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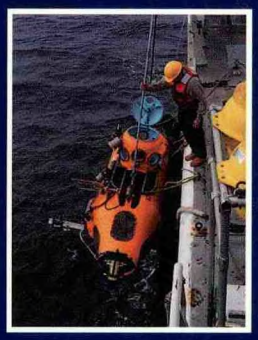
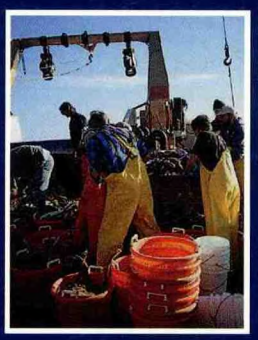
MFS Strategic Plan for Fisheries Research





December 2001

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

NMFS Strategic Plan for Fisheries Research

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Preface

The National Marine Fisheries Service (NMFS) is the agency responsible for the science-based conservation and management of the Nation's living marine resources and their environment. NMFS is part of the National Oceanic and Atmospheric Administration (NOAA) within the Department of Commerce. The agency's long-term commitment to scientific excellence via internal and external peer-reviewed scientific journals has materially advanced marine science and policy for over 125 years.

Since 1871, Federal fisheries scientists have collected, researched, analyzed, and published peer-reviewed data on the Nation's living marine resources, marine ecosystems, and the benefits that they provide. Recently, NMFS has instituted a science quality assurance program to consistently monitor and review NMFS research efforts to ensure that they are of the highest quality. Further, this program identifies gaps in infrastructure, facilities, and resources that are affecting the productivity of NMFS scientists. Under this scrutiny, important agency findings are published in many highly respected journals.

NMFS has established the position of Scientific Editor as well as the Scientific Publications Office (SPO) to ensure the editorial and scientific integrity of its research products. These and other regional NMFS publication materials serve as the basis for agency scientific reports, regulatory documents, and technical presentations to fishery managers, industry and environmental groups, the information community (media), and to the public and scientific community. 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 other aquatic environments.

This document builds upon elements of previous significant planning initiatives from both NMFS and NOAA:

NOAA Strategic Plan: A Vision for 2005
First released in 1993, this agency-wide Strategic Plan broadly covers all the major programs and missions underneath NOAA and how they contribute to the goal of bringing scientific information to bear on key societal decisions. This Plan has evolved over time in response to emerging issues and developing programs. The executive summary of the latest edition of this Plan is available from the NOAA Web site at *www.strategic.noaa.gov.*

Results of the Review of the NOAA Science Enterprise by the NOAA Chief Scientist
Released in 1995, this comprehensive review examined the quality of NOAA research with respect to its methodological approaches, the relevancy and adequacy of its science activities, and the strength and value of partnerships between NOAA's programs and outside groups.

NOAA Fisheries Strategic Plan
In 1997, NMFS published this Plan after extraordinary public involvement, including 12 public meetings. The Plan describes specific NMFS objectives and performance measures to fulfill all aspects of its stewardship mission through a rational, scientific approach. This Plan continues to serve as an outline to guide the agency and is available from the NMFS Web site at *www.nmfs.noaa.gov/om2/contents.html.*

NMFS Strategic Plan for Fisheries Research (1998)
Released in 1998 as a requirement of the Sustainable Fisheries Act of 1996, this original Plan was purposely framed to be consistent with previous planning initiatives, yet with a more detailed focus on NMFS research activities. In particular, the Plan functions as a subset of the *NOAA Fisheries Strategic Plan.* Many of the objectives found under the "Major Fishery Research Goals and Objectives" section of this Plan (and this update) generally can be matched with strategies in the *NOAA Fisheries Strategic Plan.* The 1998 *NMFS Strategic Plan for Fisheries Research* is available for download at the NMFS Web site at *www.nmfs.noaa.gov/sfa/stratpln.pdf.*

NOAA Fisheries Data Acquisition Plan
Released in September 1998, this document represents a five-year 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 become the basis for budget decisions relative to the acquisition of at-sea data. This Plan is available from the NMFS Web site at *www.st.nmfs.gov/st2/omb_link.html.*

In addition to the above internal planning documents, this Plan supports and incorporates the following external reviews by the National Research Council (NRC):

Improving Fish Stock Assessments
Published in 1998, this report commissioned by NMFS reviews the agency's current stock assessment methods and models and makes recommendations for alternative approaches. The objective of the review was to produce an authoritative report that documented the strengths and limitations of stock assessment methods relative to the diversity of available data and types of fisheries management systems. The report can be read online or purchased at the National Academy Press Web site at *www.nap.edu.*

Sustaining Marine Fisheries
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. It can be read online or purchased at the National Academy Press Web site at *www.nap.edu.*

Improving the Collection, Management, and Use of Marine Fisheries Data
Published in 2000, this 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 the 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 councils, interstate commissions, and commercial and recreational fishermen, with the objective of improving fisheries data and management. This report can be read online or purchased at the National Academy Press Web site at *www.nap.edu.*

Marine Protected Areas: Tools for sustaining ocean ecosystems
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 socioeconomic 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 the National Academy Press Web site at *www.nap.edu.*

The scope of the present document includes fisheries, habitat, and protected species research that solely addresses requirements of the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). It does not include the regulatory and enforcement components of the NMFS mission. NMFS conducts a comprehensive program of fisheries research and peer-reviewed publishing to make information available to industry, environmental groups, resource managers, and others who are dependent on fisheries science. This Plan, which updates the original *Strategic Plan for Fisheries Research* released in 1998, covers what we do now and how we expect to improve.

The research plans of NMFS are developed in constant communication with our partners and constituents. NMFS research programs are periodically reviewed by informal and formal program reviews. NMFS scientists serve on Fishery Management Council Scientific Steering Committees where research inadequacies are

National Marine Fisheries Service Mission Statement:

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

identified and then addressed through NMFS programs. Regulatory and judicