III. Research on the Fisheries

Recent Accomplishments:

The NWFSC developed and began fielding a survey to collect cost information from the West Coast groundfish trawl fleet. Phase 1 of this effort, covering Oregon trawlers, has yielded a positive response rate of over 65 percent. A recreational valuation survey of Washington and Oregon recreational anglers was also developed and initiated. A new economist was hired to coordinate data collection and model development for analyzing regional income impacts associated with West Coast fisheries. Center staff developed objectives and methodology for a cost-earnings data collection program covering West Coast groundfish fisheries and ocean troll salmon fisheries. A pilot research project on methods for enumerating and profiling Washington coast communities involved in West Coast and North Pacific fisheries, including the West Coast groundfish and salmon fisheries, was conducted. Frameworks to discuss communities in quota systems were also developed. The Pacific Fishery Management Council (PFMC) was able to select specific community options for future impact analysis in an environmental impact statement process. NWFSC staff conducted collaborative research to gain a greater understanding of management measures that have been incorporated into global individual quota systems with the specific goals of protecting or addressing community impact and issues under a quota system.

In 2005–2006, NWFSC staff provided critical responses (cruises on the R/V *Nancy Foster* and *Gordon Gunter*) through sampling of seafood species (i.e., mollusks, crustaceans, and fish) and measured chemical contaminant levels to provide information for determining suitability for consumption as a result of Hurricane Katrina. In addition, pathogens were measured in water, sediment, and tissues to assess risks to humans.

Salmon-related accomplishments included:

- Initiated research to estimate rates of early male maturation of spring Chinook salmon in Columbia Basin production hatcheries.
- Conducted research to maximize the fitness of salmon reared and released from artificial propagation programs aimed at conserving depleted salmon and steelhead populations.
- Continued cooperative activities, using Center-developed captive broodstock technology, to spawn sockeye and Chinook salmon captive broodstock for use in stock restoration activities in Idaho and Oregon. This effort returned more than 350 sea run sockeye salmon adults to the Stanley Basin Lakes over the past 8 years (1999–2006). This is more than a 20-fold increase over the number of fish returning to the Lakes during the prior 8 years (1991–1998).
- From 1998 (inception of research program) to 2006, NWFSC staff have developed and improved the technology to rear 10 species of local marine organisms from the egg to the juvenile stage. Five species had never been reared before. The capacity to produce small numbers of juvenile marine fish for laboratory study allows development of bioenergetic models to improve models used for management, and opens the door for small-scale stock enhancement and commercial aquaculture experiments with those species. Specific studies have focused on optimizing environmental conditions and nutritional quality of early life stages of a variety of marine organisms. Genetic studies and small-scale releases (less than 25 fish) of two species have occurred. Additionally, experiments designed to commercialize the culture of two species of local marine fish (sablefish and lingcod) were conducted. Studies included development of hatchery and grow-out technology, feeds development, and final product quality evaluation. Sablefish is now being reared commercially, and lingcod is being considered by industry.
- Center staff co-authored the Code of Conduct for Responsible Aquaculture in the United States Exclusive Economic Zone (EEZ) and the Draft National Offshore Aquaculture Act now before Congress.
- The NWFSC provided NOAA with the first Aquaculture Matrix Manager. Additional staff served and still serve as a part of the NOAA Aquaculture Matrix team and provide written and verbal technical information to the NOAA Aquaculture Matrix Manager.
- NWFSC HAB staff conducted a pilot field study on the effects of HABs on planktivorous fish and assessed the potential for risk by consumption of HAB-contaminated seafood using a cruise of opportunity (leveraged from PNW ECOHAB).
- The NWFSC demonstrated the utility of the zebrafish model for cross-disciplinary research with applications to both human and fish health.
- The NWFSC aquaculture team developed and demonstrated a fish/marine algae co-culture aquaculture system. The algae portion has been commercialized.
- The Center worked with partners to develop and apply hatchery reform protocols as

part of the congressionally established Puget Sound Hatchery Scientific Review Group and the U.S. Fish and Wildlife Service Hatchery Review Team for service facilities in the Columbia River Basin.

- The NWFSC led the effort to sequence the genome of the predominant bacterial pathogen of ESA-listed salmon stocks, *Renibacterium salmoninarum*, and the causal agent of Bacterial Kidney Disease (BKD). The results and data generated will aid studies on the development of more efficacious therapeutic treatments or vaccines, increasing broodstock and hatchery fish survival.
- The Center published a series of review papers on the risks of salmon culture to the Pacific Northwest marine ecosystem and human health.
- The Center organized and hosted an International Workshop on the Risk Assessment of Marine Fish Aquaculture on behalf of the United States and the European Union for the FAO Committee on Fisheries (COFI), Sub-committee on Aquaculture (April 2005).

Research Priorities, FY 2007–2012:

III.A. Social and economic research

- Expand sociological and economic research and incorporate results into the fishery management process by collecting cost earnings data from fleets and coastal communities, and developing models that can integrate with ecosystem models for evaluating the socioeconomic effects of management or stock abundance changes.
- Conduct research on the valuation of recreational fisheries and develop models for evaluating the effects of management or stock abundance changes.
- Compile and analyze socioeconomic data to be added to ecosystem management models.
- Develop and analyze information to be used in development of IFQ alternatives for the West Coast groundfish fishery.
- Investigate the interdependence of West Coast communities involved in fishing and their social and economic dependence on North Pacific and other non-West Coast fisheries.
- Describe and enumerate West Coast environmental justice communities dependent on or engaged in fishing.
- Develop methods and collect data to facilitate the evaluation of the cost-effectiveness of actions for the implementation of recovery planning for endangered species.
- Describe, characterize, and quantify non-consumptive social and economic values associated with Northwest marine mammal populations, specifically the Southern Resident killer whales of the Greater Puget Sound.
- Clarify and describe communities that are dependent on, engaged in, or otherwise impacted by the West Coast Groundfish Trawl fleet. Data will be used in the future analysis of impacts on communities under a quota management system.
- Develop behavioral models of economic incentives affecting the level and allocation of fishing effort in fisheries with FMPs.

- Expand sociological and economic research and incorporate results into the fishery management process.
- Compile and analyze additional data on harvesting and processing sector behavior.
- Expand sociological and economic research and incorporate results into the fishery management process.
- Investigate local knowledge so it may be incorporated into the design and management of marine protected areas and quota systems.
- Investigate human, institutional attributes associated with successful efforts to respond to watershed flow conditions, and that are consequently linked to the implementation of water flow controls to support salmon recovery.

III.B. Seafood safety research

- Improve methods to eliminate pathogenic *Vibrio* bacteria from harvested shellfish prior to market.
- Develop a real time Polymerase Chain Reaction (PCR) assay to test for a correlation between *Vibrio parahaemmolyticus* and algal blooms in marine waters, which may be useful for the development of new risk assessment tools for the presence of this pathogen in shellfish.
- Develop methods to rapidly assess pathogen presence in coastal waters and estimate risk of exposure through recreational water use or shellfish consumption.
- Develop biosensors for identification of phytoplankton related to human health risks.
- Develop models for predicting cardiovascular events in humans exposed to urban pollutants, and methods to mitigate such effects.
- Improve models of disease transmission processes in human populations, which take into account factors such as chemical exposure and age.
- Develop portable biosensors for rapid detection of microbial contaminants in coastal waters.
- Develop methods for routine molecular surveillance to monitor for the prevalence of influenza—and other diseases with potential human health impacts—in marine vertebrates.

III.C. Marine aquaculture

- Determine effects of growth during early juvenile rearing on adult female reproductive fitness characteristics of spring Chinook salmon to improve hatchery technology for ESA-listed stocks of Pacific salmon.
- Initiate germ cell cryopreservation program for Redfish Lake sockeye salmon to reduce risk of extinction.
- Assess timing of olfactory imprinting in juvenile sockeye salmon to improve hatchery technology for ESA-listed stocks of Pacific salmon.
- Assess and refine hatchery reform protocols to help Pacific salmon hatcheries achieve conservation and sustainable fisheries goals.

- Develop and test conservation hatchery technology to aid recovery of depleted stocks of Pacific cod and rockfish.
- Evaluate and develop methods for the production of highly nutritious seafood (high n-3 fatty acid, low contaminant) through aquaculture.
- Develop conservation hatchery technology to aid recovery of ESA-listed stocks of Pacific salmon.
- Evaluate the potential for sustainable marine fish aquaculture for conservation and commercialization. This work would focus on: sustainable feeds based on non-fish-meal/oil feedstuffs, energy and impact modeling for aquaculture systems, multitrophic and monotrophic systems design, environmental risk assessment modeling, and hatchery technology.

IV. Information Management Research

Recent Accomplishments:

- Information developed for the Essential Fish Habitat EIS is being used directly to develop a new West Coast Marine Habitat Server—an interactive mapping tool providing access to various marine habitat data through an online mapping service (ArcIMS map server). This is part of the Pacific Ocean Observation System (PaCOOS) and is funded by NOAA's Integrated Ocean Observation Program.
- The NWFSC has developed standardized routines for extracting and summarizing data for use in 2005 assessments, including survey, landings, and logbook data.
- NWFSC staff has acquired Washington State data on paralytic shellfish toxin levels and have begun dataset development and data exploration.

Research Priorities, FY 2007–2012:

- Develop a web-accessible database for bottom trawl survey data.
- Expand and maintain electronic archive of West Coast groundfish stock assessments.
- Add data to the West Coast Marine Habitat Server.

A school of yellowfin tuna.
Photo: William L. High, NMFS.

SOUTHWEST FISHERIES SCIENCE CENTER

The Southwest Fisheries Science Center (SWFSC) headquarters is located in La Jolla, California, and research is conducted at laboratories in La Jolla, Santa Cruz, and Pacific Grove, California. The current staffing level involved in MSFCMA-related activities is at about 95 full-time equivalents (FTEs). An estimated 55 percent of total SWFSC resources are assigned to MSFCMA activities. NOAA research vessels assigned to fisheries research in the SWFSC are the NOAA FSV *David Starr Jordan*, which has San Diego as its homeport, and approximately two-thirds of the time of the NOAA vessel *McArthur II*. The Center also charters in excess of 100 sea days annually aboard fishing and research vessels.

The SWFSC is a world-class research organization that conducts integrated, multidisciplinary research programs in biology, mathematics, oceanography, and economics to develop scientific technology and provide information to support the management and allocation of Pacific coastal and high-seas fishery resources. These activities support the scientific, statistical, and economic needs of the Pacific Fishery Management Council (PFMC) and international commissions for large pelagic fishes and Antarctic resources. Center programs also support efforts directed toward the reduction of protected species interactions, fishery-related porpoise mortality, and a better understanding of the biological and environmental factors affecting the marine resources exploited by U.S. commercial and recreational fisheries. The Center provides the scientific information necessary to conserve and manage the following important fisheries in the Pacific and Antarctic regions:

- Large pelagic fishes of the Pacific Ocean (tuna, billfish, shark, and swordfish).
- Groundfishes of the West Coast (Pacific hake, rockfishes, lingcod, and cowcod).
- Small coastal pelagic species of the West Coast (northern anchovy, sardine, mackerel, and squid).

- Salmon of the West Coast.
- Antarctic krill, crabs, and finfish (including Patagonian toothfish).

The SWFSC specializes in fisheries of the California Current, Pacific Oceanic, and Antarctic regions. Research is carried out on the ecology, population dynamics, fisheries, and stock assessment of small coastal pelagic species, West Coast groundfishes, Pacific billfish, tunas and sharks (in collaboration with the Pacific Islands Fisheries Science Center), and California salmon. The Center maintains and uses the largest database on tuna and tuna-related fisheries in the world. The Center makes extensive use of biological and fisheries data, which are collected by observers placed on fishing vessels by the Southwest Region, to monitor interactions with protected resources to achieve goals related to the MSFCMA. It is also considered a leader in fish survey design, conducting surveys to monitor early recruitment success of economically important fish stocks along the U.S. West Coast. It is a co-founder and co-participant in the Pacific Coast Ocean Observing System (PaCOOS) an extension of the much cited state-Federal California Cooperative Fisheries Investigations (CalCOFI), a comprehensive long-term study of the biology and oceanography of the California Current. In the Pacific, the Center is the leading source of stock assessment expertise on tunas, sharks, and billfishes for international commissions and for the PFMC. In the Antarctic, the SWFSC leads U.S. research directed at gathering ecological information to prevent overexploitation of fish and krill and to protect Antarctic living marine resources. The SWFSC provides oceanic environmental data and indices to the rest of NMFS as well as to other Federal, state, academic, and foreign fisheries scientists. Center scientists are leaders in the research and development of fisheries-relevant environmental data products. The SWFSC is home to a NOAA CoastWatch node at its Environmental Research Division in Pacific Grove, California.

Organizationally, the SWFSC consists of the Fisheries Research Division, Fisheries Ecology Division, Environmental Research Division, Protected Resources Division, the Antarctic Ecosystem Research Division, and the Operations, Management and Information Division. Nine research programs are conducted across these divisions: Coastal Pelagic Species, Highly Migratory Species, California Demersal Species, California Anadromous Species, Marine Mammals, Marine Turtles, Abalone, Antarctic Marine Living Resources, and Strategic Research. The SWFSC also has eight programs oriented around the following disciplines: 1) Population Assessment; 2) Resource Surveys; 3) Ecosystem and Climate; 4) Ecology and Ecosystem; 5) Biology and Life History; 6) Life History, Demographics & Movement; 7) Economic and Social Monitoring and Assessment; 8) Data Management; and 9) Administration and Infrastructure. These Discipline Programs cut across all Divisions and Research Programs.

SWFSC scientists have taken the lead in characterization of large- and small-scale habitats that support white abalone, groundfish, and bottomfish populations in deep water off California. This work requires an interdisciplinary approach from fishery biologists, geologists, and ecologists and couples the use of GIS with remote-sensing visual and acoustic tools, in-situ survey techniques using remotely operated vehicles, submersibles, and spatial analyses. This approach is being applied to the identification of EFH for various species, the improvement of stock assessment surveys, development of endangered species recovery plans, and the evaluation of MPAs as an effective supplement to traditional fishery management. The National Ocean Service's MPA Center is cooperatively co-located with the SWFSC's Santa Cruz Laboratory.

The SWFSC maintains an active communications network with constituents, colleagues in the scientific professions, and the public to receive input for research planning, execution, and results. The network includes frequent dialogue with commercial and recreational fishermen, leaders of environmental groups, participants of FMCs, state and Federal research agency staff, and outside scientists in the United States and foreign countries. Supporting this network is an infrastructure that includes cooperative agreements to support collaborative work with researchers in state agencies, universities, and foreign governmental agencies for collecting logbook and other types of fisheries data and for shared research projects; arrangements for data exchange; and contracts for charters of research vessels and specialty expertise. The SWFSC and its laboratories maintain up-to-date Internet sites that provide a range of information, including scientific reports and summary databases available to other researchers as well as the general public.

The SWFSC provides scientific and research support for U.S. commitments resulting from the following international arrangements and agreements in the Pacific region:

- Convention for the Conservation of Antarctic Marine Living Resource (CCAMLR), which manages the marine living resources of the Antarctic.
- Inter-American Tropical Tuna Commission (IATTC), which deals with tuna and tuna-like fishes, and the tuna-dolphin issue of the eastern Pacific Ocean.
- South Pacific Tuna Treaty (SPTT), which provides tuna fishing access to the western Pacific Ocean.
- North Pacific Interim Scientific Committee for Tuna and Tuna-like Species (ISC), which promotes research on tuna and tuna-like species of the North Pacific Ocean.
- Standing Committee on Tuna and Billfish of the Secretariat of the Pacific Community (SCTB), which facilitates collaborative research on tuna and billfish of the western Pacific Ocean.
- MEXUS-Pacifico, which promotes joint U.S.-Mexico research projects of mutual interest.
- North Pacific Albacore Workshop (NPALB), which promotes stock assessment research for North Pacific albacore.
- Commission on the Conservation of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean, which will manage the highly migratory fish resources of the western and central Pacific Ocean.
- International Whaling Commission (IWC), which promotes conservation of whale stocks.

In addition, SWFSC scientists periodically work with other scientists on joint projects sponsored by international organizations such as the FAO, Global Ecosystem Dynamics (GLOBEC), and the North Pacific Marine Science Organization (PICES).

The SWFSC maintains an exceptional and growing fisheries economic research capability. Special studies are undertaken to help explain and evaluate the potential impacts of various management options on components of the fishery or on the public. In addition, economic data collection and analyses are carried out to evaluate the economic health of fisheries or components of the fisheries.

RECENT ACCOMPLISHMENTS AND RESEARCH PRIORITIES FOR FY 2007–2012

I. Research to Support Fishery Conservation and Management

Recent Accomplishments:

- An ecosystem-based synoptic sardine survey along the entire West Coast, from British Columbia to Baja California, was conducted onboard the NOAA ships *Oscar Dyson* and the *David Starr Jordan*. Biological and physical data were collected using pelagic trawls and acoustics, CUFES (Continuous Underway Fish Egg Sampler) and plankton tows, and in situ sensor packages to obtain vertical profiles of water properties. Data from this survey is especially important for the production of sardine assessments. This was an extension of CalCOFI (California Cooperative Fisheries Investigation), one of the longest-running ecosystem approaches to monitoring living marine resources and a collaboration among academia and state and Federal agencies.
- Stock assessments for Pacific sardine and mackerel were provided to the PFMC along with economic analyses of Pacific sardine harvest guidelines and Coastal Pelagic Species performance measures. Economic analyses were used to redesign the distribution of Total Allowable Catch for Pacific sardines on the West Coast for a more equitable allocation.
- SWFSC scientists began developing Genetic Stock Identification (GSI) techniques for Pacific salmon using microsatellite DNA. This quick turnaround technique will be used to conduct mixed stock fishery analysis, reduce impacts on Klamath Basin Chinook, and maximize harvest of Central Valley fall Chinook salmon. Results of a quick turnaround-time genetic stock identification analysis of Chinook salmon port sampled in Monterey Bay were presented to the PFMC. The SWFSC, in collaboration with the NWFSC, developed a population genetics database of several California salmonid stocks for determining stock structure and to use as a baseline for future monitoring efforts. Molecular genetic data are collected from salmonids to identify genetic population structure and demographic units for management and conservation, to estimate relatedness of individuals and populations, and to estimate life-history and population-genetic parameters. Novel analytical methods will also be developed and employed to estimate population-genetic parameters, such as effective population size, probability of parentage, demographic trajectory, new ways to use genetic methods for tagging individual salmon, and manage breeding of salmonids in hatcheries for conservation purposes.
- The California Demersal Species Program provided the PFMC with stock assessments for shortbelly rockfish, bocaccio, cowcod, California scorpionfish, California sheepshead, starry flounder, widow rockfish, gopher rockfish, kelp greenling, and vermilion rockfish, as well as rebuilding analyses for boccacio, widow rockfish, and cowcod.
- The California Anadromous Program provided the PFMC with a harvest rate model for Klamath River fall Chinook salmon, a Klamath River Ocean Harvest Model, a California coastal Chinook ocean harvest jeopardy standard, hook-and-release mortality in California's ocean recreational fishery, and a Phase I recovery plan through participation in Take Reduction Teams for all listed salmon stocks.
- SWFSC researchers in the Highly Migratory Species Program provided stock assessments for North Pacific Ocean Striped Marlin and North Pacific Ocean Albacore, which the ISC used to recommend management action to the Western and Central Pacific Fisheries

Commission. Annual Stock Assessment and Fishery Evaluation reports were provided to the PFMC on recreational and commercial Highly Migratory Species fisheries, including albacore and bluefin tunas.

- The Antarctic Marine Living Resources (AMLR) program developed a prey-based ecosystem model for the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) to use in managing the Antarctic krill fishery. The model was populated with data directly from the AMLR program. CCAMLR will use the model to set krill harvest guidelines by area.

A vermillion rockfish swims in the dark depths of the Pacific Ocean. Photo: NMFS.

Research Priorities, FY 2007–20012:

I.A. Biological research concerning the abundance and life history parameters of fish stocks

- Conduct biological research by the U.S. Antarctic Marine Living Resource Program concerning abundance and life history parameters of fish stocks.
- Plan, conduct, and present results of annual predator-prey interaction studies in waters around the South Shetland Islands, Antarctica.
- Develop a new Bayesian method of stock assessment for application to data-poor groundfish species.
- Develop an advanced technology-based groundfish survey using optical technologies and sonar for the Southern California Bight.
- Continue developing a population genetics database of anadromous California salmonid stocks for determination of stock structure and as a baseline for future monitoring efforts.
- Provide quantitative estimates of the take of listed salmon in the California salmon harvest and evaluate proposals to minimize listed species take.
- Expand the archival tagging program for North Pacific albacore in cooperation with the albacore fishing industry, Japanese fishery agencies, and other groups to trace albacore movements between fisheries and countries.
- Define unit stocks using genetics and otolith chemistry in highly migratory species (albacore, thresher shark, and striped marlin), in coastal pelagic species (sardine), and in groundfishes.
- Conduct peer-reviewed assessments and statistical analyses on stocks of groundfish, coastal pelagics, tunas, sharks, swordfish, salmon, and other species.
- Develop a new generation of stock assessment models for highly migratory species and coastal pelagic species stocks of the Pacific and the state-of-the-art software to support them, using modern statistical optimization techniques, Bayesian methods, and object-oriented programming languages.

- Use pop-up satellite tags to identify forage and migration habitats of exploited shark species in the California Current.

I.B. Interdependence of fisheries or stocks of fish

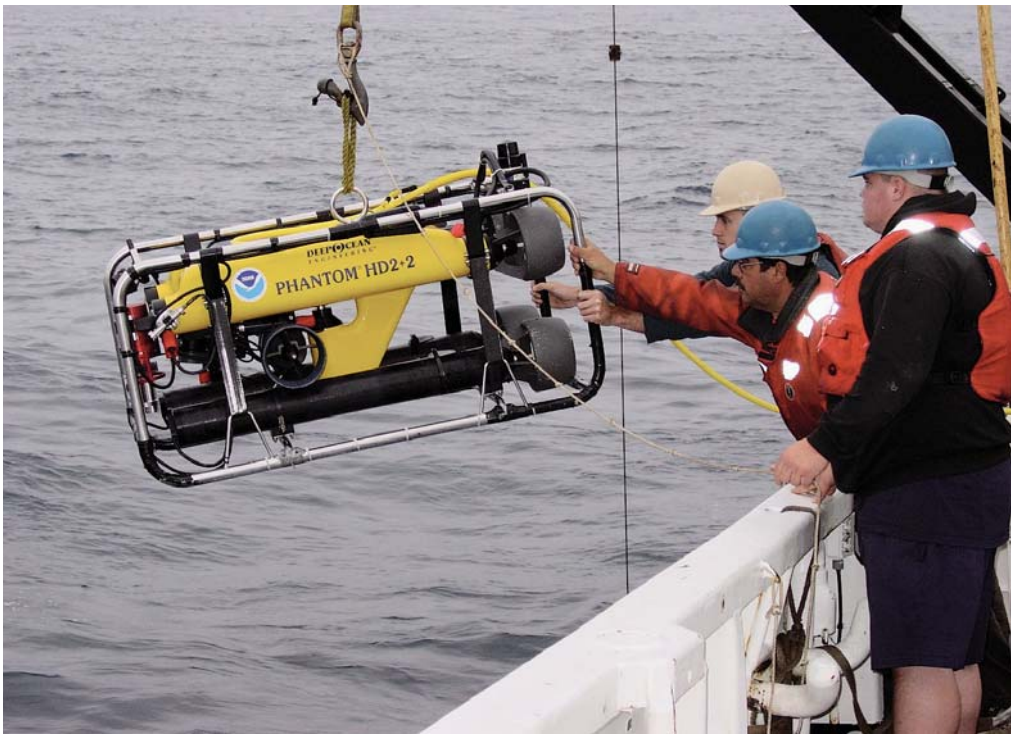
- Continue research program under the International Dolphin Conservation Protection Act to determine whether the chase-and-encirclement practice by the fishery is having a significant adverse impact on depleted dolphin populations in the eastern tropical Pacific.
- Design sampling surveys to analyze the impact of marine mammals on listed salmon.
- Develop integrative oceanic environmental indices to improve understanding of how environmental variability affects fish stocks.

I.C. Identifying, restoring, and mapping of essential fish habitat (EFH)

- Participate in salmon EFH identification and protection.
- Develop and produce digital mosaics of seafloor habitats from electro-optic images into a format compatible with other geo-referenced data sets used in GIS.
- Develop approaches to evaluate essential habitat of pelagic fishes based on satellite remote sensing and applications of archival and pop-up satellite tags.
- Evaluate EFH and monitor marine resources in "no-take" marine reserves in the Channel Islands National Marine Sanctuary.
- Define essential spawning habitat of market squid and the effects of fishing gear on that habitat and the survivorship of demersal egg capsules.

I.D. Impact of anthropogenic factors and environmental changes on fish populations

- Investigate relationship of juvenile salmon abundance and physiological status with respect to oceanographic features (e.g., estuary plumes, upwelling centers, coastal jets, eddies, and fronts).
- Determine the effects of hatchery and aquaculture operations on indigenous salmon and steelhead stocks in California by molecular genetic analysis of museum specimens and previously collected scale samples.
- Evaluate the effects of climate change of interannual, decadal, and centennial scales on fisheries and fish habitat.
- Develop models of the impacts on salmon populations of natural disturbances due to climatologies.
- Improve methods to identify pathways in estuarine ecosystems for the bio-accumulation of contaminants in salmon.
- Examine the association of recruitment of young rockfishes and climatic and oceanographic variables off central California.
- Investigate use of small estuaries on the central California coast by juvenile salmonids.
- Assess the effects of environmental variability—particularly sandbar dynamics and water quality—on growth, development, and survival.



Launching the SWFSC's remotely operated vehicle (ROV) for surveying deepwater rockfish and abalone. Photo: NMFS.

- Investigate the linkage between the dynamics of oceanic features, including eddies, fronts, and boundary currents, and the dynamics of highly migratory fishes (tunas and billfishes) in the central and western Pacific.

II. Conservation Engineering Research

Recent Accomplishments:

The SWFSC completed research to improve our understanding of fisheries impacts on marine ecosystems by developing equipment, methods, and protocols to survey abundance and distribution of demersal fish associated with offshore rocky habitats using advanced technologies. One study pioneered the use of the combination of acoustic techniques, fishing information, and direct submersible research to directly evaluate deepwater fisheries habitat. Research considered the potential of multibeam sonar, multi-frequency echosounder, and a Remotely Operated Vehicle (ROV) to estimate rockfish distributions and abundance in the Southern California Bight, suggesting that this type of direct observation is a promising independent approach to evaluate fishing effects on a scale consistent with commercial fishing activities. Species identification algorithms for acoustic surveys were also developed for bocaccio rockfish.

The Center conducted the first workshop to develop alternative gear for reducing bycatch of dolphins, turtles, and other species in the Eastern Tropical Pacific (ETP) tuna purse-seine fisheries. This workshop identified three research proposals that showed the most conservation promise and were the most cost-effective for review and evaluation at a future workshop. These were proposals to reduce fishery mortality of sharks, examine historical fishery data to establish time-area closures, and modify fish aggregating devices (FADs) to reduce sea-turtle entanglement.

Research Priorities, FY 2007–2012:

- Undertake studies to determine the most effective methods to increase survival of sea turtles on nesting beaches in the eastern and western Pacific.
- Determine how to increase survival in the economic/regulatory discards of undersized tunas, sharks, and other fishes.
- Create and test new trap designs for juvenile out-migrant salmon that will minimize predation on juveniles from larger salmonids (in cooperation with Humboldt State University).
- Develop advanced survey technology for monitoring abundance of fishes including: 1) use of LIDAR for monitoring the abundance of CPS species, 2) remote monitoring of FAD fish aggregations, and 3) testing an Autonomous Underwater Vehicle for monitoring groundfish species.
- Participate in second ETP bycatch workshop to develop best option for bycatch reduction.
- Develop method to reduce shark bycatch in tuna purse-seine fisheries around FADs.
- Develop advanced technology for automatic shipboard data logging of bioacoustic and environmental data from standard equipment on commercial fishing vessels and logging of catch. Develop algorithms for processing and analysis of these data.

III. Research On The Fisheries

Recent Accomplishments:

The SWFSC initiated and led the efforts to evaluate MPAs as a supplemental tool for groundfish management on the West Coast. The Center provides scientific advice to the Master Plan Team for California's Marine Life Protection Act, which develops recommendations for Marine Protected Area Networks to California's Fish and Game Commission. The Center also participates in a National Center for Ecological Analysis and Synthesis an (NCEAS) working group, "Development of Tools for the Practical Design of Marine Reserves." The National Marine Protected Area Center (NMPAC) Science Institute is co-located at the SWFSC laboratory in Santa Cruz, California. The Science Institute provides coordination and support of MPA research, design, monitoring schemes, and management strategies. Center staff work on several MPA-related projects for the NMPAC and NMFS on sea-floor mapping using GIS and distribution associated with habitat using ROV technology. Currently the SWFSC is leading efforts to develop a NMFS strategy to integrate MPAs into conventional fisheries science and management.

The SWFSC analyzed buybacks of tuna purse-seine vessels in the Eastern Pacific Ocean and determined the feasibility of routinely collecting input data for the Data Envelopment Analysis and for performing industry surveys of tuna fishing capacity utilization for the FAO. The SWFSC developed economic models for three different fishing capacity or productivity analyses. The projects will measure total factor productivity of tuna purse seine vessels accounting for catches of undesirable outputs, measure total factor productivity of U.S. tuna purse seine vessels in the Western and Central Pacific Ocean accounting for environmental influences, and analyze standardization of fishing effort. Data are being collected for the high seas tuna fleets and the longline fleet; computer code has been written for the high seas tuna fleet.

SWFSC researchers met in Bellagio, Italy, with international economists, marine life policy experts, legal scholars, fishing industry and fisheries professionals, conservation, sea turtle and natural resource management specialists, and development assistance researchers from governmental, nongovernmental, and private institutions to provide a scientific and policy basis to develop elements of a model treaty to conserve and promote recovery of Pacific sea turtles. The group concluded that a blueprint for sea turtle conservation must address 1) protecting all nesting beaches, 2) reducing turtle take in at-sea and coastal fisheries, 3) stimulating pan-Pacific policy actions, and 4) encouraging sustainability of traditional use of sea turtles. The first point recognizes that protecting nesting beaches has been proven to work in restoring sea turtle populations. In addition, SWFSC economists developed a model for predicting leatherback interactions with the drift gillnet fishery, estimated the costs of leatherback beach protection in the western Pacific, and estimated costs of bycatch reduction to California drift gillnet fisheries.

Research Priorities, FY 2007–2012:

III.A. Social and economic research

- Initiate economic evaluation of salmon hatchery reform actions.
- Develop automated analytical templates integrated with current fishery performance, cost, and price information for completing Regulatory Flexibility Act analyses in an efficient and timely manner. Augment these templates to include the basic demographic information required to initiate preliminary Social Impact Assessments.
- Conduct research to support the United Nations Implementing Agreement (or Provision of the United Nations Convention on the Law of the Sea [UNCLOS] Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks).
- Research intra-industry linkages and develop input-output relationships to describe and model the employment, income, and economic impacts of potential management actions on each of the FMP fisheries and fishing communities.
- Analyze recreational economics for HMS Commercial Passenger Fishing Vessels and private sport fishermen targeting tuna, marlin, and billfish.
- Initiate an economic survey of the Southern California Highly Migratory Species recreational fishery.
- Enhance existing salmon harvest models to better predict fishing effort response to changes in sport and commercial fishery regulations.
- Conduct Regulatory Impact Reviews and Regulatory Flexibility Analyses for management actions being considered for all fisheries with FMPs.
- Evaluate growth in productivity for purse seine vessels harvesting tuna in the western and central Pacific, paying special attention to the effects of fish aggregating devices (FADs).

III.B. Seafood safety research

This item is not applicable.

III.C. Marine aquaculture

- Develop techniques for culture of white abalone and other abalone species for recovery of endangered stocks, stock enhancement, and commercial production.

IV. Information Management Research

Recent Accomplishments:

The SWFSC has been a leader within NOAA in providing data to a broad spectrum of users, using methods consistent with emerging NOAA Global Earth Observation—Integrated Data Environment and Integrated Ocean Observing System (IOOS) Data Management and Communication (DMAC) standards for data access and transport providing interoperability with other NOAA data and data servers. The SWFSC continues to develop a suite of fisheries-relevant data that cover the entire spectrum of the ocean environment, from surface or near-surface wind and pressure data to surface and subsurface measurements of important oceanographic parameters. A key focus is the integration of these oceanographic and atmospheric data with biological data in support of a regional ecosystem-based management and to make these data sets readily accessible to scientists, managers, and the general public to support research on fisheries, marine mammals and protected species, and for studies in climate change and environmental variability.

In cooperation with the West Coast Regional Node of Coastwatch, over 4 terabytes of data are available online, and the amount is increasing every month. The data can accessed, subsetted, visualized, and downloaded in a variety of methods designed to reduce the time users need to spend preparing the data, and allowing users to acquire only the desired data rather than an entire dataset. The SWFSC has developed Thematic Real-time Environmental Distributed Data Services (THREDDS) catalogs, including OPeNDAP and Open Geospatial Consortium standard Web Coverage Services; provided access to a variety of near real-time and science quality satellite data; developed a variety of data delivery and integration tools for the Tagging of Pacific Pelagics (TOPP) program; developed Dapper/dchart applications for accessing aggregated in situ information; and developed data transport and access applications for the Central California Ocean Observing System (CeNCOOS) and the Pacific Coast Ocean Observing System (PaCOOS).

The SWFSC developed several software and hardware systems to modernize and standardize data collection and management for HMS biological, physical, and fisheries data through collaboration with the National Fisheries Information System and the SWFSC/PIFSC Data Coordination Team. The Data Coordination Team developed an Oracle data system integrating all types of fishery data, and a data portal to display HMS data, metadata, and data policies. Electronic calipers were field tested that will enable port samplers to more efficiently collect data from HMS fisheries and allow SWFSC data technicians to more efficiently process the data. The Data Coordination Team also continued to collect data from and monitor HMS fisheries in the Pacific for stock assessments and in support of WCPFC, PFMC, and the International Scientific Committee for Tuna and Tuna-Like Species.

The SWFSC began developing IOOS-compatible software that will allow CalCOFI biological and physical data to be accessed on the Internet by interested academic, government, and research partners. The SWFSC began long-term planning and design for an

This southern elephant seal has been fitted with non-permanent tracking apparatus on it's head so that data can be collected via satelllite. Satellite tracking tags allow researchers to collect data on migration routes, diving depths, and other aspects of behavior. Photo: Mike Goebel, NOAA.

integrated PaCOOS data management system. This system will ensure that physical and biological data from a wide variety of sources and PaCOOS partners will be available and easy to access for scientists and managers.

Research Priorities, FY 2007–2012:

- Automate quarterly and annual compilation of fisheries statistics and annual reports on FMP fisheries.
- Develop and maintain web-based coastal salmon abundance database.
- Advance approaches of data fusion to combine fisheries data and assessment model outputs with environmental data from ship, satellite, and physical models.
- Develop electronic albacore troll/baitboat fishing logbook and make it available to the fishing fleet to modernize data collection.
- Develop applications to capture HMS data with electronic calipers and transmit directly to HMS Oracle system.
- Provide electronic calipers to all HMS port samplers.

A spiny lobster crawling out of a crevice. Photo: Doug Harper, NMFS.

SOUTHEAST FISHERIES SCIENCE CENTER

The Southeast Fisheries Science Center (SEFSC) with headquarters in Miami, Florida, implements and manages a multidisciplinary science and research program that provides technical information for conserving and maintaining the sustainability and health of living marine resources and their environments. The SEFSC is responsible for the eight southeastern states, Puerto Rico, and the U.S. Virgin Islands, and research is conducted at laboratories located in Miami and Panama City, Florida; Beaufort, North Carolina (a joint NOS-NMFS facility); Galveston, Texas, with a lab facility in Lafayette, Louisiana; and Pascagoula, Mississippi, with a field station at the Stennis Space Center, Mississippi. In addition, numerous field offices provide additional information for research along the coast of the southeastern United States. The SEFSC has two fishery research vessels berthed at Pascagoula, Mississippi—the NOAA vessels *Oregon II* and *Gordon Gunter*—as well as numerous smaller research craft located at individual laboratories.

In general, the SEFSC develops the scientific information required for: 1) fishery resource conservation, 2) fishery development and utilization, 3) habitat conservation, and 4) the protection of marine mammals and endangered species. Impact analyses and environmental assessments for fishery management plans and international negotiations are also prepared, and research is pursued to address specific needs in population dynamics, fishery biology, fishery economics, engineering and gear development, and protected species biology. The SEFSC's current staffing level is 276 FTEs. Approximately 80 percent of all SEFSC resources are devoted to MSFCMA activities.

The SEFSC provides scientific support for NMFS' fishery management activities and the recommendations of the South Atlantic Fishery Management Council (SAFMC), the

Gulf of Mexico Fishery Management Council (GMFMC), and the Caribbean Fishery Management Council (CFMC) that involve 17 fishery management plans covering the following major fisheries: spiny lobster, snapper-grouper, reef fish, red drum, coastal migratory pelagic species, coral, shrimp, stone crab, queen conch, and golden crab. The SEFSC also has significant interactions with the Gulf States Marine Fisheries Commission (GSMFC), which administers the Fisheries Information Network (FIN) statistics effort; and the Atlantic States Marine Fisheries Commission (ASMFC), which administers the Atlantic Coastal Cooperative Statistics Program and exercises fishery management responsibilities through the Atlantic Coastal Fisheries Cooperative Management Act. In addition, the SEFSC maintains close ties with state fishery programs and has funded the state-Federal cooperative statistics program since 1983. Researchers at the SEFSC collaborate extensively with other Federal agencies and academia.

Internationally, the SEFSC provides scientific leadership to, and support for U.S. participation in, 1) the International Commission for the Conservation of Atlantic Tunas (ICCAT), which manages Atlantic Ocean-wide fisheries for tunas and billfishes; and 2) the International Oceanographic Commission for the Caribbean (IOCARIBE), which coordinates fishery oceanography studies among the approximately 30 islands and continental countries in the region. SEFSC scientists also work jointly with the Government of Mexico on projects of mutual interest in the Gulf of Mexico under the MEXUS-Gulf research working group.

Constituents have the opportunity to provide input to the SEFSC's research programs through representation on FMCs, participation in Council public hearings, and service on Council advisory committees. Input to the SEFSC research program is also received via the activities of interstate fishery commissions (the Atlantic and Gulf States Marine Fisheries Commissions), joint agency planning groups, and cooperative programs with state fishery agencies (GulfFIN). The SEFSC responds to the information needs of FMCs and has a formal procedure (Council Operations Plan) for matching its research program to fishery management plan requirements.

The SEFSC's high caliber of research is maintained through periodic program reviews by teams that include officials from industry, councils, state agencies, universities, and other constituents. The Center also works diligently to be responsive to the results of program reviews.

Each SEFSC laboratory is responsible for conducting research in specific subject areas and also tend to have specific geographic focuses. However, there is extensive cooperative research between SEFSC laboratories. Research activities conducted by the various laboratories are as follows:

Beaufort Laboratory:

- Conducts research on biology and fishery for reef fish—including headboat landings, fishing effort, age and growth, reproduction, and assessment of abundance—to support the management of territorial sea, EEZ, and highly migratory resources.
- Conducts research on processes affecting the distribution, abundance, and use of natural and restored habitats by fishery organisms, and develops techniques and methodologies to evaluate natural and anthropogenic impacts on fishery organisms and their habitat.

- Supports conservation and recovery efforts through evaluations of marine protected areas and also provides scientific recommendations to FMCs.
- Carries out NMFS' mandates for the recovery and conservation of protected species under the MMPA, the ESA, and related legislation.

Miami Laboratory:

- Performs stock assessments for species such as the snapper-grouper category, mackerels, and highly migratory species (e.g., sharks, swordfish, tunas, and billfish).
- Collects and analyzes catch and effort data, as well as scientific information under the Fishery Observer Program for addressing issues such as bycatch of protected species, the assessment of bycatch mitigation techniques, and discard mortality of targeted species.
- Supports cooperative research science projects with constituents, states, and local governments, and conducts economics and social science research to evaluate the socioeconomic impacts of existing and proposed fishery management actions.
- Implements research to support the conservation and recovery of depleted, threatened, and endangered species of marine mammals, sea turtles, and seabirds by: conducting species-population assessment surveys; research on stock structure including genetics, radio tagging, photographic identification, and morphological studies; and assessing strandings and unusual stranding events.
- Performs research on: "no-take" marine reserves as a fishery management tool to support sustainable fisheries and protect marine biodiversity; ecosystem structure and function; coral reefs; essential fish habitat; habitat restoration; the effectiveness of artificial reefs; fishing gear effects on populations and habitat; biological research to support stock assessments; fishery-independent assessments; and the early-life history and early-life ecology of southeastern species.
- Performs research to measure, monitor, understand, conserve, and restore marine biological diversity in ecosystems essential for fishery productivity. Research focuses on corals, invertebrates, and fishes in coral reefs, estuaries, and mangroves with complex biological diversity. Specific research goals are to improve ecosystem-based stock assessments; maintain healthy stocks; eliminate overfishing; restore habitat damaged by human or natural disturbances and rebuild overfished stocks important to commercial, recreational, and subsistence fisheries.
- Collaborates with state and other Federal agencies in research, modeling, and monitoring programs to support more effective management of watersheds and freshwater flows to coastal waters in order to restore and protect coastal fishery habitat by ensuring appropriate quantity, quality, timing, and location of freshwater inflows. Other goals are to increase long-term economic and social benefits to the nation from living marine resources by reducing fishery conflicts that involve protected species; by protecting, conserving, and restoring habitat and marine ecosystem goods and services, including biological diversity, connectivity, and resilience.
- Conducts research to ensure that coastal ecosystems are improved and are not harmed by the Comprehensive Everglades Restoration Project, which will modify freshwater inflow to estuaries and nearshore areas in southern Florida.

Panama City Laboratory:

- Conducts research on reef fishes and mackerels as related to fishery biology, life history, recruitment dynamics, ecology, essential fish habitat, fisheries, stock assessment/population modeling, and fishing gear selectivity patterns.
- Performs research on spatial variability at various scales in population traits of reef fishes.
- Studies fish community structure of near-shore and mid-shelf hard bottom/rocky reef habitats, including fishery-independent estimates of relative abundance and demographics of reef fishes on these habitats.
- Conducts research on coral and rocky reef habitats as they relate to fishery species of interest.
- Monitors proposed and enacted marine protected areas/reserves with respect to the extent and nature of reef habitat, to abundance and composition of reef fishes, and to impacts of fishing activity.
- Conducts stock assessments and population modeling of pelagic, large coastal, and small coastal sharks, as well as sharks for which harvest is prohibited.
- Conducts research to develop a fishery-independent index of juvenile shark abundance. Performs studies on several aspects of elasmobranch life history, delineation of Essential Fish Habitat, and ecosystem modeling.
- Coordinates observer programs to monitor catch and bycatch in directed shark fisheries and fishery interactions with whales and sea turtles.
- Conducts collaborative national and international projects and actively participates in international scientific fora such as ICCAT and CITES.
- Conducts research on, and monitoring of, endangered and threatened species such as sturgeon, sawfish, marine mammals, and Johnson's seagrass, participates in the development and implementation of their recovery plans, and participates in stranding networks for marine mammals and sea turtles.

Mississippi Laboratories:

- Develop fishery-independent estimates for FMP species abundances via trawl, plankton, trap/video and longline surveys.
- Monitors status of finfish and invertebrates, and environmental variables using these surveys.
- Conduct visual and acoustic assessment surveys of cetacean stocks.
- Conduct research and development of new gear technology and fishing practices to reduce bycatch, including Turtle Exclusion Devices (TEDs), trawl Bycatch Reduction Devices (BRDs), and longline fishing practices.
- Develop advanced technology approaches to improving data collection at sea.
- Participate in remote sensing programs, including distribution of CoastWatch/OceanWatch operational data.

Galveston Laboratory:

- Conducts research on essential fish habitats and the use of landscape techniques to identify Essential Fish Habitat by integrating GIS tools into assessments of habitat value; habitat modifications caused by sea level rise, subsidence, changes in freshwater inflow, coastal eutrophication, and broad scale hypoxia; habitat restoration research; wetland restoration; and ecosystem models for estuarine and coral reef systems.
- Conducts research to determine, monitor, and describe shrimp population characteristics, as well as associated effort trends.
- Monitors temporal and spatial finfish and protected species bycatch levels from commercial shrimp trawl and reef fish vessels using fishery observers.
- Using observers, monitors and documents sea turtle and marine mammal interactions during petroleum platform removal operations in the Gulf of Mexico.
- Conducts captive rearing of loggerhead sea turtles for use in turtle excluder device (TED) certification trials and other fishery-related studies (e.g., turtle responses to longline fishing gear).

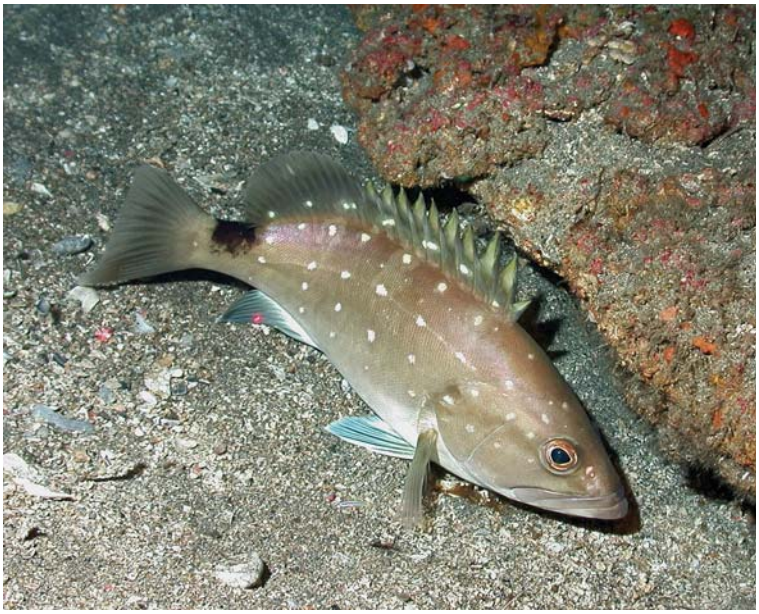
RECENT ACCOMPLISHMENTS AND RESEARCH PRIORITIES FOR FY 2007–2012

I. Research to Support Fishery Conservation and Management

Recent Accomplishments:

- The SEFSC has fully supported the FMC-led Southeast Data Assessment and Review (SEDAR) process for conducting stock assessments. SEDAR was initiated in 2002 to improve the quality and reliability of fishery stock assessments in the South Atlantic, Gulf of Mexico, and U.S. Caribbean. SEDAR emphasizes constituent/stakeholder participation and an independent scientific review of stock assessments, and benefits greatly from the expertise of existing stock assessment-related committees and panels of Councils and Commissions. The SEDAR Steering Committee—composing of representatives from the CFMC, GMFMC, SAFMC, ASMFC, GSMFC, and NMFS—meets regularly and schedules stock assessments.
- Assessment and independent scientific review of 25 critical stocks from the region have been completed using this process, which requires from 9 months to several years to accomplish. The stocks thus far assessed using the SEDAR process include stocks of red porgy, Atlantic vermilion snapper, black seabass, Florida yellowtail snapper, Atlantic menhaden, croaker, tilefish, snowy grouper, king mackerel, goliath grouper, hogfish snapper, gulf red snapper, Caribbean yellowtail snapper, spiny lobster, gulf vermilion snapper, greater amberjack, gray triggerfish, Atlantic and gulf gag grouper, large coastal sharks, and blacktip and sandbar sharks.
- The SEFSC has successfully incorporated "risk assessment," "uncertainty," and the new SFA guidelines on "overfished" and "overfished status" into stock assessment methodologies for numerous species in the Gulf of Mexico, Atlantic, and Caribbean.
- Rebuilding plans for overfished stocks, including red snapper and a number of those noted above, have been developed based on SEFSC scientific efforts.

- The SEFSC continues its national and international leadership roles in the provision of scientific advice for fisheries management.
- The SEFSC instituted several mechanisms for training and recruiting the next generation of quantitative fisheries scientists to support increasing demands for fisheries management advice.
- The SEFSC is recognized for its expertise in the fields of habitat research and restoration and has successfully developed criteria to define and assess areas of EFH.
- The SEFSC recently completed the fifth and sixth annual assessments of fish populations at the Madison-Swanson and Steamboat Lumps Marine Protected Areas in the northeastern Gulf of Mexico as part of the planned 10-year baseline required by the GMFMC for a decision on reauthorization.



A snowy grouper in rocky reef habitat off North Carolina. Photo: NMFS.

In addition, the SEFSC:

- Conducted a worldwide review of the nursery value of salt marshes and mangroves for fishery species in comparison with other estuarine habitat types.
- Conducted surface long-line fishery experiments in the Northeast Distant (NED) waters to improve hook design to reduce bycatch of protected species while maintaining catch of targeted fishes.
- With the fishing industry, developed improved tools and procedures to minimize injury and release protected species hooked in long-lines.
- Conducted research indicating that seasonality, tidal cycles, and "internal tides" movements of sub-surface ocean waters that occur at or near tidal periods, play a significant role in the supply of pink shrimp, a valuable commercial species in the southwest Florida fisheries economy.
- Completed a review of Biscayne Bay, Florida, commercial pink shrimp bait and food fisheries showing the influence of salinity and freshwater flow on landings.
- Developed non-destructive, fishery-independent, length-based methods for fishery stock assessment.
- Conducted ecosystem-based, multispecies, reef fish stock assessments for the Florida Keys and Dry Tortugas regions of Florida.
- With partners, improved mapping, classification, and evaluation of reef habitat in the southeast United States.
- Completed a meta-analysis and review of factors that contribute to catch and release mortality by recreational angling.

- Evaluated the importance of mangroves as juvenile goliath grouper habitat in southern Florida and the Keys.
- Published identification guides and descriptions of fish eggs, larvae, and juveniles of 2,285 species and all 214 families with pelagic early life history stages known to inhabit FAO Fishing Area 31, which includes the western central North Atlantic, Caribbean Sea, and Gulf of Mexico. The two-volume *Early Stages of Atlantic Fishes: An Identification Guide for the Western Central North Atlantic* includes over 2,600 pages and 3,000 illustrations with contributions of over 70 authors.
- Conducted research on coral reef EFH to determine causes of coral disease, assess population genetic structure, and coral reef restoration possibilities.
- Completed and published many fishery biodiversity studies to provide data and resource understanding necessary to manage fishery resources in the southeast United States.
- Collected data and conducted modeling efforts to support the Comprehensive Everglades Restoration Program (CERP).

Research Priorities, FY 2007–2012:

I.A. Biological research concerning the abundance and life history of fish stocks

- Understand and model the linkages between habitats, environmental characteristics, and fishery productivity in order to implement ecosystem-based management.
- Develop innovative techniques to assess genetic diversity and habitat utilization of managed fish and invertebrate stocks.
- Develop and maintain high-quality fishery-dependent and fishery independent long-term data sets for stock assessments. A main component of this effort will be the expanded use of at-sea observers on commercial and recreational fishing vessels to report on catch and bycatch. Emphasis will be on collecting a wide range of information, including biological and environmental data, gear type deployed, and method of deployment.
- Incorporate marine ecosystems data into conceptual models of food webs to link habitat to productivity and increase the Center's ability to survey, inventory, and understand the dynamics of marine systems and their biota.
- Continue to assess and monitor protected fish species (e.g., goliath grouper and Nassau grouper, dusky and night sharks, smalltooth sawfish, and gulf sturgeon).
- Conduct research on HMS stocks, particularly in the areas of stock identification, life history, and precautionary approach methodologies.
- Develop basic life history information and conduct assessments on fish and invertebrate stocks in support of management for the Commissions (ASMFC, GSMFC) and management recommendations of the Councils (SAFMC, GMFMC, and CFMC).
- Conduct research to improve methods of stock assessment and improve modeling of the effects of fishery management on stocks.
- Improve the effectiveness of fishery resource management programs by refining the definition of stocks (including the "management unit" within species).

- Conduct research to monitor and evaluate effectiveness of fishery regulations to support sustainable fisheries.
- Conduct research to move ecosystem-based management principles from theory into practice.
- Conduct research to assess and reduce bycatch from various fisheries, including shark drift gillnet, bottom long-line, and surface long-line fisheries in the Southeast Region.
- Continue providing national and international scientific leadership in development and provision of fishery management advice while accounting for uncertainties in stock abundance and productivity.

I.B. Interdependence of fisheries or stocks of fish

- Evaluate the catch of non-target species by recreational and commercial fisheries, using applicable programs including the observer program, particularly in cases where the population status of non-target species, and the community dynamics of important southeast U.S. marine ecosystems, stand to be impacted.
- Increase our understanding of the interactions of protected species (e.g., sea turtles, marine mammals [bottlenose dolphin and large whales]), dusky shark, night shark, and fish candidate species (e.g., smalltooth sawfish, goliath grouper, and Nassau grouper) with ongoing fisheries in the Southeast Region, including research to assess marine mammal interactions with the menhaden fishery.
- Prevent the extinction and promote the recovery of marine species and at-risk populations through interventions and the continued development of recovery strategies.
- Develop scientific methodology for multispecies or ecosystem approaches toward the management of fishery resources, and where appropriate, transition from single-species approaches.

I.C. Identifying, restoring, and mapping of essential fish habitat (EFH)

- Define and characterize EFH and develop an understanding of natural and anthropogenic threats.
- Develop mapping techniques for more precise positioning of boundaries and for evaluation of fishery values of existing and proposed marine reserves.
- Investigate downstream and coastal impacts of agricultural and urban activities and provide the technical basis for designing and implementing programs for ensuring sustainable coastal communities.
- Gain a better understanding of the structure and function of estuarine, coastal, and marine systems to enhance the conservation and restoration of wetland, benthic, and aquatic areas of EFH.
- Explore innovative techniques to determine the functional value of natural habitats and to evaluate the restoration success relative to the fish and invertebrate community rather than solely to the plant community.
- Develop restoration techniques for EFH including corals, salt marshes, and seagrasses; and determine whether habitats created or restored with such techniques are ecologically functional.

A nesting sea turtle. Photo: Ben Higgins, NMFS.

- Integrate EFH research with stock assessments to develop an ecosystem approach for managing fisheries.

I.D. Impact of anthropogenic factors and environmental changes on fish populations

- Continue to engage in joint efforts with state and other Federal agencies to restore the ecological integrity and water quality in regional estuaries upon which fish depend.
- Continue research efforts under the South Florida Restoration Effort, particularly in the areas of modeling fishery dynamics, recovery of protected resources, restoring EFH.
- Determine the impacts of fishing on reef fish population structure, genetic diversity, and resilience.
- Derive more accurate assessments of fishing and other anthropogenic impacts on living marine resources by incorporating risk and uncertainty into models used to predict natural living marine resource variations.
- Develop techniques and scientific data necessary to support the effective application of precautionary approaches to fisheries management.
- Continue to evaluate the efficacy of marine reserves, no-take and limited-take zones, and time closures as fishery management tools.

II. Conservation Engineering Research

Recent Accomplishments:

- Innovative approaches to bycatch reduction device (BRD) design have been developed. For example, the SEFSC has conducted in-situ observations of red snapper behavior during shrimp trawling to aid in the design of more effective BRDs, and has successfully led efforts to significantly reduce the bycatch of non-target species such as red snapper in the Gulf of Mexico shrimp fishery.
- The development and use of improved TEDs is contributing to the recovery of sea turtles, especially Kemp's ridley in the Southeastern Region.

- A recovery model for impacted subtropical seagrass habitats was developed and has been used successfully in court to demonstrate impacts to sanctuaries.

Research Priorities, FY 2007–2012:

- Continue investigations on the importance of environmental cues in the spatial orientation and migration behavior of sea turtles.
- Develop and test new gear technology and fishing techniques to minimize bycatch. The SEFSC continues to explore options to reduce bycatch and mitigate mortality of sea turtles and other non-target species captured in the distant water longline fisheries.
- Develop and test new gear technology and fishing techniques to minimize adverse impacts on EFH. The Center will continue to document the extent and assess the impact of various fishing gears on EFH in support of conservation and management activities.
- Promote efficient harvest of target species. The Center will conduct investigations into limited access options (e.g., Individual Transferable Quotas [ITQs]) as resource management alternatives to aid increased harvest efficiency.

III. Research on the Fisheries

Recent Accomplishments:

- Provided economic information, analyses, and evaluations for numerous proposed southeast fishery management actions.
- Implemented a program in conjunction with existing logbook reporting requirements to collect operating and ownership costs from boats in the Atlantic snapper-grouper and mackerel fisheries and in the Gulf of Mexico reef fish and mackerel fisheries.
- Collected and summarized economic data from a sample of commercial trap fishermen in the Caribbean. Results were published in Agar et al (2005).
- Developed a model to estimate the effect of climatic variables on fishing effort and landings for red snapper by the headboat fishery in the Gulf of Mexico.
- Worked with contractors and the Southeast Regional Office Social Science Branch staff to identify and describe fishing communities in the Caribbean, Gulf of Mexico, and South Atlantic. Final reports for the Gulf of Mexico and South Atlantic are available online at http://sero.nmfs.noaa.gov/economics/economics.htm.
- Worked with contractors to document the effects of the 2005 hurricane season on the charterboat industry in the Gulf of Mexico.
- Worked with contractors to document the effects of Hurricane Katrina on fishing communities in the Gulf of Mexico.
- Developed and implemented the Gulf Shrimp Vessel and Gear Characterization Form.
- Worked with the Gulf Council's Ad Hoc Shrimp Effort Committee to help develop theory and methods for estimating MSY, MEY, and socially optimal levels of fishing effort and harvest in the Gulf shrimp fishery.

Research Priorities, FY 2007-2012:

III.A. Social and economic research

- Expand the collection of economic data to include all major commercial fisheries managed with FMPs in the southeast.
- Develop improved models of commercial and recreational fisheries to evaluate proposed management alternatives.
- Estimate economic relationships such as demand curves, production functions, and recreational benefit functions needed to support the evaluation of management decisions.
- Collaborate with Southeast Regional Office Social Science Branch staff to conduct ethnographic research to develop community profiles for fishing communities in the southeast, and incorporate resulting information into FMPs.
- Collaborate with Southeast Regional Office Social Science Branch staff to evaluate and improve baseline data for research about the Gulf and south Atlantic shrimp fisheries, and incorporate resulting information into FMPs.

III.B. Seafood safety research

- Support research aimed at identifying and characterizing marine pathogens, especially viruses, in aquaculture shrimp products, and the extent of viruses in wild shrimp stocks.
- Continue to develop biological and chemical analytical methods for toxic contaminants (e.g., mercury), assess their presence in seafood, and define their impacts on marine ecosystems.
- Improve methods to detect, forecast, and evaluate the ecological significance of harmful algal blooms and their impact on fish stocks, marine mammals, and other protected species.

III.C. Marine aquaculture

- Develop the scientific foundation and technical guidelines for establishing ecologically responsible marine aquaculture.
- Continue to investigate the natural occurrence of shrimp viruses.

IV. Information Management Research

Recent Accomplishments:

- Completed migration of over 90 percent of our text-based applications to web-based applications that are SSL-enabled, to provide secure access by constituents and the public to SEFSC information resources via web-based technologies.
- Redesigned our systems infrastructure to improve performance and facilitate improved continuity of operations.
- Developed global information systems capability to provide enhanced ability to analyze and distribute scientific data.

Research Priorities, FY 2007–2012:

- Fully support the Fisheries Information System, a fishery database and information management system that will allow the full use of information in support of effective fishery conservation and management.
- Enhance accessibility to data collections by migrating existing metadata to the FIS InPort metadata catalog,
- Expand our capability and use of GIS applications to enhance access to and understanding of fisheries information with spatial characteristics.
- Enhance the utility of current and historical data collections through implementation of Oracle Datawarehouse and other database-driven, web-enabled applications.

Tagging sharks yields valuable data for NMFS researchers. Top, a blacktip shark is being tagged. Bottom, an Atlantic sharpnose shark with an acoustic tag. Photos: NMFS.

The FSV *Henry B. Bigelow* after being lauched from the shipyard where it was built. Photo: NOAA.

NORTHEAST FISHERIES SCIENCE CENTER

The Northeast Fisheries Science Center (NEFSC) has facilities in Woods Hole, Massachusetts; Narragansett, Rhode Island; Milford, Connecticut; Highlands, New Jersey; and Orono, Maine, and the National Systematics Laboratory (NSL) is housed at the Smithsonian Institution in Washington, D.C. The NOAA FSVs *Albatross IV* and *Delaware II* along with the R/V *Gloria Michelle* are berthed in Woods Hole and support the majority of the Center's fisheries survey and research cruises. Commercial fishing vessels and academic research ships have been used periodically to support ecosystem surveys on the northeast continental shelf. Two smaller vessels, the R/V *Nauvoo* and the R/V *Victor Loosanoff*, support inshore research activities in the Center and are berthed in Highlands and Milford, respectively. The R/V *Gloria Michelle* supports cooperative research between the NEFSC, Massachusetts Division of Marine Fisheries, and the University of Massachusetts School of Marine Science and Technology.

The FSV *Henry B. Bigelow*, delivered during summer 2006, is the second new fisheries survey ship to be built by NOAA, representing a significant achievement in NOAA's efforts to modernize its fleet of fisheries, oceanographic, and hydrographic survey ships. The primary objective of the ship will be to study, monitor, and collect data on a wide range of sea life and ocean conditions in the waters from Maine to North Carolina. It will also observe weather, sea state, and other environmental conditions; conduct habitat assessments; and survey marine mammal and marine bird populations. All missions support the application of ecosystem principles to fishery management. The FSV *Bigelow* is a state-of-the-art, 40-day endurance, research ship with multiple science mission capabilities, including bottom trawling, midwater trawling, hydroacoustic surveying (the ship's "quiet" hull minimizes underwater sound made by the ship), and oceanographic and hydrographic operations. In addition, it has capabilities for handling specialized gear such as MOCNESS frames,

floating and moored buoys, towed vehicles, dredges, and bottom corers. Also available are marine mammal and bird observation stations to track and identify protected species such as North Atlantic right whales, humpback whales, and harbor porpoises.

The NEFSC research activities range from assessments of finfish populations during trawl surveys conducted annually since the 1960s, to process-oriented research projects such as studying the impacts of global climate change on the coupling of zooplankton to cod and haddock larval distributions and predation on Georges Bank. Surveys are also conducted for ocean quahogs, surfclams, and sea scallops. In addition, grants are provided to support surveys of Gulf of Maine northern shrimp and finfish surveys in state waters.

Aquaculture research focuses on mollusks and finfish, including the development of efficient systems by improving biological and physical rearing parameters. Interdisciplinary research in husbandry, physiology, genetics, immunology, chemical ecology, and nutrition is conducted to optimize growth and production in culture systems. Projects extend to include study of harmful algal blooms (HABs) and exploration of aquaculture-based stock enhancement strategies.

Long-term changes in the ecosystem supporting fisheries are monitored through surveys of that ecosystem; research is under way to convert these data into indices on the health of the ecosystem. Additional process-oriented research projects focus on the effects of pollution on coastal species (e.g., winter flounder and bluefish); biological characteristics of selected shark species in the North Atlantic; field investigations on the effects of trawling on seabed habitats; and descriptions of essential fish habitat (EFH) for most finfish species. The Center also conducts social and economic research in support of the fishery management process. The NSL provides taxonomic expertise on finfish, crustaceans, and squids for all of NMFS.

Reliable information—critical to the development of regional FMPs, subsequent amendments, and ultimately to the maintenance of sustainable fisheries—is produced through the Northeast Regional Stock Assessment Workshop (SAW) process. This cooperative effort is guided by the Northeast Regional Coordinating Committee composed of the directors of the NEFSC, Northeast Regional Office (NERO), New England Fishery Management Council (NEFMC), Mid-Atlantic Fishery Management Council, and Atlantic States Marine Fisheries Commission (ASMFC). The Northeast Regional Stock Assessment Review Committee (SARC) is an important part of the SAW process, which includes peer-assessment development (SAW Working Groups or ASMFC technical committees), assessment peer-review, public presentation, and document publication. The process has been in place since 1985, and has provided a forum for preparing, peer reviewing, and reporting on stock assessments of over 40 species/stocks in the region. The SAW is the oldest such process for review of assessments by peers in the Nation and has been used as a model in developing similar protocols around the United States and in Europe. All meetings are open to the public and widely announced. As currently constituted, the SAW has three parts: 1) SAW working group meetings where the assessments are developed (or ASMFC technical/stock assessment groups when stock assessment are prepared by the ASMFC), 2) a high-quality peer review of the assessments by an independent panel of assessment/management experts, and 3) presentation of results/reports from the SARC meeting to the FMCs and ASMFC. The Plan Development Teams and Technical Committees of the FMCs use the Stock Assessment Reports and the peer reviewers' reports to develop management advice for the FMCs that is consistent with existing FMPs.

The Northeast Cooperative Research Partners Program (NCRPP)—NMFS' largest cooperative research program in the northeast—was established in 1999 in conjunction with the New England Fishery Management Council. The NCRPP is one of six regional cooperative research programs nationwide. The program has funded more than $26 million in cooperative research projects both large and small, and just over $1 million in 2005. Cooperative research programs promote trust and understanding among fishermen, scientists, and managers; provide a way for fishermen to contribute their empirical knowledge of the sea and marine life to the scientific process; and can strengthen both the information underlying fishery management decisions and the decisions themselves.

Much recent gear research in the Northeast has been accomplished through grants, with Northeast Regional Office (NERO) oversight. These grants have gone to fishermen, or to organizations such as states and universities, which carry out the research with the help and cooperation of the fishing industry. The NERO Fisheries Engineering Group is also involved with data analysis for exempted fishery permits and fishway engineering for anadromous fish. Conservation engineering activities in the NERO have recently been concentrated on the problem of entanglement of large whales in fixed fishing gear (e.g., lobster traps and gillnet gear). The fishing industry aided this effort through its participation in the Gear Advisory Group to the Atlantic Large Whale Take Reduction Team by devising solutions and by volunteering vessels and time for observations and testing. Also, NERO and the NEFSC are collaborating on experiments using pingers and acoustic reflective nets as deterrents to marine mammal entrapment in gillnets.

RECENT ACCOMPLISHMENTS AND RESEARCH PRIORITIES FOR FY 2007–2012

I. Research to Support Fishery Conservation and Management

Recent Accomplishments:

- A two-volume taxonomic atlas of eggs and larvae of fishes of the western North Atlantic has been completed.
- The distribution, abundance, and basic biochemistry of an invasive tunicate (sea squirt) *Didemnum* sp. on eastern Georges Bank has been documented; as of August 2005, the species was present over at least 82 n.mi.^{2} of the productive gravel bottom on the eastern bank.
- Led the monitoring for a community-based oyster restoration in the Navesink River in New Jersey. The project led to the first successful oyster spawning and setting in the river in over a decade.
- A peer review of alternative EFH designation methodologies was conducted.
- EFH documents were completed for the 39 species for which management recommendations are provided by the Mid-Atlantic and New England Fishery Management Councils.
- Updated EFH information on 49 species of sharks, tunas, and billfishes used data from observer and tagging databases for the Draft Consolidated Atlantic Highly Migratory Species Management Plan.
- Resistance to PCBs was demonstrated in an anadromous fish (tomcod) collected from

throughout the Hudson River estuary. This is the most widespread occurrence of such resistance found to date.

- Methods were developed for detecting the effect of contaminants on gene expression and regulation in winter flounder.
- The Center demonstrated that diet influences contaminant composition in young-of-the-year bluefish.
- The Center demonstrated that contaminant composition pattern in young-of-the-year bluefish uniquely identifies individuals to nursery estuary with a resolution of less than 15 km.
- The concentration of manganese accumulated on gills of American lobsters was found to be an indicator of exposure to hypoxia in estuaries with degraded habitat quality. A paper in the *Journal of Shellfish Research* may help us understand the vulnerability of lobsters in marginal estuaries to events such as the recent mass mortality in Long Island Sound.
- The NEFSC demonstrated rapid accumulation of PCBs in young-of-the-year bluefish in the Hudson River estuary with an indication of dilution by exponential growth.
- The NEFSC demonstrated the inadequacy of existing bathymetric maps in the Hudson Canyon for purposes of habitat definition.
- The oceanographic conditions on the Northeast Shelf were measured and the interannual variability was documented in a report each year. The data were used in stock assessment activities and available to the scientific community via the web.
- Shelf-wide surveys of ecosystem conditions from Cape Hatteras to the Gulf of Maine were completed, along with monthly continuous plankton recorder transects of the Gulf of Maine and across the Middle Atlantic Bight using ships of opportunity in cooperation with NOAA's Global Ocean Observing Program. These activities contribute to our understanding of the role of plankton for fish recruitment and demonstrate the success of the program.
- An analysis of the demographics of the *Calanus finmarchicus* population in the Mid-Atlantic Bight was completed and published.
- Drifter deployments were conducted in support of monitoring the red tide event in New England waters during spring 2005. The drifter location data were made available in real-time via a web page display.
- The Center completed studies examining the habitat dynamics of juvenile winter flounder predation in a shallow coastal nursery area.
- Studies of species-specific predator-prey interactions affected by changes in structural refuge were completed, supporting previous field research that complex seafloor habitats contribute to juvenile fish survival.
- The occurrence and possible ecological role of thin layer formation in the water column in the New York Bight was examined, revealing layers of varied community composition and dynamic habitat interactions.
- Evidence of Atlantic menhaden spawning at lower temperatures than previously recorded was documented in the New York Bight Apex.

- An acoustic tagging study showed that black sea bass and summer flounder were patchily distributed in a disturbed coastal environment with higher occurrences in shallow, complex habitats and little evidence of long-term residency.
- The predator survival behaviors of three young-of-the-year temperate reef fish species were characterized.
- Studies were conducted that demonstrated low winter temperatures and salinities in the Hudson-Raritan estuary do not harm adult female blue crabs.
- Initiated the ecosystem project entitled "Energy Modeling and Analysis eXercise" (EMAX) that applies a food web model to four subregions of the northeast U.S. continental shelf. Completed initial report describing baseline conditions in the ecosystem.
- Developed consumption estimates of all major predators of Atlantic herring (commercially targeted forage fish), and translated values into preliminary estimates of predation mortality.
- Assisted in the development, initialization, and parameterization of a Multi-species Virtual Population Analysis (MSVPA) for the mid-Atlantic species complex. Emphasis was on menhaden as focal species with major predators including those stocks that are recreationally important.
- Assisted in the development of a multi-species/ecosystem model toolbox.
- Provided prey field information to assist with the designation of EFH for all species for which management recommendations are provided by the NEFMC. Diet compositions of all managed stocks and location of prey distribution (using stomachs as samplers) have been calculated.
- In 2005, the R/V *Gloria Michelle* sailed to Kings Point U.S. Merchant Marine Academy to conduct fisheries training for NOAA Corps' Basic Officer Training Class 106.
- The R/V *Gloria Michelle* has conducted acceptance testing of the Macartney towed underwater vehicle. The multibeam sonar head can be operated on this vehicle to further extend its abilities. In addition, the task of using the multibeam sonar for sea floor habitat mapping the waters of Massachusetts has begun.
- Developed a method to estimate the age of butterfish from otolith weights.
- Developed standardization methods to estimate the accuracy and precision of age data to monitor Quality Assurance/Quality Control (QA/QC) and provide estimates of aging error for assessment models.
- Convened or participated in Aging Workshops for Atlantic cod, haddock, pollock, Atlantic herring, and surfclam to ensure consistency in conventions, methodologies, and age interpretations between Federal, state, academic, and international aging laboratories.
- Evaluated changes in mean weights at age, growth rates, and sex ratios for five commercially important species of flatfish.
- Published validated age estimates for the shortfin mako shark in Atlantic waters.
- Completed blue shark stock structure analyses based on Cooperative Shark Tagging Program mark/recapture data detailing size composition and movements between Atlantic regions.

- Completed an examination of the predator-prey relationships between the shortfin mako and bluefish (its primary prey), to compare contemporary and historic levels of predation on bluefish.
- Completed survival rate estimates for shortfin mako shark in the Atlantic using the Cooperative Shark Tagging Program mark/recapture data.
- Produced a pictorial field guide to sharks, tunas, and billfishes of the U.S. Atlantic and Gulf of Mexico for identifying large pelagics.

A great white shark, one of the large pelagic species of shark. Photo: NOAA.

- Produced a pictorial field guide and dichotomous key for identifying shrimp and decapod species of the Georges Bank-Gulf of Maine region.
- Authored 59 taxonomic papers including several book chapters. These publications improve our knowledge of the diversity of marine organisms and contribute critical baseline information required in decisions involving marine ecosystem management.
- A Center systematics scientist was a co-recipient of $2.9 million grant awarded by the National Science Foundation to support systematic research on cnidarians. This collaborative research effort, "Assembling the tree of life—An integrative approach to investigating cnidarian phylogeny," is funded through NSF's Assembling the Tree of Life Program, 2005–2009.
- Provided leadership and technical advice in the development of the new Oceans Hall Exhibit, co-sponsored by NOAA, at the Smithsonian's Natural History Museum.
- Completed a report on the status of deepwater corals in northeast U.S. marine waters.
- Continued development of dedicated research program on deep-sea coral ecosystems and associated fauna on the U.S. southeast continental shelf. A Center scientist was co-Principal Investigator on two NOAA Ocean Expedition projects to examine deep coral reefs in the South Atlantic Bight and co-authored a chapter on deep-sea corals in the Southeast Region for NOAA's Status of Corals report, and participated in two USGS/MMS-funded deep coral research expeditions in the Gulf of Mexico.
- Completed a study of selected fauna of Bear Seamount (New England Seamount chain) providing baseline information on seamount ecosystems from the field program on the mount.
- Completed a series of species checklists for families of fishes published by the California Academy of Sciences, which included evaluations of all valid species and all of the scientific names used for members of the families Scombridae, Belonidae, Scomberesocidae, and Hemiramphidae.
- Juvenile lobster have been captured, marked, and released on a natural cobble reef in Long Island Sound, Connecticut. A recapture rate of approximately 7 percent has enabled the determination of movement, site fidelity, growth, and estimated population size.
- A field ecological study of the introduced Asian shore crab has quantified their impact

on natural settlement of recruiting barnacles in Long Island Sound, Connecticut. Information on predator density effects and diet preference has been identified.

- Experimental calibrations have been conducted that will enable use of RNA/DNA measurements of muscle tissue of finfish to estimate growth potential. This increases confidence in using this biochemical method to evaluate wild-caught and aquaculturally reared fish.
- The NEFSC had the lead role in an international intercalibration study of biochemical methods for measuring RNA/DNA ratios in larval and juvenile fish. These methods are used to determine recent growth and condition of the organisms.
- A preliminary experiment to evaluate stock enhancement potential of black sea bass was conducted: approximately 2,000 laboratory-reared and fin-clipped fish were released on a rock reef in Long Island Sound, Connecticut. Some recaptured fish were at liberty for up to 3 months.
- A study of the diet of juvenile tautog has identified size-related shifts in food preferences.
- The Center introduced, validated, and applied novel flow-cytometric applications in marine science, including: immunological analysis of invertebrate hemocytes, live-sorting of bivalve hemocytes, determination of nutrient status in individual phytoplankton cells, quantification and size-distribution analysis of phytoplankton and other particles in seawater, isolation of microorganisms using flow-cytometric sorting, and quantification of grazing activity of filter-feeding mollusks on phytoplankton.
- Completed a report providing guidance for determining whether the Eastern oyster should be listed as an endangered or threatened species. This work was conducted as part of the activities of an agency-supported Biological Review Team for Eastern oyster.
- Participated in an extensive research program on tomcod, an important component of the Hudson River ecosystem and a compressed-life model for research on gadid fishes. Staff coauthored "Evidence of spatially extensive resistance to PCBs in an anadromous fish of the Hudson River" and "Characterization of the aryl hydrocarbon receptor repressor and a comparison of its expression in Atlantic tomcod from resistant and sensitive populations."
- Established a partnership with the United Nations Environmental Program (UNEP) wherein the LME projects and their Strategic Action Programs under way in the 19 UNEP Regional Seas areas around the globe will, through agreed-upon transboundary ministerial actions, constitute the principal assessment and management authorities for recovering depleted fish stocks, restoring degraded habitats, and reducing and controlling coastal pollution through the introduction of ecosystem-based practices for sustaining marine resources and their environments.
- In cooperation with the Global Environment Facility and its $600 million in grant aid to 121 countries in Africa, Asia, Latin America, and eastern Europe, provided scientific and technical assistance in the introduction of ecosystem-based management practices framed around five ecosystem assessment and management modules: 1) productivity, 2) fish and fisheries, 3) pollution and ecosystem health, 4) socioeconomics, and 5) governance.

- Assisted in training scientists from developing countries in: 1) modeling of the carrying capacity for maximum sustainable fisheries, 2) modeling of nitrogen and phosphorus, and 3) modeling of particle spectra as indicators of ecological condition of LMEs.
- Issued the first advisory on the ecological condition of the Northeast Shelf Large Marine Ecosystem, based on an analysis of two decades of time series measurements of chlorophyll, primary productivity, zooplankton, and temperature that described the plankton component of the ecosystem as robust with no significant change in average annual primary.
- NEFSC scientists co-edited a special issue of *Deep Sea Research* reporting results of the U.S. GLOBEC Georges Bank program, which investigated the influence of environmental variability on the physics, plankton, and fish populations of the bank. NEFSC scientists were also lead authors or co-authors on 7 of the 18 contributions in the volume.
- Published an atlas of fish egg distributions on Georges Bank during the U.S. GLOBEC Georges Bank Program (1995–1999).
- Demonstrated the palatability of the invasive colonial tunicate (sea squirt) to three common marine invertebrates: the purple sea urchin, common spider crab, and Asian shore crab. Cunner, a local wrass, did not ingest the tunicate.
- Analyzed food value of a colonial tunicate (sea squirt) collected from a variety of locations in New England, revealing that the squirt contained a high and variable content of indigestible matter for potential animal consumers.

Research Priorities, FY 2007–2012:

I.A. Biological research concerning the abundance and life history of fish stocks

- Implement an image-analysis-based method to generate production fecundity estimates for numerous species.
- Expand research in the development of micro-constituent chemical analysis techniques for stock identification.
- Develop, test, and implement multispecies and ecosystem-based models including new approaches for dynamic ecosystem modeling, resulting in assessments for groups of stocks or entire systems and decision analysis tools for fishery managers and ecosystem committees.
- Using the Barcode of Life methods adopted by the Census of Marine Life, develop a DNA barcode library for species of interest and their prey (e.g., fish, plankton, protected species), and combine this information with emerging technologies to develop the next generation of species-specific sensors for use in ecosystem surveys, ecosystem research, and regulatory enforcement.
- Determine distribution and abundance of young finfish and lobster in nearshore coastal habitats and nursery areas, through sampling over multiyear time series.
- Locate and describe habitat characteristics of winter flounder, *Pseudopleuronectes americanus*, spawning areas by sampling of demersal eggs.

Juvenile haddock from a trawl sample collected on the NOAA ship *Albatross IV*. Sampling is an essential part of fisheries research. Photo: NMFS.

- Conduct comprehensive health assessments of bivalve mollusks, including nutritional, physiological, immunological, histological, and bacteriological variables, with the overall objective of detecting and identifying sources of sub-lethal stress that impact production by slowing growth or increasing susceptibility to parasites and pathogens.
- Enhance consumption rate estimates for commercially valuable stocks utilizing the NEFSC's food habits data. This effort will calculate consumption for a wide range of species which can then be used to track both changes in growth and changes in mortality.
- Sample haddock, cusk, eelpout, and redfish on boulder reefs inside and outside the Western Gulf of Maine Closure by means of fish pots, determine diet composition and utilize stable isotopes to assess feeding habitats and effective trophic level; expand the food web study into deep mud habitats, using trawl sampling; obtain further data from a previously sampled gravel-bottom habitat; and make fuller use of food web (stable isotope and stomach) samples from shoal habitats.
- Develop calibration approaches to compare survey results for current multispecies bottom trawl surveys conducted on the RV *Albatross IV* using a Yankee 36 trawl, with new bottom trawl surveys conducted on the FSV *Henry B. Bigelow* using an improved 4-seam, 3-bridle trawling system.
- Develop calibration approaches to compare survey results for current Sea Scallop dredge surveys conducted on the RV *Albatross IV* using a standard NEFSC scallop dredge to surveys conducted on a leased University-National Oceanographic Laboratory System (UNOLS) vessel utilizing an improved scallop dredge design developed in conjunction with industry stakeholders.
- Develop calibration approaches to compare survey results for current Surf Clam and Ocean Quahog dredge surveys conducted on the RV *Delaware II* using a standard NEFSC clam dredge, to surveys conducted on a leased commercial vessel platform utilizing an improved clam survey dredge design developed in conjunction with industry stakeholders.
- Continue to assess the status of marine mammals and turtles in the Northwest Atlantic Ocean through a three-pronged approach—stock identification, abundance estimation, and mortality assessment—thereby providing a better understanding of the spatial/temporal overlap between protected species and fisheries.

I.B. Interdependence of fisheries or stocks of fish

- Establish Marine Integrated Ecosystem Assessments (MIEAs) for all U.S. regional LMEs following the process of 1) National Workshop for identifying, compiling, and vetting ecological indicators; 2) Regional Working Groups for culling National Stan-

dard Ecological Indicators; 3) National Ecosystem Modeling Workshop; 4) Regional Ecosystem Modeling Working Groups; 5) Regional Ecosystem Plan Assimilation Teams; and 6) National Ecosystem Assessment Reporting Group.

- Define food habits and predator-prey relationships of marine finfish in nearshore coastal nursery areas.
- Use RNA/DNA ratios in muscle tissue of finfish as a biochemical indicator of growth in wild-caught and aquaculturally reared fish.
- Develop the capacity for quantitative, integrated ecosystem assessments including development, culling, and vetting of a wide range of ecological indicators, including the ability to quantitatively model major ecosystem processes, tracking the major forcing functions of key ecosystem indicators.
- Develop multispecies models to provide the analytical framework for evaluating management decision tradeoffs. A wide range of multispecies models—including MSVPA, MSYPR, MSProd, MSFore, Network Analysis, and Atlantis—are under development and parameterization. The Center will explore their utility in the management context to simulate various decisions.
- Enhance estimates of factors that influence stock mortality, particularly as related to species interactions, by incorporating factors into stock assessments beyond fishing mortality that have the potential to alter stock abundance, structure, and production. The particular emphasis is to examine the role of predation mortality on stocks that are important forage for many other species and are also targeted themselves.

I.C. Identifying, restoring, and mapping of essential fish habitat (EFH)

- Conduct studies to document and understand the behavior and movement of fish in areas of critical habitat.
- Identify and provide EFH information as required by the MSFCMA for FMPs.
- Continue to conduct research to determine the functional value of estuarine and nearshore habitats, including restored sites, to the sustainability of fishery resources.
- Continue to improve GIS capabilities in order to map seabed habitats and indicate EFH with respect to various human activities.
- Use fine-scale seabed mapping and GIS to identify distribution of finfish across different habitat types.
- Develop a quick and cost-effective method for the broad-scale characterization of marine habitats, initially in the Gulf of Maine, using existing hydrographic and geological data; define sensitive habitats; and help to predict changes to ecosystems as a result of climate change.
- Determine habitat use of finfish and lobster utilizing tagging and tracking techniques (both internal sonic tags and external tags), focusing on defining growth-rates, site fidelity, movement, and population estimates.

I.D. Impact of anthropogenic factors and environmental changes on fish populations

- Determine biological, environmental, and habitat processes controlling the reproductive success of important fishery resources.

- Continue field and modeling research activities to better understand the influence of environmental variability and climate change on lower trophic level productivity and fish recruitment.
- Continue to monitor oceanographic and biological conditions on the Northeast Shelf and document ecosystem variability in order to determine its role in the recovery and sustainability of depressed fish stocks.
- Establish a Northeast Shelf Ecosystem analysis center as a research group focused on the relationship between resource species and the environment, examining the relationship between climate and recruitment, the impact of climate change on the reproduction and yield of species, and the variation in ecosystem and food web interactions.
- Understand how high densities of organisms (e.g., copepods), which are a primary food source for right whale populations frequenting the Gulf of Maine region, are maintained through physical and biological processes. This understanding will lead to improved capabilities to forecast the locations of whales and their prey.
- Partner with NSF to jointly undertake long-term ecological research in the coastal ocean under the Long-Term Ecological Research (LTER) program, focusing on coastal ocean and estuarine effects of global warming, eutrophication, or other stressors, thereby supporting improved ecosystem management capabilities.
- Investigate effects of hypoxia in the Middle Atlantic Bight and its estuaries through coordinated modeling (coupled physical-NPZ), field, and laboratory studies resulting in a modeling capability to support ecosystem management that would address resource-level effects and sampling criteria for improved monitoring to support the operational modeling, as part of the IOOS.
- Develop and deploy an Ecosystem Productivity Observing System (EPOS) to rapidly map 3-dimensional patterns of ocean productivity across an LME and provide integrated 3-dimensional assessments of the health and productivity of the lower trophic levels by synergistically combining several state-of-the-art sampling technologies, including in situ platforms and satellites.
- Investigate skeletal anomalies in finfish as possible indicators of environmental quality.

II. Conservation Engineering Research

Recent Accomplishments:

- The first survivability study on elasmobranchs and more specifically, juvenile spiny dogfish (*Squalus acanthias*) that included stress measurements and survival assessment in the Atlantic trawl fishery. In addition, research investigated short- and long-term survivorship following trawl exposure and discard.
- Morphometric measurements of key groundfish species collected during standard fishing operations on commercial fishing vessels in the Gulf of Maine. Variability of body measurements for each length class of fish was calculated and a simple model formulated to estimate the mesh size and configuration through which commercial fish species of any size will be most likely to escape. The model enables managers and the fishing industry to predict potential retention rates of major commercial fish species for a range of mesh sizes and configurations.

- The effectiveness of two cod-avoiding trawl net designs—the "Ribas" and "Topless" trawls—has been tested and verified, using larger versions of the designs and including nighttime testing.
- A Southern New England Working Group that focused on bycatch and gear conservation engineering was established to share knowledge and skills of fishermen and gear researchers for the development of collaborative efforts in conservation gear engineering projects.
- Mesh size selectivity studies aboard a large, commercial fishing vessel were conducted and results integrated into the study of yield-per-recruit (YPR) and spawning-stock biomass-per-recruit (SSBPR) models evaluating the effects of incrementally increasing mesh sizes. Specifically, 1) mesh selectivity studies were conducted using an alternate tow method aboard commercial fishing vessels, 2) selectivity analyses on resulting data were conducted and selectivity curves generated for each species by mesh size and shape, and 3) YPR and SSBPR analyses were conducted and isopleths generated.
- Blue shark behavior toward a variety of baits, both natural and artificial, were carried out to learn which bait characteristics are distasteful to the species. During 10 sea trials offshore, blue sharks were presented with a series of natural and artificial baits. Shark responses were recorded and comparisons made between reactions to artificial baits and control baits that are widely used by pelagic longliners for tunas and swordfish.
- Developed gear-based solutions to sea turtle bycatch in Virginia pound net gear, and partial solution to turtle bycatch in scallop trawl gear. Research is continuing on ultimate gear modifications to reduce turtle bycatch in dredge and trawl gear.
- Developed and tested a new Mariner Shuttle System (MSS) for monitoring primary productivity in near-real time. The MSS towed body undulates in the upper 50m of the water column and carries a payload of additional sensors for chlorophyll, zooplankton, temperature, salinity, oxygen, and light.

Research Priorities, FY 2007–2012:

- Coordinate with the Pacific Ocean Shelf Tracking (POST) program of the Census of Marine Life to deploy an acoustic array on the Northeast Shelf to track fish movements and stock mixing, not only along the coast but also in the significant inshore and offshore components.
- Develop and test calibration procedures for multibeam systems to ensure data accuracy, to develop data acquisition and analytic processes as well as new database structures, to rapidly provide post-processed data to analysts, and to upgrade current underwater remote sensing capability, in order to estimate species composition and target strengths of water column organisms, benthic organisms, and habitat types.
- Undertake a collaborative research study to assess the discard survivability and escape vent efficiency in the deep-water red crab fishery off the New England continental shelf, in addition to quantifying bycatch composition of this fishery.

III. Research on the Fisheries

Recent Accomplishments:

- Conducted benchmark assessments of 18 fish stocks through the Stock Assessment

Scallops on the sea floor of Georges Bank at a depth of 94 meters. Photo: NMFS and USGS.

Review Committee (SARC: http://www.nefsc.noaa.gov/nefsc/saw/) peer-review process. An additional 19 groundfish stocks were assessed at the Groundfish Assessment Review Meeting in August 2006.

- Contributed extensively to the benchmark assessment of American lobster by the ASMFC. Center scientists regularly provide updates on the status of several species, including summer flounder, spiny dogfish, and sea scallops, among others.
- Internationally, conducted assessments of Georges Bank yellowtail flounder, Georges Bank cod, haddock, and Atlantic herring as part of the Transboundary Resource Assessment Committee (TRAC).
- Assessments of 30 northeast U.S. marine mammal stocks were completed and reviewed by the Atlantic Scientific Review Group. Assessments were updated for five large whale, 21 small cetacean, and four pinniped stocks.
- Center scientists have led the development and implementation of programs for stock assessment in the NMFS Toolbox—a software package comprising classical and modern estimation methods, forecasting tools, and advanced simulation testing programs.
- Center scientists developed methods to comprehensively evaluate the precision and accuracy of aggregate discard estimates in the groundfish, monkfish, and fluke-scup-sea bass fisheries and used optimization methods to improve the allocation of observer days to fleets.
- Significant advances in the theory of rotational fisheries management have been developed and implemented as part of the Atlantic sea scallop FMP.
- Field research on Atlantic salmon focuses on obtaining smolt production estimates, telemetry studies of emigrating hatchery and wild smolts, fishery-independent sampling through marine smolt trawling surveys, and monitoring of fishery removals on the high seas. Smolt production in various rivers is monitored through the use of in-river traps. Annual monitoring of the biological characteristics of Atlantic salmon in West Greenland fishery continued as well.
- Continue protected species bycatch mitigation program though a combination of at-sea monitoring of fisheries through the Fishery Sampling Branch's observers, estimation of bycatch in observed fisheries, research on the environmental conditions and fishery practices associated with this bycatch, development of gear-based solutions to bycatch reductions, and assessment of economic alternatives to and impacts of mitigation measures. The NEFSC staff will continue to advise MMPA Take Reduction Teams, Turtle Expert Working Groups, and Regional/National Protected Resources managers on bycatch mitigation.
- Developed marine mammal passive acoustics research program in the Northeast. Began multiyear program using passive acoustics to monitor presence of large whales in

Northwest Atlantic waters; hired full-time permanent acoustician; co-hosted (with the NMFS Office of Science and Technology) first NMFS national passive acoustics workshop; and developed multiyear funding initiative with the NOS, NMFS Office of Science and Technology, and PIFSC to implement a national passive acoustics monitoring program.

- A report was completed (with NERO and New England Fishery Management Council staff) on characterizing fishing gears used in northeast U.S. marine waters, and potential effects on EFH.
- Cooperative research efforts between the fishing industry and Center scientists include extensive tagging programs for yellowtail flounder, black sea bass, and scup.
- A Study Fleet program has been developed for commercial vessels in Southern New England and the Gulf of Maine to provide high-resolution (temporal and spatial) self-reported data on catch, effort, and environmental conditions. An advanced electronic logbook system (ELB) has been developed to acquire the information. In the past 2 years the logbook has been deployed on 33 fishing vessels and has been used to record over 1,100 fishing trips.
- Center anthropologists have established National Standard 8 protocols for short and extended community profiles, published a "Practitioners' Manual" for work under National Standard 8, organized a "Social Impacts Assessment" workshop, and published a series of articles on the nature of community dependence on fishing, on defining Magnuson Fishing Communities, on the use of diversification indices for communities, and on the use of GIS to visualize land/sea connections.
- Center economists and anthropologists have undertaken efforts to facilitate Council consideration of market-based institutions to facilitate efficient fisheries management. These include establishing of days-at-sea (DAS) categories of effort units, modeling DAS trading and pricing with the University of Rhode Island and developing draft guidelines for the establishment and operation of sectors.
- Developed and used extensive Input/Output models of fishery regulatory impacts on the marine economy with county level impacts for New England, Mid-Atlantic, and New England linkages, recreational fisheries components, forward linked impacts to processing and wholesaling, and published "On the Use of I/O in Marine Fisheries."
- Center economists are engaged in a national effort to measure excess and overcapacity in U.S. fisheries using Data Envelopment Analysis (DEA) and other models developed at the NEFSC. In addition, designed and assessed a series of buy-back programs over the past 5 years.
- Center economists have worked jointly with Canada's Department of Fisheries and Oceans (DFO) to estimate models of U.S.-Canada haddock trade in response to varying joint harvest strategies for eastern Georges Bank haddock.
- Under ecosystem approaches to management, developed a survey program to measure the public's valuation of marine protected area (MPA) ecological reserves in the Northeast Region. In addition, published manuscripts on fishery zoning, national asset valuation of living marine resources, the utility of portfolios in the appropriate exploitation of the marine ecosystem, and the value of rents in several fisheries.
- Conducted annual broadscale multispecies bottom trawl surveys covering 78,000 n.mi.^{2} along the continental shelf of the northwest Atlantic Ocean. Data produced included

biomass and abundance indices, size distributions, age distributions, maturation data, and diet information. The survey data provide an essential fishery-independent component to the population assessment for 45 stocks of finfish and invertebrates.

- Conducted annual sea scallop dredge surveys along the continental shelf of the northwest Atlantic Ocean covering approximately 17,000 n.mi.^{2} and 500 stations. The survey data provided an essential fishery-independent component to the population assessment of the Atlantic sea scallop (*Pacopecten magellanicus*). In 2005, sea scallops were the most valuable commercial landings in the northeastern United States, finally eclipsing American lobsters, which has been the region's perennial front runner. Since 2000, New Bedford, Massachusetts, has been the top-grossing U.S. fishing port, mostly because of sea scallop landings. The fishery is also the largest harvest of wild scallops in the world.
- Conducted a triennial dredge survey to assess the status of surfclams, *Spisula solidisima*, and ocean quahogs, *Arctica islandica*, covering approximately 31, 900 n.mi.^{2} along the continental shelf of the northwest Atlantic Ocean. The survey data provided an essential fisheries-independent component to the population assessment of these two species, which, along with sea scallops, represent the three primary offshore bivalves targeted by industry in the northeast U.S. coast.
- Conducted biannual fishery-independent survey of Atlantic large and small coastal sharks to monitor the species composition, distribution, and abundance of sharks and to collect biological samples for life history studies.
- In cooperation with state agencies, conducted annual surveys of shark nursery areas in major coastal Atlantic states to identify shark species utilizing coastal zones as pupping and nursery grounds, gauge the relative importance of these areas, and determine migration and distribution patterns of neonate and juvenile sharks.
- Conducted annual shark longline survey to assess and monitor the juvenile sandbar shark population during the nursery season in Delaware Bay to provide the only young-of-the-year and juvenile sandbar shark relative indices of abundance.
- Conducted annual surveys of northern shrimp in the Gulf of Maine to produce biomass and abundance indices, as well as size, age, and sex distributions. This information is the primary input for the population assessment of Gulf of Maine stock of northern shrimp.
- Conducted annual fall NEFSC Herring Hydroacoustic Surveys and derived estimates of spawning population biomass for Atlantic herring in the Georges Bank and Gulf of Maine regions, which are used in the U.S./Canadian TRAC Assessment for Atlantic herring.
- Developed an online Intranet system of digital video and photos, audio, and text information providing age structure, maturation, and diet dissection techniques for 40 species of finfish and invertebrates. This information, now available on board NOAA research vessels on stations during data collection, is designed to improve performance and consistency during at-sea sampling.
- Improved routine acoustic survey operations using the EK500 and EK60 Scientific Echosounders through a variety of field and laboratory experiments in collaboration with other NMFS Centers and extramural collaborators, including an EK calibration workshop sponsored by the NMFS Advanced Sampling Technology Working Group.
- Developed acoustic capabilities with the multibeam sonar (models EM3002 on R/V

Gloria Michelle, EM70 on FSV *Bigelow*, and SM2000 scheduled to be installed aboard FSV *Delaware II*) through various training workshops and hands-on field trials. These multibeam systems will provide water-column and seafloor backscatter measurements that will potentially improve NEFSC stock assessment, conservation engineering, and EFH research.

- Developed optical technology capabilities and infrastructure that are routinely implemented aboard NEFSC cruises involved with trawl and dredge performance tests, seabed classification, and acoustic target recognition.
- A recently constructed portable fiber-optic Advanced Fisheries Technology Vehicle (AFTV) provides the NEFSC with a universal towfish platform (with 2000 m depth capability) for deploying advanced technologies (integrated acoustic-optic-environmental sensors) to support various strategic missions (SAIP, EFH, IOCM).
- The NEFSC created the Northeast Fisheries Observer Program Training Center. Since May 2005, eight 3-week training classes as well as numerous refresher classes for specific sampling issues have been held. The Training Center represents a commitment to professionally training and preparing observers in order to collect high-quality fisheries-dependent data.
- Tolerances of young bay scallops to un-ionized ammonia and other nitrogen compounds have been quantified in bioassay procedures. The study found that the pH plays an important role in determining toxicity and is important in properly maintaining optimal conditions in re-circulating aquaculture systems.
- A series of experiments have allowed a general assessment of the aquaculture potential of black sea bass. Some experiments were conducted at a local aquaculture-themed high school with the help of students, as part of the Center's outreach and education activities.
- Generated new knowledge on several topics relevant to improving the effectiveness of hatchery production of bivalve mollusc seed for aquaculture, including: determination of sterol nutritional requirements in bivalves, development of probiotic bacteria for hatchery use, clarification of light and nutrient interactions in microalgal feed cultures, development of selected genetic lines of bay scallops, and risk analysis of transferring non-native harmful algal blooms during transplant of bivalve seed.
- Based on national template, established region-specific protocol for describing communities involved in fishing and completed 130 profiles of key coastal communities in the Northeast Region using that protocol.
- Led the working group for development of a national protocol using quantitative indicators (primarily from existing secondary data sources) for identifying fishing communities relative to MSFCMA National Standard 8 requirements.
- Investigated, through interviews and case studies, the growing interest in and policy environment for development of community and sector-based collaborative management initiatives; co-authored two related peer-reviewed journal articles.
- Through case studies, focus groups, and interviews elucidated the differential vulnerabilities of varied populations in the region's fisheries and co-authored final report.
- Investigated methods for defining fishing communities that both address MSFCMA requirements and are grounded in sociocultural theory. Recommended key topics for investigation in order to identify fishing communities (including indicators from sec-

ondary sources and ethnographic data to provide context) and published results as a peer-reviewed journal article.

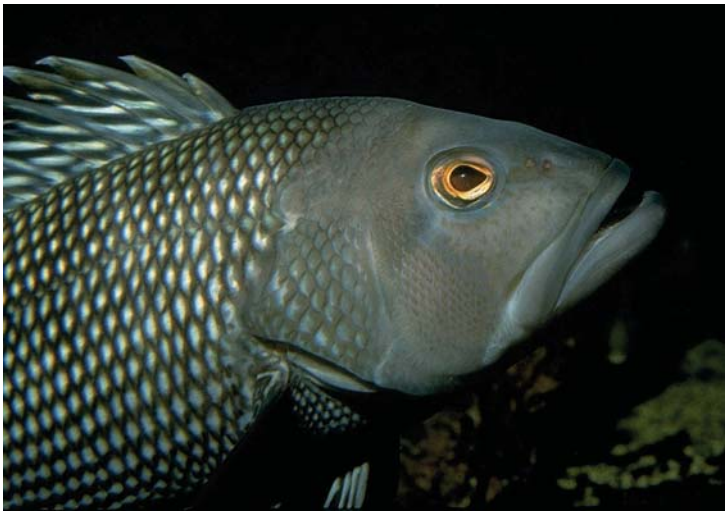
- Participated in the development of a national social-impact assessment conceptual model and co-authored resulting peer-reviewed journal article.
- Edited and wrote selected articles for a theme issue of a major peer-reviewed applied anthropology journal on the topic of research and resource management in North American fisheries.

Research Priorities, FY 2007–2012:

III.A. Social and economic research

- Develop methods to allow decision makers to evaluate the benefits and costs of alternative ecosystem outcomes, to compare ecosystem-wide mixes of uses employing, for example, spatially defined methods and zone-defined portfolios. Develop methods to determine ecosystem services and stock valuations focusing on national asset accounting methods.
- Collect socioeconomic information through surveys with preparation assistance from a Stakeholder Steering Committee. The survey will be followed by a series of meetings throughout Maine, New Hampshire, and Massachusetts to report and interpret resulting data with stakeholders.
- Train fishermen in safety, damage control, rescue procedures, and first aid to improve their knowledge and skills; increase interaction between the Coast Guard and fishermen to improve communication and collaboration; work closely with the New Bedford Safety Task Force and the Coast Guard to develop a long-term program that will provide ongoing opportunities for and participation in safety training for fishermen; and explore potential for lowering the costs of safety equipment and/or insurance in part through active participation in safety training.
- A comprehensive strategy for experimental resource enhancement trials will be implemented considering both risks and benefits, using mathematical population models. This will result in testable hypothesis-based experimental design to determine success and return on investment.
- Perform multivariate statistical analyses of observer and Study Fleet data to identify species assemblages and appropriate strata for estimation of landings and discards to lay the groundwork for subsequent ecosystem modeling for Ecosystem-based Approaches to Fisheries (EAF) and Ecosystem-based Approaches to Management (EAM), resulting in refinements and new methods for estimation of fishing effort and fishing mortality.
- Define strategies for stock restoration or enhancement of the bay scallop, *Argopecten irradians*, by cooperating with many local activities in New England.
- Develop regional ecosystem management procedures setting up a Management Strategy Evaluation framework to simulate and explore properties of various management decisions before they are enacted. This effort will particularly elucidate a holistic and integrated view of all living marine resources, be they targeted, protected, or otherwise.
- Continue to produce and update baseline community profiles per the 3- to 5-year updating cycle implemented nationally.

- Broaden social and cultural investigation beyond fishermen, to include more women and those involved in fishing-related industries (such as processing workers).
- Continue to explore use of GIS to assist in describing and analyzing the social and cultural dimensions of fisheries and fishing communities.
- Continue to flesh out the social and governance aspects of Northeast fisheries, to facilitate expanded use of ecosystem management.
- Conduct statistical analysis of fixed-cost and trip-cost data to develop cost and/or profit functions to be used in regulatory analysis of management actions.
- Perform statistical analysis of changes in marine industries in regional economies over time, and investigate the relationships between these changes and resource conditions.



An adult black sea bass.
Photo: Karen Roeder, NOAA.

III.B. Seafood safety research

This item is not applicable.

III.C. Marine aquaculture

- Develop hatchery technologies to provide large quantities of shellfish or finfish "seed" animals for stocking grow-out systems in an environmentally conscientious manner.
- Quantify transfer of biologically important elements from aquaculture operations to the marine food web.
- Develop aquaculture methods for the black sea bass and bay scallops in recirculating aquaculture systems by experimentally establishing optimal nutritional, physical, and chemical rearing conditions.
- Determine physiological responses of marine invertebrates to different rearing conditions in aquaculture systems, by measuring animal and molecular health and growth performance.
- Make progress in the domestication of farmed bivalve species by selectively breeding for desired traits and identifying the genetic and proteomic bases for successful phenotypes for aquaculture production in different environments.
- Complete development of and field test a suite of environmental measurements to quantify interactions between shellfish farming practices and the ecosystems in which they are contained.

IV. Information Management Research

Recent Accomplishments:

- Provided technical support for databases used by Center scientists, including: at-sea Fisheries Scientific Computing System (FSCS), Biological Sample Monitoring Data Base System (BSMDBS), Commercial Fisheries Data Base System (CFDBS), Food Habits Data Base System (FHDBS), Observer/Sea Sampling Data Base System (OB-DBS), Northeast Survey Database System (SVDBS), and Mark/Recapture Database System (MRDBS).
- Continued implementation of the allocation scheme for 1994–2005 commercial fisheries, which uses vessel logbook data to allocate effort to trip-level catch data.
- Supported the NERO in their efforts to implement mandatory commercial fisheries processor (dealer) and vessel electronic reporting by providing programming and database management services.
- Continued to design, develop, and implement new systems to support electronic capture of data at sea using Personal Digital Assistants (PDA) technology and rugged PC tablets. These systems are used by observers and scientists aboard commercial and research vessels to collect scientific data electronically.
- Implemented the Industry-Based Survey website, which is accessible from the NEFSC and NERO public websites. Atlantic cod, yellowtail flounder, and monkfish surveys are currently available.
- Implemented an interactive web page that provides public access to all of its hydrographic data sets. This activity is in support of the Regional Associations of the IOOS for the Middle Atlantic Bight and Gulf of Maine regions.
- Opened Centerwide e-library, providing virtually all NEFSC staff with desktop access to core journals, citation databases, reference works, and search instruments.
- Managed internal technical and peer reviews and tracked publishing history for approximately 600 staff-authored publications including manuscripts, websites, posters, abstracts, and presentations, and distributed a list of publications annually.
- Developed and produced NEFSC's online public magazine *The Ffiles*, profiling Center research, researchers, and community involvement.

Research Priorities, FY 2007–2012:

- In cooperation with regional partners, continue activities to promote the regional IOOS and to develop web-based tools for easy access to IOOS data in support of management needs.

Mokumanamana, the second island in the Northwest Hawaiian Island chain, approximately 460 miles from Honolulu. Photo: NOAA.

PACIFIC ISLANDS FISHERIES SCIENCE CENTER

The Pacific Islands Fisheries Science Center (PIFSC) conducts multidisciplinary basic and applied research on insular and pelagic living marine resources and fisheries of the Pacific Islands and central and western Pacific. The PIFSC is located in Honolulu, Hawaii, adjacent to the University of Hawaii at Manoa campus. The PIFSC maintains a Honolulu shoreside research facility at Kewalo Basin and a satellite office in west Oahu where its primary wet laboratory facilities are located. These facilities house over 170 people, including Federal employees as well as collaborating staff of the NOAA-University of Hawaii Joint Institute of Marine and Atmospheric Research, University of Hawaii students, and visiting scientists. The primary platform supporting PIFSC field activities in fisheries is the NOAA FSV *Oscar Elton Sette* and the NOAA ship *Hiʻialakai*, with additional support from chartered, contracted, and cooperating commercial fishing vessels.

Fisheries research activities at the PIFSC support the scientific information and advice needs of NOAA Fisheries Pacific Islands Regional Office; the Western Pacific Fishery Management Council; the Papahānaumokuākea Marine National Monument; other federally managed marine resources; and the marine resource management agencies of the State of Hawaii, the Territories of American Samoa and Guam, and the Commonwealth of the Northern Mariana Islands. They also contribute to U.S. scientific support of international organizations concerned with the management and conservation of tunas, billfishes, and other highly migratory pelagic species in the central and western Pacific. Such organizations include the Western and Central Pacific Fisheries Commission and its scientific and technical committees and the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean. Highly migratory species research at the PIFSC is often collaborative and coordinated with the Southwest Fisheries Science Center. Other

collaborative and cooperative research partners include Federal and State of Hawaii agencies; academic institutions; foreign research institutions; the government agencies of American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands; and the public sector, including the commercial fishing industry, seafood markets, and recreational and environmental interests.

The PIFSC conducts biological, ecological, and socioeconomic research on the following living marine resources that fall under existing FMPs for this region:

- Large pelagic fishes of the Pacific Ocean (including tunas, billfishes, sharks, and a number of other incidentally caught but commercially important species).
- Crustaceans of the insular habitats (lobsters and shrimp).
- Bottomfish (snappers, groupers, and jacks) and seamount groundfish of the deep slope and seamount areas.
- Precious corals.
- Coral reef ecosystems.

In addition, from a marine ecosystem perspective, many PIFSC research programs rely on information about the physical environment in the central and western Pacific Ocean. The Center uses satellite remotely sensed ocean and atmospheric data, including the CoastWatch/Ocean Watch station with the National Environmental Satellite, Data, and Information Service; ocean circulation models; a comprehensive physical and biological Coral Reef Ecosystem Integrated Observing System; information from research cruises; and fisheries data to advance our understanding of the dynamic physical and biological ecosystems found in the Pacific region. The PIFSC also makes extensive use of biological and fisheries data collected by observers placed on fishing vessels by the Pacific Islands Regional Office's Observer Program. These observers monitor fishery interactions with protected species to achieve goals related to the MSFCMA, Endangered Species Act, Marine Mammal Protection Act, and Migratory Bird Treaty Act.

Organizationally, marine ecosystem and fisheries research at the PIFSC primarily is carried out by four of the Center's research divisions: the Coral Reef Ecosystem Division (CRED), the Ecosystems and Oceanography Division (EOD), the Fish Biology and Stock Assessment Division (FBSAD), and the Fisheries Monitoring and Socioeconomics Division (FMSD):

- CRED conducts multidisciplinary ecosystem-based research, monitoring, and habitat mapping that provides the scientific basis for effective management and conservation of coral reef ecosystems in the U.S.-affiliated islands of the central and western Pacific Ocean. Specific research activities include: 1) ecological assessment and monitoring to quantify and document spatial and temporal changes in the health of coral reef living resources resulting from either natural or human-induced impacts; 2) detailed taxonomic surveys of reef-associated organisms to assess conservation of biodiversity in using ecosystem approaches to management; 3) habitat mapping and characterization to define and understand the dynamics of habitat-ecosystem-resource linkages; 4) monitoring of oceanographic processes affecting reefs to identify conditions that influence coral reef ecosystem health; and 5) reef restoration through the assessment, monitoring, and mitigation of the effects of marine debris on coral reef ecosystems. Complementary applied research includes evaluating the effectiveness of marine protected areas, developing

non-extractive fishery-independent methods to assess and study bottomfish and their habitat associations, and development of active and passive acoustic technologies to improve capabilities to remotely monitor indicators of ecosystem health.

- EOD conducts research to advance our understanding of the structure and dynamics of marine ecosystems in the Pacific Islands region and the broader North Pacific. Research focuses on: 1) the role of living resources in the ecosystem and 2) how these resources might respond to change, both on the local scale (e.g., predators or prey availability) and on broader temporal and spatial scales (e.g., ocean climate change). EOD's multidisciplinary projects address ecosystem, environmental, and anthropogenic effects on a range of species, including the Hawaiian monk seal, several species of sea turtles, highly migratory target species such as tunas and billfishes, and incidentally harvested species such as marlins.
- FBSAD conducts state-of-the-art research on the population biology, stock assessment, ecology, and life history of exploited marine resources and associated species (e.g., prey, bycatch, and protected species) in the central and western Pacific. FBSAD integrates biological, ecological, oceanographic, and economic data to advance stock assessments and to advise resource management at both the species and ecosystem levels while addressing mandates for conservation and management objectives. Activities undertaken by FBSAD research programs include population modeling, resource survey cruises, fishing experiments, determination of vital rates and other life-history parameters, characterization of environmental physiology, research on distributional ecology, and development of methods to mitigate fishery interactions with protected species.
- The FMSD is the focal point for much of the fishery data collection and all of the socioeconomic research for the PIFSC. This Division collects, quality-controls, and processes fishery-dependent information (i.e., logbooks); issues quarterly and annual reports on federally managed fisheries (including the pelagic longline, bottomfish, and crustacean fisheries); and conducts socioeconomic research on federally managed fisheries. Also residing in FMSD is the Western Pacific Fisheries Information Network (WPacFIN), which collects and processes data from Pacific island agencies (i.e., Territories of Guam and American Samoa, Commonwealth of the Northern Mariana Islands, and State of Hawaii). FMSD also provides technical support to develop and implement data collecting, processing, summarizing, analyzing, and report-generating systems for these island agencies.

RECENT ACCOMPLISHMENTS AND RESEARCH PRIORITIES FOR FY 2007–2012

I. Research to Support Fishery Conservation and Management

Recent Accomplishments:

- Stock Assessment and Fish Biology.
  - Stock assessment research includes conducting baseline assessments of key species and regular updates for fishery management and conservation purposes. Baseline assessments include a metapopulation stock assessment model completed for lobsters in the Papahānaumokuākea Marine National Monument, which will become a complete population assessment in 2007. Pursuant to Proclamation 8031 establishing the Monument and its codifying regulations, lobsters in the Monument are subject to a zero harvest guideline. The assessment of Hawaiian archipelago bottomfish was

updated using a new standardized time-series of catch per unit effort in 2006. An independent assessment of bottomfish was also contracted, confirming the previous baseline approach and results, and providing an alternative model for future analyses. An updated stock assessment of Pacific swordfish was conducted that indicates the resource can well sustain exploitation at the highest levels of fishing effort that have been exerted to date without becoming overfished. In addition, an updated stock assessment on blue sharks was conducted which indicated that, since the 1990s drift net ban, biomass has increased well above minimum levels needed to sustain maximum yield. In collaboration with the Oceanic Fisheries Program of the Secretariat of the Pacific Community, stock assessments of yellowfin and bigeye tuna were also updated, which indicated that overfishing is now occurring on both stocks. Working group meetings of the International Scientific Committee on Tuna and Tuna-Like Species in the North Pacific were held to foster cooperative international stock assessments of blue shark, striped marlin, and swordfish.

  – In addition, several analyses of fish biology were completed or are under way. PIFSC scientist Bruce Mundy published a 704-page book entitled, *Checklist of the Fishes of the Hawaiian Archipelago*, which describes the known diversity, biogeographic origins, behaviorally defined habitats, and conservation status of the 1,250 fish species known from the area. An age and growth study based on growth rings on hard parts was completed on swordfish, and similar studies are under way on targeted bottomfish species as well as on bycatch species in the longline fishery (snake mackerel and lancet fish).

  – Using ocean models to describe larval transport, the PIFSC also developed a metapopulation dynamics model of larval movement within the Hawaiian Archipelago. This work included specimen collections and laboratory analyses of trace elements in otoliths, which are used to characterize the pelagic environments experienced by individual larvae during the planktonic dispersal stage. Completion of this work will ultimately provide a series of case studies elucidating connectivity and dispersal among main Hawaiian Island and Papahānaumokuākea Marine National Monument metapopulations of representative species of shallow-water reef fishes.

  – A multi-year cooperative tag and release study of lobster growth and mortality is being conducted with chartered commercial fishing operations in the Papahānaumokuākea Marine National Monument. Annual lobster survey cruises are also conducted in the Monument. In addition, PIFSC scientists published a new morphometric method for estimating body size at sexual maturity in slipper and spiny lobster populations. These studies also provide insight to the health of the Monument ecosystem, and the annual lobster survey provides a long-term time-series of both lobster abundance and the abundance of other shallow-water demersal species.

- International Cooperation on Resource Management.

  – The PIFSC hosted or attended meetings and conferences that brought together Pacific-wide delegations to coordinate marine resource conservation and management. The PIFSC led the U.S. delegation to the annual meeting of the North Pacific Marine Science Organization (also known as PICES) in Yokohama, Japan; NOAA scientists from four science centers and several other NOAA research offices participate in the PICES working groups. PICES serves as a vehicle for enhancing ecosystem research coordination in the North Pacific, with an increasing emphasis on living marine resource conservation and management. The PIFSC also represented the United

States on the Scientific Committee of the Western and Central Pacific Fisheries Commission (WCPFC), and PIFSC scientists conducted stock assessment and related research in conjunction with the WCPFC's Scientific Committee and also with the advisory working groups of the ISC. The Center also sponsored the 3rd Northwestern Hawaiian Islands Science Symposium, presenting the results of over 20 years of living marine and terrestrial research throughout the Northwestern Hawaiian Islands. A wide variety of agencies and universities participated in the symposium, which also drew large public participation.

- Habitat Characterization and Remediation.
  - Several habitat mapping projects were completed. PIFSC scientists surveyed 3000 km^2 of seafloor during multibeam mapping operations on the NOAA ship *Hi'ialakai* and the 25-ft PIFSC survey launch *AHI*. Major surveys were conducted at French Frigate Shoals, Maro Reef, Pearl and Hermes Atoll, and Kure Atoll in the Papahānaumokuākea Marine National Monument, and at Niihau and Penguin Bank in the main Hawaiian Islands. Using these data, accurate delineation of 25-, 50-, and 100-fm isobaths, an important management need for the Monument, was completed. The PIFSC collaborated with the University of Hawaii's Hawaii Mapping Research Group, the Hawaii Undersea Research Laboratory, and other key NOAA partners to produce the Bathymetric Atlas of the Northwestern Hawaiian Islands.
  - In addition, high-resolution bathymetric data for coral reef habitats in the Commonwealth of the Northern Mariana Islands, Guam, and the Territory of American Samoa were published. Surveys were conducted by the 25-foot survey launch *AHI*, equipped with a Reson 8101ER multibeam echosounder. PIFSC scientists also used multibeam and video validation data to characterize benthic habitat for anchorage at Saipan, in the Commonwealth of the Northern Mariana Islands, for the U.S. Navy.
  - The first Pacific Reef Assessment and Monitoring Program cruises were conducted in the main Hawaiian Islands aboard the NOAA ships *Oscar Elton Sette* and *Hi'ialakai*. The Pacific RAMP cruises are multidisciplinary research cruises to conduct assessments and monitoring of fish, corals, other invertebrates, and algae in the context of their benthic and oceanographic habitats in coral reef ecosystems. The second Marianas Archipelago Reef Assessment and Monitoring Program (MARAMP) cruise—to the Commonwealth of the Northern Mariana Islands, Guam, and Wake Atoll—was conducted in partnership with University of Guam Marine Lab; the Commonwealth of the Northern Mariana Islands' Divisions of Fish and Wildlife, Environmental Quality, and Coastal Resources Management; U.S. Army; and Guam Division of Aquatic and Wildlife Resources.
  - The PIFSC also participated in a multiagency expedition led by the Scripps Institution of Oceanography to the northern Line Islands (U.S.: Palmyra and Kingman Atolls; Kiribati: Christmas and Fanning Atolls, Washington Island) in a multidisciplinary assessment of the effects of human exploitation on fishery resources and related aspects of their coral reef ecosystems.
  - The PIFSC also completed Pacific RAMP surveys of coral reef ecosystems around all islands of American Samoa (ASRAMP) in 2002, 2004, and 2006 and the U.S. Line and Phoenix Islands in 2000, 2001, 2002, 2004, and 2006. Surveys included quantitative spatial and temporal monitoring of biological populations of fish, coral, algae, macroinvertebrates, and important oceanographic processes of ecosystem function. Using monitoring surveys, PIFSC scientists documented that the ecosystem

Abandoned fishing nets such as these are prime examples of marine debris. Photo: USCG.

impact of a foreign longline fishing vessel grounding (1993) to the reef at Rose Atoll has now persisted for over a decade, as characterized by a significantly greater abundance of algae/cyanobacteria and greater density of herbivorous fishes at the site of impact.

– In 2005, the Center's Marine Debris Team completed a 5-year large-scale marine debris removal effort from the coral reefs and beaches of the Northwestern Hawaiian Islands (now the Papahānaumokuākea Marine National Monument) after removing about 550 metric tons of primarily derelict fishing gear. With the conclusion of the large-scale debris removal effort, the Marine Debris Team initiated a "maintenance mode" removal by collecting 19 tons of debris in 2006 and completed a detailed debris accumulation study that documents average annual accumulation in the Monument of greater than 52 metric tons.

– PIFSC scientists made several key findings regarding the role of algae in the Pacific Islands marine environment. The PIFSC reported in *Status of Coral Reefs of the World: 2004* that macro algae, not corals, dominate many healthy subtropical reef systems in the Northwestern Hawaiian Islands. Center scientists also published discovery of two algal species new to science from the Northwestern Hawaiian Islands in 2004: *Acrosymphtyon brainardii* and *Scinaia huismannii*. To foster algal research in the Pacific Islands, PIFSC scientists entered into collaborative partnerships with molecular researchers from the University of Ghent, Belgium, and the University of Louisiana, Lafayette, to understand molecular population structure of select algal species in the tropical Pacific, and also published a rapid ecological assessment algal sampling protocol designed specifically for remote tropical islands.

– In support of NOAA's emphasis on Habitats of Particular Concern within Essential Fish Habitat, PIFSC scientists published a paper in 2004 documenting the importance of sheltered habitats at Northwestern Hawaiian Island atolls as juvenile reef fish nursery habitats, and a second paper also in 2004 documenting the disproportionate abundance of endemic species in shallow reef fish assemblages of the Northwestern Hawaiian Islands.

– Other habitat-related accomplishments included: completion of a cooperative NOAA and State of Hawaii survey of black (deep sea) corals; completion of an in-depth fisheries oceanography survey of the American Samoa tuna fishing grounds; and collaboration with the National Ocean Service to develop an on-line encyclopedia of marine plants in the Papahānaumokuākea Marine National Monument.

Research Priorities, FY 2007–2012:

I.A. Biological research concerning the diversity, abundance, distribution, and life history of living marine resources

- Conduct peer-reviewed assessments and statistical analyses on stocks of insular and pelagic species.
- Conduct research to better understand the stock dynamics and influence of environmental conditions on pelagic stocks (North Pacific and around American Samoa) and insular stocks of the Papahānaumokuākea Marine National Monument.
- Continue development of non-extractive fishery-independent methods to assess and study bottomfish and their habitat associations.
- Conduct comprehensive biodiversity surveys of understudied invertebrates, algae, and microbes throughout the U.S.-affiliated Pacific Islands to improve ability to implement ecosystem approaches to fisheries management.
- Develop a comprehensive insular resource survey using chartered commercial fishing and research vessels for the Hawaiian Archipelago.
- Assess the connectivity of spatially structured insular populations in the Hawaiian Archipelago.
- Develop and implement an international tagging program for highly migratory species in the Pacific Ocean to trace their movements between fisheries and countries, and provide biological data to advance stock assessments.
- Develop a new generation of stock assessment models for stocks of highly migratory and coastal pelagic species in the Pacific Ocean and state-of-the-art software to support them, using modern statistical optimization techniques, Bayesian methods, and simulation.
- Use pop-up satellite tags to identify forage and migration habitats of exploited species and protected resources in the central and western Pacific.
- Continue analysis of longline experiments to understand highly migratory species' habitat requirements and options for bycatch reduction.
- Develop a spatial and temporal model to predict the catch of bigeye and yellowfin tuna in the Palmyra region.
- Assist local resource management agencies to develop systems of marine protected areas appropriate for each island's marine ecosystems.
- Develop methods to assess the efficacy of various marine protected areas, ecosystem preserves, and other time-area closures in restoring fish stocks and increasing sustainable yields.
- Examine the role of ocean circulation on larval transport and recruitment of fish, corals, algae, and crustaceans with the goal of improved understanding of ecosystem dynamics and an ability to evaluate the effectiveness of no-take marine protected areas as refugia and replenishment areas.

I.B. Interdependence of fisheries or stocks of fish with other ecosystem components

- Develop integrative oceanic environmental indices to improve understanding of how environmental variability affects fish stocks.

- Extend analysis of factors affecting longline-turtle and longline-sea bird interactions to include more detailed oceanographic, tagging, and behavioral analysis.
- Integrate central Pacific pelagic and insular ecosystem monitoring with stock assessments.
- Develop ecosystem models to describe ecosystem structure and dynamics for pelagic and insular ecosystems.
- Conduct fishery dynamics research on the American Samoa longline fishery.
- Continue work on developing better methods for estimating the incidental take of protected species.
- Expand the surveys of the deepwater coral community throughout the Pacific region, using archival instruments to characterize environment.
- Expand ECOPATH parameters beyond the French Frigate Shoals region.
- Continue work associated with identifying and understanding ecological links between deep slope and shallow ecosystems with a focus on habitat aspects, particularly for fishery and protected species.
- Conduct studies on deep slope black coral foraging habitat of monk seals and juvenile snappers in the main Hawaiian Islands.

I.C. Identifying, restoring, and mapping of essential fish habitat

- Continue studying the bank summit habitat ecology, and specifically study seasonality and growth of algal meadows using archival technology.
- Continue the research on deep slope habitat ecology, and specifically explore the use of acoustics technology to assess deep slope species.
- Continue and improve program to rapidly characterize and map benthic habitats of coral reef ecosystems around Hawaii, American Samoa, Guam, Commonwealth of the Northern Mariana Islands, and the Pacific remote island areas.
- Determine the spatial distributions, composition, extent, and health of the benthic substrates.
- Determine and define the Essential Fish Habitat and Habitat Areas of Particular Concern for the coral reef areas.
- Associate identified habitats with distributions of the biological components of the ecosystem, including fish, invertebrates, and algae.
- Determine depth or habitat-based boundaries to support marine protected areas and the Coral Reef Ecosystem Fishery Management Plan.
- Provide high-resolution in-situ data to assist National Ocean Service in ground-truthing remote sensing-based mapping data of shallow water areas.
- Examine changes over time of the distribution and health of selected habitats, particularly corals, algae, and sand.
- Continue development and implementation of a multi-platform Coral Reef Ecosystem Integrated Observing System to monitor the key physical and biological parameters

likely to affect coral reef ecosystem health, including expanded use of passive acoustic technologies.

- Continue the development of passive acoustic technologies to detect vessel activities in marine protected areas.
- Examine the role of ocean circulation on transport, distribution, and accumulation of marine debris and continue development of technologies, including remote sensing and use of Unmanned Aerial Vehicles, to significantly improve capabilities for efficiently and cost-effectively removing debris at sea.
- Develop geographic information system applications for identifying the interrelationship of precious (gold) coral and Hawaiian monk seal habitat.
- Investigate Palmyra Atoll as an ecosystem hotspot.

I.D. Impact of anthropogenic factors and environmental changes on fish populations

- Evaluate the effects of climate change of interannual, decadal, and centennial scales on fisheries and fish habitat.
- Examine associations between the recruitment of juvenile insular species and climatic and oceanographic variables in the Hawaiian Archipelago.
- Investigate the linkage between the dynamics of oceanic features (including eddies, fronts, and boundary currents) and the dynamics of highly migratory fishes (tunas and billfishes) in the central and western Pacific.
- Develop and utilize a combination of remotely sensed observations of winds, temperature, sea surface height, and ocean color to define regions of oceanic convergence and the likely accumulation of marine debris, and then develop methods to track and interdict marine debris at sea before it damages coral reef ecosystems.
- Identify derelict fishing gear and its probable sources based on gear type, material of construction, and construction methods used.
- Assess the amount of and evaluate the impacts of marine debris present on the coral reefs of the U.S. Pacific Islands.
- Remove marine debris from coral reefs and beaches to prevent further damage to the coral reef ecosystem and to mitigate entanglement hazards to the animals within the ecosystem.
- Continue to develop a campaign that promotes public awareness and education of marine debris affecting the U.S. Pacific Islands, focusing on educating the commercial fishing and maritime industries regarding the damage to coral reef ecosystems caused by marine debris and on efforts to minimize future damage by reducing or eliminating the sources.
- Initiate basic fisheries biology work for bottomfish fishing areas other than the Papahānaumokuākea Marine National Monument (e.g., main Hawaiian Islands), including otolith studies.

II. Conservation Engineering Research

Recent Accomplishments:

PIFSC scientists have made several advances in protected species bycatch reduction. The Hawaii-based longline fishery has reduced seabird takes from thousands per year and sea turtle takes from hundreds per year during the late 1990s to only a few dozen per year in 2005. This was accomplished using bycatch reduction measures developed by scientists at the PIFSC and the NMFS Southeast Fisheries Science Center working with the fishery councils and conservation groups. In addition, PIFSC scientists are collaborating in on-going experiments to reduce sea turtle bycatch with longline fisheries in Hawaii, Japan, Korea, the Philippines, Mexico, Costa Rica, Guatemala, Ecuador, Peru, Brazil, Uruguay, Spain, and Italy, and are developing logistics for similar experiments in Indonesia, Papua New Guinea, and Vietnam.

Seabirds on a Hawaiian shore. Photo: NOAA.

Scientists also are working to identify protected species hot spots to support efforts to minimize protected species-fisheries interactions. Bottom-mounted high-frequency acoustic recording packages were placed in strategic locations to provide acoustic information where marine mammal/fishery interactions (false killer whales and longline fishing vessels) are known to occur in the Pacific Islands Region. In addition, using satellite telemetry of 43 juvenile loggerhead turtles (*Caretta caretta*) in the western North Pacific together with satellite remotely sensed oceanographic data, the Kuroshio Extension Bifurcation Region was identified as important loggerhead turtle forage habitat. In the Kuroshio Extension Bifurcation Region, juvenile loggerheads resided in Kuroshio Extension Current meanders and the associated anti-cyclonic (warm core) and cyclonic (cold core) eddies during the fall, winter, and spring when the Kuroshio Extension Current water contains high surface chlorophyll. This work was conducted jointly with the Port of Nagoya Public Aquarium in Japan.

With respect to recreational fisheries in the main Hawaiian Islands, PIFSC scientists have developed a successful outreach, education, and data collection program for shoreline and near-shore fishermen in Hawaii to investigate the use of barbless circle hooks to increase survival of fish caught in tag and release programs and to reduce injury to protected species such as green sea turtles and Hawaiian monk seals when accidentally hooked.

Research Priorities, FY 2007–2012:

- Continue studies to determine the best methods to reduce interactions and increase survival of protected, prohibited, or sensitive species caught by longline and troll vessels and make this information widely available to fishery managers both domestically and internationally.
- Determine ways to reduce incidental capture of sea turtles in longline fishing gear through various sensory physiology experiments on sea turtles and targeted fish species

(e.g., swordfish and tuna) to determine mechanisms used to attract (and eventually deter) both fish and turtles to bite baited hooks.

- Determine effective fishing gear modifications for reducing longline interactions with sea turtles, including performing at-sea experiments with the commercial longline fleet.
- Continue research on the use of barbless hooks in nearshore fisheries to minimize injury to incidentally hooked species (e.g., Hawaiian monk seals and green turtles).

III. Research on the Fisheries

Recent Accomplishments:

PIFSC researchers have made substantial progress in characterizing the socioeconomic structure of the Hawaii longline fishery. One key accomplishment was the implementation of a successful economic data collection system for the fishery through cooperation with the Pacific Islands Regional Office's Observer Program and longline fishery participants. Another key accomplishment was completion of a study of the socio-cultural dynamics and characteristics of longline participants. Using the data collected, PIFSC scientists prepared a number of socioeconomic analyses of this fishery. The results of these analyses, including a detailed look at the use of contract foreign labor in the fishery, were presented at international conferences.

Research Priorities, FY 2007–2012:

III.A. Social and economic research

- Expand sociological and economic research and incorporate results into the fishery management process (e.g., National Environmental Policy Act analysis).
- Develop behavioral models of economic incentives affecting the level and allocation of fishing effort in federally managed fisheries.
- Evaluate the regulatory impacts of recent and potential time-area closures in the Hawaii domestic longline fishery using an updated economic programming model with the latest catch, effort, and price data.
- Develop automated analytical templates integrated with current fishery performance, cost, and price information for completing Regulatory Flexibility Analyses in an efficient and timely manner. Augment these templates to include the basic demographic information required to initiate preliminary Social Impact Analyses.
- Continue to research and update intraindustry linkages and develop input-output relationships to describe and model the employment, income, and economic activity impacts of management actions being considered for each of the federally managed fisheries and fishing communities.
- Develop methods to compare and assess the socioeconomic impacts of various management options, including marine protected areas, ecosystem preserves, and other time-area closures designed to restore fish stocks and increase sustainable yields.
- Develop methods and models to assess the effects of various management options on the recreational and subsistence fisheries in the island areas.

- Research the social and economic ramifications of the various management options on the recreational and subsistence fisheries in the island areas.
- Study small-boat and charter-boat anglers to elicit explicit non-market economic values for blue marlin using standard contingent valuation techniques.
- Resurvey the Hawaii-based domestic longline fleet to provide an updated database for conducting regulatory impact analyses on forthcoming regulations.
- Develop a long-term monitoring program to provide data on trends in economic and social conditions for use in making fisheries management decisions.
- Develop an economic data collection program that will cover fishing club members and tournament participants in Hawaii.
- Develop profiles of fishing ports and communities in Hawaii, Guam, American Samoa, and Commonwealth of the Northern Mariana Islands, to support analysis of patterns of engagement in and dependency on fishing and associated activities.
- Examine the economic values and policy tradeoffs associated with conservation and protection of threatened and endangered sea turtles in the Pacific.
- Enhance the empirical model and extend the application to include other fisheries (troll, handline, and recreational fishing), which could enable an estimation of the change in the tradeoff value between small boats and longline fishery due to regulations.
- Conduct Regulatory Impact Reviews and Regulatory Flexibility Analyses for management actions being considered for all federally managed fisheries.
- Evaluate alternative specifications of the economic programming models to test the impact of critical assumptions concerning longline fishing industry behavior.
- Initiate research into agent-based modeling (ABM) as a method to characterize and understand fishing effort.

III.B. Seafood safety research

This item is not applicable.

III.C. Marine aquaculture

This item is not applicable.

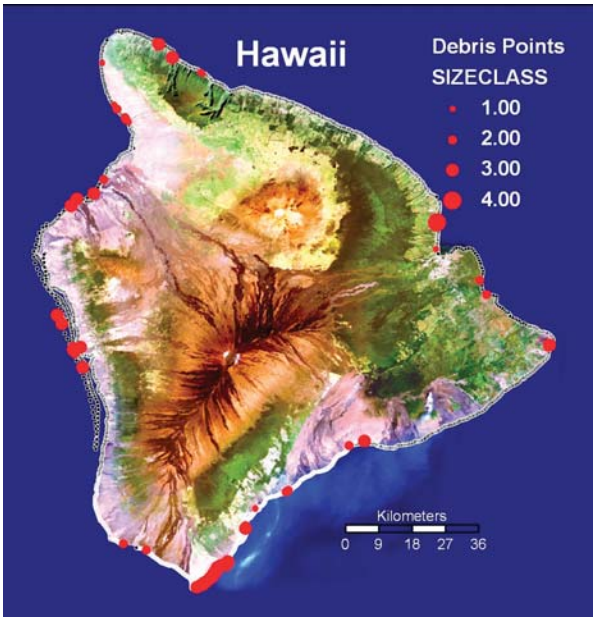
IV. Information Management Research

Recent Accomplishments:

The PIFSC has implemented projects that improve both data collection procedures and access to data holdings. One key accomplishment was the implementation of major shoreline-based creel surveys in American Samoa and the Commonwealth of the Northern Mariana Islands to improve monitoring of coral reef fisheries resources in cooperation with local fisheries agencies.

In addition, PIFSC personnel have developed detailed metadata describing the Center's collections and holdings of fisheries statistics and fisheries research survey data. These metadata have been packaged into a Data Catalog for posting on the Center's Intranet,

making the information readily available to all Center staff. In a related effort, the PIFSC developed, refined and beta-tested the web-enabled InPort Data Catalog prototype for the FIS Program. The InPort system has been approved and accepted as the standard for the FIS Program and is now in use for the entry of metadata on current fisheries information holdings in all regions. InPort is designed to maintain and search a "who, what, where, and when" catalog of fisheries data holdings. InPort provides capabilities to: 1) share data across NMFS; 2) search and study existing data for use in fisheries science, management, and regulation; and 3) ensure the quality and understandability of our data in support of ecosystem-based management. InPort also stores details on the quality and completeness of data, its confidentiality policies, research models, data collection protocols, methodologies, and usage constraints.



A map showing Hawaiian locations where marine debris has been found and requires removal. Mapping systems such as GIS greatly enhance the ability of researchers and managers to study marine life and habitat. Image: NOAA.

Research Priorities, FY 2007–2012:

- Implement a comprehensive Oracle-based integrated system for storing and distributing, via the Internet, appropriate PIFSC data holdings, including fisheries-dependent, research cruise, remote sensing, laboratory, and video data.
- Develop GIS technology for mapping and spatial analysis of fisheries, oceanographic, and habitat information.
- Advance approaches of data fusion to combine fisheries data and assessment model outputs with environmental data from ship, satellite, and physical models.
- Automate quarterly and annual compilation of fisheries statistics and annual reports on federally managed fisheries.
- Maintain and improve the web-based access to non-confidential data. Investigate new avenues for public access to data.
- Research, develop, and implement electronic data reporting programs for all areas and technology for fisheries-dependent information, i.e., electronic logbooks, seafood dealer reporting systems, etc.
- Research and develop alternate data reporting instruments and ways of archiving data to fulfill the Paperwork Reduction Act requirements.
- Develop automated systems for integrating data sets with common fields (e.g., longline logbook and observer reports, NOAA research vessel cruise data, and satellite oceanographic remote sensing).
- Continue to improve data security and data quality practices.
- Enhance and improve the fisheries monitoring input and output programs of island areas.
- Support InPort migration to Headquarters and metadata gathering.

- Complete modularization of Hawaii Longline Observer Data System.
- Improve and package Data Issues Manager Tool, Data Validation Management, and Workflow Management.
- Continue support of regional, national, and international information systems.
- Work with stakeholders to identify emerging research needs and identify resources that can be reprogrammed to address those needs.
- Work with stakeholders to expedite dissemination of data and analyses by providing them in formats other than final publications while still meeting Information Quality Act (IQA) requirements.

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APPENDIX A:

Relationship of This Plan to Other Plans

RELATIONSHIP BETWEEN THE NOAA STRATEGIC PLAN AND NMFS PROGRAMS

The NOAA Strategic Plan (NOAA 2005a) comprehensively addresses the NOAA mission: **To understand and predict changes in Earth's environment and conserve and manage coastal and marine resources to meet our Nation's economic, social, and environmental needs.** The Plan's focus through 2011 is on five goals:

1. Protect, restore, and manage the use of coastal and ocean resources through an ecosystem approach to management.
2. Understand climate variability and change to enhance society's ability to plan and respond.
3. Serve society's needs for weather and water information.
4. Support the Nation's commerce with information for safe, efficient, and environmentally sound transportation.
5. Provide critical support for the above four Mission Goals.

To build on its core strengths, NOAA has selected five essential activities called "Cross-Cutting Priorities" that are closely allied and essential to support its goals:

- Developing, valuing, and sustaining a world-class workforce.
- Integrating global environmental observations and data management.
- Ensuring sound, state-of-the-art research.
- Promoting environmental literacy.
- Exercising international leadership.

Virtually all of the NMFS programs, including the research programs, are encompassed within NOAA's Mission Goal 1, focused on coastal and ocean resources. The NOAA program areas included in this goal are: Aquaculture; Coastal and Marine Resources; Corals; Ecosystem Observations; Ecosystem Research; Enforcement; Fisheries Management; Habitat; and Protected Species. A small NMFS component, within the Climate and Ecosystems program, is encompassed within NOAA's Mission Goal 2, and other NMFS climate-related research on ecosystem productivity is closely associated with this goal. Many NMFS programs have outputs that also serve the Cross-Cutting Priorities. For example, to advance research capabilities, NMFS is active in developing and applying state-of-the-art tools including computational models, survey ships, and sensing instruments. By being attuned to broader needs, program managers can ensure additional benefits are obtained.

NOAA has identified two desired outcomes under Goal 1: 1) Healthy and productive coastal and marine ecosystems that benefit society; and 2) a well-informed public that acts

as a steward of coastal and marine ecosystems. The associated performance objectives are the following:

- Increase number of fish stocks managed at sustainable levels.
- Increase number of protected species that reach stable or increasing population levels.
- Increase number of regional coastal and marine ecosystems delineated with approved indicators of ecological health and socioeconomic benefits that are monitored and understood.
- Increase number of invasive species populations eradicated, contained, or mitigated.
- Increase number of habitat acres conserved or restored.
- Increase portion of population that is knowledgeable of and acting as stewards for coastal and marine ecosystems.
- Increase environmentally sound aquaculture production.
- Increase number of coastal communities incorporating ecosystem and sustainable development principles into planning and management.

The NOAA Strategic Plan is available at:
http://www.ppi.noaa.gov/pdfs/STRATEGIC%20PLAN/Strategic_Plan_2006_FINAL_04282005.pdf.

RELATION OF THE NOAA RESEARCH PLAN AND THIS NMFS STRATEGIC PLAN FOR FISHERIES RESEARCH

To focus the research efforts necessary to accomplish the NOAA Strategic Plan, NOAA has a companion research plan, called Research in NOAA: Toward Understanding and Predicting Earth's Environment (NOAA 2005c). It covers all research undertaken in support of NOAA's various mission as described in the NOAA Strategic Plan. Its planning horizon is FY 2007–2011 and is undergoing revision with a similar schedule as this update of the NMFS Strategic Plan for Fisheries Research (NSPFR). It has a somewhat different goal structure than the NSPFR because it is based on broad themes designed to bring all of the NOAA resources together in an integrated fashion to address societal needs. The NSPFR, on the other hand, follows a legislatively driven outline guiding the much narrower suite of programs designed to achieve the research objectives of NMFS necessary to implement the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) as amended by the Sustainable Fisheries Act (SFA). Thus, the NSPFR encompasses much of NMFS research activities regarding fisheries and habitat issues and includes specific Fisheries Science Center plans as well. Research on marine mammals, turtles, and protected species of fish is included, but only when it is directed at MSFCMA requirements. The NSPFR is more comprehensive and goes into much greater detail regarding NMFS MSFCMA-related research than does any other strategic planning document in NOAA.

Nearly all of the NMFS research program falls under the NOAA Ecosystem Goal and its supporting research program, which has five themes: supporting collaborative approaches to science and management at the regional level, understanding the impacts of climate on ecosystems, enhancing social and ecological resilience to hazards, protecting marine and coastal resource security, and developing a more robust ecosystem modeling capability to serve current and future management information needs. These research priorities can be

organized in an end-to-end portfolio that covers advancing the understanding of ecosystems; providing new insight into the oceans through discovery and identification of new resources; forecasting biological events or consequences of natural and human-induced changes in the environment; and developing scenarios to simulate potential impacts on marine and coastal resources.

Except for climate-related research on ecosystem productivity that resides in the NOAA Climate Goal, most of the NOAA Research Plan milestones for the Ecosystem Goal are all related to this NSPFR. The exceptions are several milestones related to the NOAA Ocean Exploration Program of NOS and the Ecosystem Forecasting work of OAR. The NSPFR-related milestones of the NOAA Research Plan, by NOAA Goal are as follows:

Ecosystem Mission Goal: Protect, Restore, and Manage Use of Coastal and Ocean Resources through Ecosystem Approach to Management

Research Milestones For Advancing Understanding of Ecosystems to Improve Resource Management

- Define the primary forcing factors and time and space scales that affect fish recruitment and fisheries production for selected regions.
- Measure the natural scales of variability regarding physical-biological coupling, food web dynamics and ecosystem production in selected ecosystems.
- Expand ecosystem models to advance the scientific framework for the provision of advice through integrated ecosystem assessments.
- Provide integrated ecosystem assessments that evaluate the ecological response to various anthropogenic stressors.
- Identify ecosystem carrying capacity for critical protected species as a step in providing more efficient recovery strategies.
- Map and evaluate habitat (existing and restorable) and identify key habitat functions; evaluate the function/health of habitat.
- Estimate ambient noise budgets in regional ecosystems by characterizing the nominal acoustic environments.
- Develop environmentally sound aquaculture technologies for marine species.

Research Milestones For Forecasting Our Ecosystems

- Develop forecasts for the ecological effects of varying weather patterns and extreme physical events.
- Develop forecasts for the ecological effects of sea level rise and climate change.
- Define the primary forcing factors and time and space scales that cause HABs and anoxia for selected coastal, ocean, and Great Lakes regions.
- Define the primary forcing factors and time and space scales that affect water quality and quantity for selected coastal and Great Lakes regions.
- Identify sentinel species and other proxies for early detection of pathogen and microbial contaminants.

- Define the primary forcing factors and time and space scales that affect fish recruitment and fisheries production for selected coastal and Great Lakes regions.
- Study aquatic biodiversity and how anthropogenic stresses, extreme environmental events, and climate influence population dynamics of coastal and marine ecosystems.

Research Milestones For Developing Scenarios and Building Capacity to Support Regional Management

- Evaluate the risk/value of alternative ecosystem-based management strategies using integrated ecosystem assessments.
- Research to improve our understanding of the factors affecting threatened species and the potential success of alternative remediation/management strategies.
- Develop methodologies and tools for estimating non-monetary ecosystem value that can be translated into decision support tools for stewardship of coastal and marine ecosystems.
- Expand extension and education approaches to provide scientific information in advance of actions and regulations and to assist NOAA in fostering increased understanding and partnerships among fishermen, conservation and environmental groups, coastal use communities, and scientists.
- Provide cost-benefit forecasts and risk analyses of management decisions and human use of coastal and Great Lakes ecosystems.

Climate Mission Goal: Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond

Research Milestones For Understanding Impacts Of Climate Variability And Change On Marine Ecosystems To Improve Management Of Marine Ecosystems

- Development of a model to incorporate the effects of climate into living marine resource assessments for the Bering Sea.

RELATION OF THE NMFS STRATEGIC PLAN AND THIS PLAN FOR FISHERIES RESEARCH

The NMFS Strategic Plan (NMFS 2005), guides NMFS activities in support of NOAA's mission and its underpinning goals and objectives. It interweaves with the NOAA Strategic Plan by establishing indicators of progress, and their associated performance measures and metrics primarily in the context of NOAA's Strategic Goal 1. Details regarding the NMFS Strategic Plan are available at http://www.nmfs.noaa.gov/mb/strategic/.

The NMFS Strategic Plan requires the support of research to meet most of its objectives. As an agency-wide strategic plan, it must address all relevant legislative mandates, and closely correspond to the NOAA Strategic Plan. However, this NMFS Strategic Plan for Fisheries Research (NSPFR) has a somewhat different structure that is specific to the content mandated by the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

This NSPFR guides the suite of programs that address the research objectives of NMFS necessary to implement the MSFCMA as amended by the Sustainable Fisheries Act (SFA). This encompasses much of NMFS research activities regarding fisheries and habitat issues and includes specific Fisheries Science Center plans as well. Research on marine mammals, turtles, and protected species of fish, is included but only when it is directed at MSFCMA requirements.

Table Comparing the NMFS Strategic Plan and the NMFS Strategic Plan for Fisheries Research

Table 1 presents the outline of the NMFS Strategic Plan goals and elements in the left column and corresponding elements of this MSFCMA-required NMFS Strategic Plan for Fisheries Research in the right column.

Table 1. Corresponding elements of the NMFS Strategic Plan and the NMFS Strategic Plan for Fisheries Research.

NMFS Strategic Plan Outline	NMFS Strategic Plan for Fisheries Research
NOAA Mission Goal 1: Protect, Restore, Manage PROGRAMS	
• Ecosystem Observations	I.A Biological research concerning stock abundance I.B. Interdependence of fisheries or stocks of fish I.C. Identifying, restoring, and mapping essential fish habitat I.D. Impact of anthropogenic factors and environmental changes on fish populations II. Conservation engineering research III.A. Social and economic research
• Ecosystem Research	I.B. Interdependence of fisheries or stocks of fish I.D. Impact of anthropogenic factors and environmental changes on fish populations
• Fisheries Management	Not Fisheries Research
• Protected Species	I.A. Biological research concerning stock abundance I.B. Interdependence of fisheries or stocks of fish II. Conservation engineering research
• Enforcement	Not Fisheries Research
• Habitat	I.C. Identifying, restoring, and mapping of essential fish habitat
• Coral Reef Conservation	I.A. Biological research concerning stock abundance I.B. Social and economic factors affecting abundance levels I.B. Interdependence of fisheries or stocks of fish I.C. Identifying, restoring, and mapping of essential fish habitat
• Aquaculture	III.C. Marine aquaculture
NOAA Mission Goal 2. Understand Climate Variability and Change	I.B. Interdependence of fisheries or stocks of fish I.D. Impact of anthropogenic factors and environmental changes on fish populations
NOAA Support Goal: Provide Critical Support for NOAA's Missions	IV. Information management research Indirect support across all programs
Not Specifically Included	III.B. Seafood safety research

OVERVIEW OF PLANNING DOCUMENTS

Over the past several years there have been numerous outside reviews of Federal ocean and fisheries programs. NMFS research programs and plans have been developed to implement the recommendations of these reviews. Both broad and program-specific reviews and planning efforts have had significant impact on NMFS research and are reflected in this present Plan. Overviews of the more important reviews and plans are presented below.

Internal Planning Documents:

- **U.S. Ocean Action Plan**
  In response to the U.S. Commission on Ocean Policy, President Bush delivered the U.S. Ocean Action Plan to guide actions to make the oceans, coasts, and Great Lakes cleaner, healthier, and more productive. It calls for management strategies that ensure continued conservation of coastal and marine habitats and living resources while at the same time ensuring that the American public enjoys and benefits from those same resources. The Plan lays out an approach to obtain the best science and data to inform decision-making, based on an ecosystem approach in making decisions related to water, land, and resource management in ways that do not erode local and state authorities and are flexible to address local conditions. It envisions stronger partnerships between Federal, state, tribal, and local governments, the private sector, international partners, and other interests. The Plan is available at http://chartmaker.ncd.noaa.gov/ocs/hsrp/admin/mar2005/oceanactionplan.pdf.

- **NMFS Marine Fisheries Stock Assessment Improvement Plan (SAIP) (October 2001)**
  The Marine Fisheries SAIP is the report of the NMFS National Task Force for Improving Fish Stock Assessments. This report is part of a series of plans for enhancing and modernizing NMFS programs for data collection, information technology, data management, stock assessments, scientific research, and fisheries management. The report includes specific recommendations for improving the quality of NMFS' stock assessment programs and emphasizes the need for the agency to foster partnerships and cooperative research programs with other Federal agencies, state agencies, private foundations, universities, commercial and recreational fishing organizations and individuals, environmental groups, and others with a vested interest in collecting similar types of data. Recommendations from the SAIP have formed the basis for successful budget initiatives to augment funding for improving stock assessments. The SAIP is available at: http://www.st.nmfs.noaa.gov/StockAssessment/index.html (NMFS 2001).

- **NMFS Strategic Plan for Fisheries Research (1998, 2001, and 2004)**
  Originally released in 1998 as a requirement of the Sustainable Fisheries Act of 1996, these Plans are consistent with contemporaneous planning initiatives, yet with a more detailed focus on NMFS research activities. In particular, the Plans function as a subset of the NSP. The objectives found under the "Major Fishery Research Goals and Objectives" section of the Plans can be matched with strategies in the counterpart NSPs.

- **NOAA Fisheries Data Acquisition Plan (1998)**
  This September 1998 document represents a strategy for meeting NMFS' rapidly growing at-sea data requirements. The Plan provides an overview of the existing data acquisition program, describes anticipated growth and changes to data requirements in the future,

details options available, and presents a suite of recommendations for meeting these challenges, including the construction of a fleet of modern Fisheries Research Vessels. Recommendations from the Plan have formed the basis for budget decisions relative to the acquisition of at-sea data. This Plan is available from the NMFS website at http://www.st.nmfs.gov/st4/documents/DataPlan.pdf.

External Reviews by the National Research Council (NRC)

- **Review of Recreational Fisheries Survey Methods (2006**)
  This 2006 report commissioned by NOAA reviewed NOAA recreational fisheries survey methods used to estimate catch per unit effort and effort in NOAA and state/Federal cooperative programs. The study examined representative survey types, but did not evaluate every regional or state survey method. It also considered the match or mismatch between options for collecting recreational fisheries data and alternative approaches for managing recreational fisheries. The report recommended that the current survey programs be redesigned to improve sampling and estimation procedures, their applicability to various kinds of management decisions, and their usefulness for social and economic analyses. The report also emphasized that state and Federal agencies must work together to provide ongoing technical evaluation and modification of survey programs to meet emerging management needs and to achieve much greater degree of standardization among state and Federal surveys. It recommended treating the For-Hire fishing sector as a "commercial" sector, and proposed that mandatory timely reporting of all catch and effort by that sector be required. The report also called for NOAA to set a firm deadline linked to sufficient program funding to implement the recommendations (NRC 2006a).

- **Dynamic Changes in Marine Ecosystems (2006)**
  This 2006 report commissioned by NOAA reviews the many recent scientific papers about the effects of fishing on marine food webs and the productivity of species. The objective of the review was to evaluate these effects in the context of relevance to fisheries management, future research and stewardship. Recommendations in this report call for a more comprehensive ecosystem-based approach to fisheries management, rather than the species-by-species approach currently being used. It calls for supporting research on the extent of fishing effects on ecosystems and the development of comprehensive models suitable for portrayal of different management scenarios. These models should include food webs and species interactions within the ecosystems and the intertwining social and economic factors (NRC 2006b).

- **Marine Protected Areas: Tools for Sustaining Ocean Ecosystems (2001)**
  Published in 2001, this NOAA-commissioned report evaluates marine protected areas (MPAs) as a tool to supplement conventional fishery management. The report recommended networks of MPAs, some for fishery management, embedded within broadly zoned management areas in the coastal ocean. Additionally, the study indicated that the basic knowledge gained through monitoring and evaluation of MPAs on the structure, function, and variability in marine ecosystems would enhance the design of reserves and allow more accurate evaluations of their ecological and socio-economic consequences. Reserves would also allow more accurate estimation of parameters such as natural mortality rates—an essential variable in stock assessment models. This report can be read online or purchased at www.nap.edu/ (NRC 2001). While this report was not a specific review of NMFS science and management efforts, it sought and made recommendations

on how MPAs should be used and is thus useful in guiding NMFS research programs (NRC 2001).

- **Improving the Collection, Management, and Use of Marine Fisheries Data (2000)**
  This 2000 NRC-commissioned report assesses methods for improving data for stock assessments and fisheries management. The summer flounder fishery was used as a case study in this report because it supported a fishery that spanned state and Federal waters over a vast geographic area, both recreational and commercial fishermen targeted the species, and there was an abundance of data available for assessments. The report analyzed summer flounder stock assessments and implicit and explicit modeling assumptions that affected modeling outcomes. The study also examined data collection and use and made 40 recommendations to Federal and state fishery agencies, Congress, regional FMCs, interstate commissions, and commercial and recreational fishermen with the objective of improving fisheries data and management. (NRC 2000).

- **Sustaining Marine Fisheries (1999)**
  Published in 1999, this NRC-commissioned report explores the nature of marine ecosystems and the complex interacting factors that shape their productivity. The book documents the condition of marine fisheries in 1999, highlighting species and geographic areas that were under particular stress. Challenges to achieving sustainability are discussed, and shortcomings of existing fisheries management and regulation are examined. The report calls for fisheries management to adopt a broader ecosystem perspective that encompasses all relevant environmental and human influences, but also emphasizes that the first step towards ecosystem-based management is to reduce fishing mortality on individual stocks to optimal levels. It can be read on-line or purchased at the National Academy Press Web site at www.nap.edu/ (NRC 1999). While this report was not a specific review of NMFS science and management efforts, it sought and made recommendations on how the ecosystem approach should be used and is thus useful in guiding NMFS research programs (NRC 1999).

- **Improving Fish Stock Assessments (1998)**
  This 1998 report commissioned by NMFS reviews the agency's stock assessment methods and models and makes recommendations for alternative approaches. The report authoritatively documented the strengths and limitations of stock assessment methods relative to the diversity of available data and types of fisheries management systems (NRC 1998).

External Review by the Institute of Medicine

- **Seafood Choices: Balancing Benefits and Risks (2006)**
  This 2006 report commissioned by NOAA reviewed evidence on the benefits and risks associated with seafood consumption to recommend ways to guide U.S. consumers in making seafood selections to meet their needs. Seafood contributes to a variety of nutritious benefits to the American diet. Contamination of marine resources, however, whether naturally occurring or anthropogenic is a concern to U.S. consumers. Because of the potential for adverse health effects, consumers—particularly subpopulations, which may be at increased risk—need authoritative information to make informed choices that provide desired nutrients balanced against exposure to potential toxicants. The study is being used a centerpiece of information for the agency to focus its extensive fishery food science expertise to assist other Federal agencies and the U.S. consumer to develop

a decision path to balance seafood choices to obtain needed nutritional benefits while minimizing exposure. The study is also being used to identify data gaps and recommendations for future research. The NAS report has been published and reaffirms the benefits of seafood consumption and makes specific recommendations to encourage increased seafood consumption by the public, including those specific subpopulations that may be at risk (IOM 2006).

All of these external reports can be read online or purchased at www.nap.edu/.

APPENDIX B:

RESPONSE TO COMMENTS ON THE PUBLIC DRAFT OF THE NSPFR

Comment: Numerous comments noted the need for more information and research into a variety of topics to address potential concerns related to marine aquaculture, including but not limited to: genetics, disease, competition from escapes, feeds (including use of fish meal and oil), economic impacts, water quality, and benthic impacts. Other comments recommended that the plan be restructured consistent with the topic areas described in the report of the Woods Hole Marine Aquaculture Task Force (Task Force).

Response: NMFS agrees with these comments, and has revised the plan accordingly. The intent of the NSPFR was to include all of the research topics described by the Task Force, but NMFS agrees they were unnecessarily grouped together and therefore not adequately addressed individually. The Plan was revised to more explicitly address the key research topic areas as described by the Task Force by breaking out a single objective in the draft plan into four individual objectives. It should be noted, however, that some of the Task Force's recommendations are for regulatory matters and therefore were not included in this research plan.

Comment: Instead of having a rigid calendar period assigned to the time when fishing is allowed, NMFS could allow some flexibility in the schedule for bad weather.

Response: This is a regulatory suggestion and not within the scope of the NSPFR.

Comment: The Plan acknowledges the need to manage fisheries within an ecosystem context, but fails to focus on this issue and to develop it as a focus of strategic research.

Response: NMFS has strengthened the concept of ecosystem-based science throughout the document, but note that this is a research plan that must provide the information necessary for resource management. The first two elements of the first research area (Research to support management) treat ecosystem research intensively, demonstrating its importance as a strategic focus to NMFS. Additionally, specific wording has been added to the NSPFR for GOAL 1 and its first two objectives to show that research must provide scientifically sound information and data sufficient to support ecosystem-based fishery conservation and management.

Comment: The present document fails to articulate the vital role of research partnerships in realizing a strategic research vision for the national fisheries.

Response: NMFS recognizes the need for partnerships in conducting the research mission and had already included improvement in this area as a sixth goal to help focus efforts on building partnerships. Also, the introductory sentence of the Science Centers section

discusses these cooperative relationships. We believe that the present treatment is adequate for the purposes of this document.

Comment: To ensure the progression to ecosystem-based management stays on course, NMFS should design a research program specifically geared toward the recommendations of the Ecosystems Principles Advisory Panel (EPAP) Report to Congress, with schedules and milestones to gauge progress.

Response: The EPAP recommendations are useful for measuring progress towards providing information to support ecosystem-based management. The Plan addresses the EPAP recommendations in section **I.B. Interdependence of fisheries or stocks of fish**.

Comment: The Plan notes that an ecosystem-based approach is needed to take into account the various factors that affect the status of a stock and the importance of a stock to other components of the ecosystem, but omits a comprehensive initiative that would serve to implement the first step toward an ecosystem-based approach recommended by the Ecosystems Principles Advisory Panel Report to Congress—that fishery managers consider how fishing affects predator-prey interactions.

Comment: While the NSPFR does not directly address regulatory matters, NMFS notes (as explained in the prior ecosystems-related comment) that the agency has increased its emphasis on a holistic approach to resource management. By bringing ecosystem-wide information and advice to resource managers, NMFS helps to ensure that managers will be in a better position to consider predator-prey and all other relevant ecosystem interactions.

Comment: NMFS should direct the Science Centers to investigate the ecological roles of commercially important forage species in each region so that these roles can be qualitatively and quantitatively described.

Response: The role of forage species is a fundamental aspect of ecosystem research, and is a high priority addressed in section **I.B. Interdependence of fisheries or stocks of fish**.

Comment: This Plan reflects an inherent bias towards research that contributes to managing and maximizing fishery yields over that for protected species.

Response: The NSPFR, as mandated by Congress, deals with only fisheries conservation and management. It includes only protected species issues that are derived from interactions with recreational or commercial fisheries. Otherwise, protected species research is not part of this Plan, as is explained in the Introduction. When there is known bycatch or entanglement problems due to fishing gear, these issues are addressed through gear research (such as turtle excluder devices or dolphin/tuna net innovations), and through regulatory measures (such as closed fishing areas or seasons when protected species are present). There is considerable effort identified for gear research concerning protected species in this Plan's Goal 2 and corresponding Objectives (pages 40–41) as well as the six individual Science Center sections devoted to conservation engineering research (starting on pages 57, 78, 91, 104, 118, and 136).

Comment: The Plan should not promote expansion of open-ocean aquaculture.

Response: NMFS does support development of open-ocean aquaculture (OOA) in a manner

that is sustainable and minimizes environmental impacts. It is important to note that no commercial aquaculture currently is ongoing offshore (i.e., in Federal water), and very little open ocean aquaculture is currently underway. Therefore, even a small industry would represent "expansion." NMFS will conduct an environmental impact statement, using the best available science, to help determine appropriate locations and permit conditions for OOA, taking into account environmental and other impacts, including cumulative impacts.

Comment: Strongly agree with research Objective 1.11 (Conduct additional research to provide needed information to refine EFH designations). Many of the EFH descriptions and designations are now effectively fish habitat descriptions and fail to identify any particular areas that are truly EFH. Research should be conducted to better distinguish between "essential" fish habitat and fish habitat generally.

Response: NMFS has changed the wording of Objective 1.11 to further clarify the intent of the objective.

Comment: The work of the fisheries aspect of NOAA is outstanding and should be fully funded by Congress. NOAA should include Great Lakes waters in its Fisheries studies and request adequate funding for that work from Congress.

Response: NOAA has responsibility for some aspects of research in the Great Lakes, but not that related to fisheries stewardship. That role falls to the states and Canadian provinces that border the Lakes. Coordination of fisheries research and stewardship occurs through the Canadian/U.S. Convention on Great Lakes Fisheries as implemented by the Great Lakes Fishery Commission. A similar arrangement exists along the ocean coastal states where federally chartered Coastal States Marine Fisheries Commissions coordinate state roles in research and stewardship. The research addressed in this Strategic Plan for Fisheries Research is primarily that in support of stewardship in Federal waters and on the high seas.

Comment: The greatest threat to the coastal environment right now is the influx of raw and treated sewage, and increased amounts of farm fertilization and waste runoff being discharged into the fragile back bay and tributary environments instead of being piped a few miles offshore. Also, the industrial waste and byproducts which are causing increased risk of cancer or other disease to humans should be immediately eliminated everywhere.

Response: Nutrient loading through sewage, land runoff, and other causes is a major problem leading to eutrophication of many estuaries and coastal waters. NMFS works with the U.S. Army Corps of Engineers, the Environmental Protection Agency, the states, and others to reduce pollution, for the benefit of both the resources and their human and other users. The research-related aspects of this comment are already included in the Plan.

Comment: Mass catching methods (such as purse seining and long-lining are causing complete and utter shutdown of certain populations within our marine habitat.

Response: Fish removals must not be disruptive to ecosystems. The agency works internationally with regional fisheries organizations, with the United Nations fisheries organization, and with individual nations, to coordinate research and stewardship of high seas fisheries. In such work we address such concerns as long lining, bycatch of fish and turtles in shrimp trawls, taking of dolphins in tuna purse seines, and unregulated fishing by fleets

from non-participating nations. Domestically, we work with the states and Fishery Management Councils to focus our research and stewardship actions on the most important problems affecting resource conservation. The research-related aspects of this comment are already included in the Plan.

Comment: 1) Ban all genetically modified organism (GMO) species and manipulation, so marine species are not altered in any way, 2) Coordinate national and international regulation of fisheries, and 3) Continue qualitative and quantitative research.

Response: NMFS believes that: 1) unintended release of (GMOs) into the marine environment is to be avoided, 2) that fisheries regulations need to be coordinated, and 3) that qualitative and quantitative research needs to continue to develop a basis for decisions.

NOAA policy (http://govdocs.aquake.org/cgi/reprint/2003/514/5140040.pdf) with respect to GMOs is that regulations and decisions regarding the risk to biodiversity, particularly from introduction of aquatic organisms and use of genetically altered organisms, should be guided by internationally accepted codes of practice, existing Federal regulations and procedures and, where appropriate, by approaches and regulations in use at the state level. The same protocols should be used as tools in any evaluations of impact subsequent to the agency's decisions. This Plan will assist decision makers by making the best science available so that appropriate decisions can be made.

With respect to coordination of fisheries regulations, we work internationally with regional fisheries organizations, with the United Nations fisheries organization, and with individual nations, to coordinate the research underlying regulatory regimes and the stewardship of high seas fisheries. In such work we address such concerns as long lining, bycatch of fish and turtles in shrimp trawls, taking of dolphins in tuna purse seines and unregulated fishing by fleets from non-participating nations. Domestically we work with the states and Fishery Management Councils to focus our research and stewardship actions on the most important problems affecting resource conservation. The need for continuation and strengthening of our research program is evidenced throughout the Plan.

Comment: Somewhere in this extensive NOAA NMFS document there should be a credible discussion of overfishing.

Response: Much of NMFS' scientific work is devoted to assessing and monitoring the fish stocks, including the scientific basis for determining whether they are overfished or experiencing overfishing. NMFS agrees that overfishing and overfished should be better defined and has included the operational definitions used by this agency. A stock that is subject to overfishing has a fishing mortality (harvest) rate above the level that provides for the maximum sustainable yield. A stock that is overfished has a biomass level below a biological threshold specified in its fishery management plan. This is treated at much greater depth and with respect to each of the major fisheries in the Annual Report to Congress on the Status of U.S. Fisheries, available on the NMFS site at http://www.nmfs.noaa.gov/sfa/sfweb/.

Comment: Greater effort needs to be put into direct manipulation of Bering Sea commercial fisheries to better determine their role and impacts in areas where there are ongoing declines in marine mammals.

Response: NMFS recognizes that the effects of indirect interactions between commercial fisheries and marine mammals will not be understood solely by studying marine mammals. To this end, the AFSC has designed and supported a suite of studies directed at both Steller sea lions and their prey, including commercially important forage fish. Studies that involve manipulation of the commercial fishery have not been pursued due to operational and logistic difficulties, and because fishery management measures taken to protect Steller sea lions effectively provided the changes in fishing effort that could aid in assessing responses in Steller sea lion survival, reproduction, or foraging patterns. However, studies that involve manipulations in fishing effort in some areas might be appropriate in the future should indirect interactions continue to be a serious issue for marine mammals in the Bering Sea.

Comment: Clearly the discussion in the Plan focuses on salmon recovery. Indeed many species of salmon are listed under the ESA and are still declining. While there is an impressive list of activities, it is clear that either research is not properly focused or management action arising from the research is inadequate, since the fish continue to decline. NMFS should examine whether the interplay between its research and management actions is logical and robust.

Response: NMFS concurs that many salmon stocks remain threatened or endangered. NMFS supports the need to ensure that the science to inform management is the best possible given the funding constraints to meet all mandates for the agency. To achieve this end in regard to salmon science, the NWFSC has conducted both internal and external peer reviews of our science plans to achieve a credible effort that can inform management in critical areas in as timely a manner as possible. Moreover, multistakeholder-authored recovery plans and targets now exist for nearly all listed ESU's from which measured gains in relation to management actions can be documented. In many cases, improvements in the status of many stocks have been observed, although delisting has only been achieved for one stock at this time.

Comment: NMFS should shift the focus of the Northwestern Hawaiian Islands lobster assessment from establishment of harvest guidelines to use as an indicator of ecosystem health.

Response: Lobster in the Papahānaumokuakeā Marine National Monument are subject to a zero harvest guideline pursuant to Proclamation 8031 and its codifying regulations. NMFS believes that the data gathered in these assessments is useful as an indicator of the ecosystem health of the Monument, and has modified text accordingly.

Comment: NMFS should initiate collection of age-length data for central Pacific non-pelagic (i.e., bottomfish) species from otolith reading, to support examination of the impacts of fishing on age structure and to estimate mortality rates. Given that the Proclamation establishing the Papahānaumokuakeā Marine National Monument restricts fishing activity, NMFS should focus on main Hawaiian Islands bottomfish stocks.

Response: NMFS agrees that more basic fisheries biology work is important for the other bottomfish fishing areas, and has revised text accordingly.

Comment: Development of tagging programs for highly migratory species in the central

and western Pacific seems more in the realm of international fishery management agencies than a NMFS-specific responsibility.

Response: NMFS agrees that such tagging programs should be developed in conjunction with regional fishery management organizations, and has modified the text accordingly.

Comment: NMFS should ensure that studies examining the impacts of gear modifications on longline fisheries are performed and that the results of the studies be analyzed, reviewed, and made available to fishery managers.

Response: NMFS agrees that dissemination of the results of such studies is extremely important, and has worked assiduously both domestically and internationally to disseminate these results. The text has been modified to reflect this.

Comment: NMFS should use agent-based modeling to analyze how the participation of individual fishermen in small boat fisheries in the western Pacific region can affect catch rates and, in turn, stock assessments that rely on catch rates as a measure of biomass.

Response: NMFS agrees that agent-based modeling (ABM) is a potentially fruitful approach towards understanding fishing effort from both a biological and economic perspective, and has initiated research in this direction. The text has been modified accordingly.

APPENDIX C:

ABBREVIATIONS AND ACRONYMS

ABC	acceptable biological catch
ABL	Auke Bay Laboratory
ACCSP	Atlantic Coastal Cooperative Statistics Program
AFA	American Fisheries Act
AFSC	Alaska Fisheries Science Center
AI	Aleutian Islands
AKFIN	Alaska Fisheries Information Network
AOP	Annual Operating
ASMFC	Atlantic States Marine Fisheries Commission
ASRG	Alaska Scientific Review Group
BASIS	Bering Aleutian Salmon International Survey
BRDs	bycatch reduction devices
BSAI	Bering Sea and Aleutian Islands
BSMDBS	Biological Sample Monitoring Data Base System
CAGEAN	catch-age analysis
CalCOFI	California Cooperative Fisheries Investigations
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
CDQ	community development quota
CFDBS	Commercial Fisheries Data Base System
CFMC	Caribbean Fishery Management Council
CPS	coastal pelagic species
CPUE	catch-per-unit-of-effort
CRED	Coral Reef Ecosystem Division
DNA	deoxyribonucleic acid
DOC	Department of Commerce
EBS	Eastern Bering Sea
EEZ	Exclusive Economic Zone
EFH	essential fish habitat
EIS	Environmental Impact Statement
EOD	Ecosystems and Oceanography Division
EPA	Environmental Protection Agency
ESA	Endangered Species Act
ESU	evolutionarily significant unit
FAD	fish aggregating device
FAO	Food and Agriculture Organization of the United Nations
FBSAD	Fish Biology and Stock Assessment Division
FHDBS	Food Habits Data Base System
FIN	Fisheries Information Network
FMC	fishery management council
FMP	fishery management plan
FOCI	Fisheries Oceanography Coordinated Investigations

FSCS	Fisheries Scientific Computer System
FTE	full-time equivalent
GIS	geographic information system
GLOBEC	Global Ocean Ecosystems Dynamics
GMFMC	Gulf of Mexico Fishery Management Council
GOA	Gulf of Alaska
GSMFC	Gulf States Marine Fisheries Commission
GulfFIN	Gulf of Mexico Fisheries Information Network
HAB	harmful algal bloom
HAPC	habitat areas of particular concern
HMS	highly migratory species
IATTC	Inter-American Tropical Tuna Commission
ICCAT	International Commission for the Conservation of Atlantic Tunas
ICES	International Council for the Exploration of the Seas
IFQ	Individual Fishing Quota
IOCARIBE	International Oceanographic Commission for the Caribbean
ISC	Interim Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean
ITQ	individual transferable quota
IWC	International Whaling Commission
LIDAR	light detection and ranging
LME	large marine ecosystem
LMR	living marine resource
MMPA	Marine Mammal Protection Act
MPA	marine protected area
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
MSY	maximum sustainable yield
NEFMC	New England Fishery Management Council
NEFSC	Northeast Fisheries Science Center
NEPA	National Environmental Policy Act
NERO	Northeast Regional Office
NSP	NMFS Strategic Plan
NMFS	National Marine Fisheries Service
NMML	National Marine Mammal Laboratory
NOAA	National Oceanic and Atmospheric Administration
NODC	National Oceanographic Data Center
NOS	National Ocean Service
NPAFC	North Pacific Anadromous Fish Commission
NPALB	North Pacific Albacore Workshop
NPFMC	North Pacific Fisheries Management Council
NRC	National Research Council
NSL	National Systematics Laboratory
NSPFR	NMFS Strategic Plan for Fisheries Research
NWFSC	Northwest Fisheries Science Center
NWHI	Northwestern Hawaiian Islands
OBDBS	Observer Data Base System
OCC	ocean carrying capacity
OMB	Office of Management and Budget
OY	optimum yield
PacFIN	Pacific Coast Fisheries Information Network

Pacific RecFIN	Pacific Recreational Fisheries Information Network
PCR	polymerase chain reaction
PFMC	Pacific Fishery Management Council
PICES	North Pacific Marine Science Organization
PIFSC	Pacific Islands Fisheries Science Center
PIT	passive integrated transponder
PMEL	Pacific Marine Environmental Laboratory
RACE	Resource Assessment and Conservation Engineering Division, AFSC
RecFIN	Recreational Fisheries Information Network
REFM	Resource Ecology and Fisheries Management Division, AFSC
ROV	remotely operated vehicle
SAFE	stock analysis and fishery evaluation
SAFMC	South Atlantic Fishery Management Council
SAIP	Stock Assessment Improvement Plan
SARC	Stock Assessment Review Committee
SAW	stock assessment workshop
SCTB	Standing Committee on Tuna and Billfish
SEDAR	Southeast Data Assessment and Review
SEFSC	Southeast Fisheries Science Center
SFA	Sustainable Fisheries Act of 1996
SPO	NMFS Scientific Publications Office, Seattle, WA
SPTT	South Pacific Tuna Treaty
SWFSC	Southwest Fisheries Science Center
TED	turtle excluder device
TRT	technical recovery team
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
URI	University of Rhode Island
WPacFIN	Western Pacific Fisheries Information Network
WPRFMC	Western Pacific Region Fishery Management Council

APPENDIX D:

GLOSSARY

Acceptable biological catch (ABC): The ABC is a scientific calculation of the sustainable harvest level of a fishery as determined by Federal fisheries biologists.

Anadromous: Fish stocks that migrate from salt water to fresh water to spawn.

Anthropogenic: Human caused; usually used in reference to risks created to fish stocks by human activities.

Aquaculture: The propagation and rearing of aquatic organisms in controlled or selected aquatic environments for any commercial, recreational, or public purpose.

Atlantic Coastal Cooperative Statistics Program (ACCSP): A cooperative state-Federal marine and coastal fisheries data collection program. The goal of the program is to cooperatively collect, manage, and disseminate fishery statistical data and information for the conservation and management of fishery resources of the Atlantic coast and to support the development and operation of a national data collection and data management program.

Benthic: Refers to organisms which live at or near the bottom (see Demersal).

Biomass: The total weight of organisms in a defined group, such as a fish stock or year class.

B_{MSY}: 1) Long-term average biomass that would be achieved if fishing at a constant fishing mortality rate equal to F_{MSY}. 2) The weight (biomass) of a group of fish necessary to produce maximum sustainable yield (MSY).

Broodstock: Adult fish used to propagate the subsequent generation of hatchery fish.

Bycatch: The Magnuson-Stevens Fishery Conservation and Management Act defines bycatch as "fish which are harvested in a fishery, but which are not sold or kept for personal use, and includes economic discards and regulatory discards... [But not] fish released alive under a recreational catch and release fishery management program."

Bycatch reduction device (BRD): Any of a number of implements that have been certified to reduce the likelihood of capturing nontarget species.

Catch per unit effort (CPUE): The amount of fish that is caught by a given amount of fishing effort. Typically, effort is a combination of gear type, gear size, and length of time the gear is used.

Charter fishing: Fishing from a vessel carrying a passenger(s) for hire who is engaged in recreational fishing.

Commercial fishing: Fishing in which the fish harvested, either in whole or in part, are intended to enter commerce or enter commerce through sale, barter, or trade.

Conservation engineering: The practice of determining the modification in gear design that will meet conservation objectives, such as decreasing bycatch and bycatch mortality by increasing the selectivity of gear and increasing the survival of fish and other living marine resources that fishing gear encounter inadvertently.

Continental shelf: Submerged margin of continent from low-tide line to a point (generally between the 50- and 100-fathom isobaths) at which there is a marked increase of slope (i.e., the continental slope) to greater depth.

Delisting criteria: Determination as to what indicators need to exist before stocks can be taken off the list of endangered species. Typically, delisting criteria are elaborated by policy decisions regarding various recovery activities, such as reforming hatchery practices, reducing harvest, eliminating impacts of dams or restoring habitat.

Demersal: Fish and animals that live near the bottom of an ocean.

Fish Aggregating Device: Artificial or natural floating objects placed on the ocean surface, often anchored to the bottom, to attract schooling fish species underneath, thus increasing their catchability.

Endangered species: A species is considered "endangered" if it is in danger of extinction throughout a significant portion of its range; it is considered "threatened" if it is likely to become an endangered species.

Endangered Species Act (ESA): The Federal law, enacted by Congress in 1973, to provide protection for, and promote recovery of, animal and plant species considered as threatened or endangered because of natural or anthropogenic conditions.

Essential fish habitat (EFH): The Magnuson-Stevens Fishery Conservation and Management Act defines essential fish habitat as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity."

Evolutionarily significant unit (ESU): An ESU is a distinctive group of Pacific salmon, steelhead, or sea-run cutthroat trout that is uniquely adapted to a particular area or environment and cannot be replaced.

Exclusive Economic Zone (EEZ): The zone contiguous to the territorial sea of the United States, the inner boundary of which is a line coterminous with the seaward boundary of each of the coastal states and the outer boundary of which is a line drawn in such a manner that each point on it is 200 nautical miles from the baseline from which the territorial sea is measured. This zone was established by Proclamation Numbered 5030, dated March 10, 1983.

Exploitation rate: The proportion of a population at the beginning to a given period that is caught during that time period (usually expressed on a yearly basis). For example, if 720,000 fish were caught during the year from a population of 1 million fish alive at the beginning of the year, the annual exploitation rate would be 0.72.

Ex-vessel value: The amount paid to vessel's owner or operator for its catch, excluding any value added by at-sea processing.

Fishery: a) One or more stocks of fish which can be treated as a unit for purposes of conservation and management and which are identified on the basis of geographical, scientific, technical, recreational, and economic characteristics; and b) any fishing for such stocks.

Fishery Management Council (FMC): One of eight regional groups established under Section 302 of the Magnuson-Stevens Fishery Conservation and Management Act to prepare and oversee fishery management plans for fisheries conducted principally within the Exclusive Economic Zone.

Fishery management plan (FMP): A plan developed by a regional Fishery Management Council, or the Secretary of Commerce under certain circumstances, to manage a fishery resource in the U.S. EEZ pursuant to the Magnuson-Stevens Fishery Conservation and Management Act. Includes data, analyses, and management measures for a fishery.

Gillnet: A flat net suspended vertically in the water used to capture fish which entangle themselves in the net, usually by the forward part of the body near the gills.

Groundfish: Any species of fish, usually finfish that live on or near the sea bottom part of the time.

Juvenile: A young fish, usually resembling an adult in appearance, but which has not yet become sexually mature.

Krill: Small abundant crustaceans that form an important part of the food chain in Antarctic waters.

Landings: The number or poundage of fish unloaded at a dock by commercial fishermen or brought to shore by recreational fishermen for personal use. Landings are reported at the points at which fish are brought to shore.

Marine Mammal Protection Act (MMPA): The MMPA is a statue which was enacted in 1972 to protect marine mammals and their habitat. These species include whales, dolphins, seals, seal lions, walruses, and others.

Maximum Fishing Mortality Threshold (MFMT, $F_{threshold}$): One of the status determination criteria (SDC) for determining if overfishing is occurring. It will usually be equivalent to the fishing mortality (F) corresponding to the maximum sustainable yield (MSY) control rule. If current fishing mortality rates are above $F_{threshold}$, overfishing is occurring

Maximum Sustainable Yield (MSY): A management goal specifying the largest long-term average catch or yield (in terms of weight of fish) that can be taken, continuously (sustained) from a stock or stock complex under prevailing ecological and environmental conditions, without reducing the size of the population.

Metapopulation: A group of partially isolated populations (or subpopulations) belonging to the same biological species (or subspecies) and connected by migratory pathways. These partially isolated populations or subpopulations can exchange individuals, which

are potentially able to recolonize sites within the metapopulation from which the species or subspecies recently became extinct.

Minimum Stock Size Threshold (MSST, $B_{threshold}$): A status determination criteria (SDC). The greater of: a) 1/2 BMSY, or b) the minimum stock size at which rebuilding to BMSY will occur within 10 years while fishing at the maximum fishing mortality threshold (MFMT). MSST should be measured in terms of spawning biomass or other appropriate measures of productive capacity. If current stock size is below $B_{threshold}$, the stock is overfished.

Optimum yield (OY): a) The amount of fish which will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities, and taking into account the protection of marine ecosystems; b) is prescribed as such on the basis of the maximum sustainable yield from the fishery, as reduced by any relevant economic, social, or ecological factor; and c) in the case of an overfished fishery, provides for rebuilding to a level consistent with producing the maximum sustainable yield in such fishery.

Overfished: 1) An overfished stock or stock complex "whose size is sufficiently small that a change in management practices is required to achieve an appropriate level and rate of rebuilding." A stock or stock complex is considered overfished when its population size falls below the minimum stock size threshold (MSST). A rebuilding plan is required for stocks that are deemed overfished. 2) A stock is considered "overfished" when exploited beyond an explicit limit beyond which its abundance is considered 'too low' to ensure safe reproduction. In many fisheries fora the term is used when biomass has been estimated to be below a limit biological reference point that is used as the signpost defining an "overfished condition." This signpost is often taken as being FMSY, but the usage of the term may not always be consistent. (see **Minimum Stock Size Threshold**) Comment: The stock may remain overfished (i.e., with a biomass well below the agreed limit) for some time even though fishing pressure might be reduced or suppressed.

Overfishing: 1) According to the National Standard Guidelines, "overfishing occurs whenever a stock or stock complex is subjected to a rate or level of fishing mortality that jeopardizes the capacity of a stock or stock complex to produce maximum sustainable yield (MSY) on a continuing basis." Overfishing is occurring if the maximum fishing mortality threshold (MFMT) is exceeded for 1 year or more; 2) In general, the action of exerting fishing pressure (fishing intensity) beyond the agreed optimum level. A reduction of fishing pressure would, in the medium term, lead to an increase in the total catch.

Pinger: High-frequency acoustic devices that may keep marine mammals from entering and becoming entangled in fishing nets.

PIT-tag: The passive integrated transponder (PIT) tag is an electronic tag 10 mm long by 2.1 mm in diameter that can be coded with one of 35 billion codes. The tag can be automatically detected and decoded in situ and eliminates the need to sacrifice, anesthetize, handle, or restrain fish during data retrieval. The tag has been developed as a research and management tool for monitoring the movement of juvenile and adult fish species.

Plankton: Plants (phytoplankton) and animals (zooplankton) which float in the upper portion of the water column and provide the basic constituents of the oceanic food web. Most

planktonic organisms are microscopic in size. Eggs and larvae of many fisheries species are also components of the plankton community.

Population: A group of interbreeding organisms generally inhabiting a given geographic area.

Quota: The maximum amount of fish that can be legally landed in a time period. It can apply to the entire fishery, an individual fisher's share under an individual fishing quota (IFQ) system, or refer to the size of fish.

Recreational Fisheries Information Network (RecFIN): A cooperative state-Federal effort among marine fisheries agencies to improve collection and management of marine recreational fisheries statistical information.

Recruitment: A measure of the weight or number of fish which enter a defined portion of stock, such as the fishable stock or the spawning stock.

Regulatory impact review (RIR): The part of a Federal fishery management plan that describes impacts resulting from the plan.

Relative abundance: An index of fish population abundance used to compare fish populations from year to year. This does not measure the actual numbers of fish, but shows changes in the population over time.

Saltonstall-Kennedy Grant Program: A competitive program that provides funds through grants or cooperative agreements for research and development projects to benefit the U.S. fishing industry. The Saltonstall-Kennedy Act, as amended [15 U.S.C. 713 (c) (3)], is the program's statutory authority.

ShoreZone: A coastal habitat mapping and classification system in which geo-referenced aerial imagery is collected specifically for the interpretation and integration of geological and biological features of the intertidal zone and nearshore environment. Additional information is available at: http://www.shorezone.org/

Stakeholder: One who is expected to receive economic or social benefits from the conservation and management of living marine resources.

Stock: A more-or-less discrete and identifiable unit of fish or other exploited species, often referring to a management unit.

Stock assessment: The biological assessment of the status of the resources. This analysis provides the official estimates of stock size, spawning stock size, fishing mortalities, recruitment, and other parameters.

Stock assessment workshop (SAW): A cooperative stock assessment activity in which scientists from various agencies evaluate the status of fish stocks.

Subsistence fishing: Fishing for personal consumption or traditional/ceremonial purposes.

Technical Recovery Team (TRT): A panel of scientists set up to define "delisting criteria" in specific geographic domains for endangered salmon and steelhead species on the west coast.

Trophic web: The network that represents the predator/prey interactions of an ecosystem.

Turtle excluder device (TED): An implement that has been certified to reduce the likelihood of capturing turtles.

Yield-per-recruit: The average weight of fish ultimately harvested for each fish that enters the fishery.

Virtual population analysis: A mathematical analysis in which catch data are used to estimate absolute abundances of age-classes in a stock and the fishing mortality that has been sustained by those age-classes.

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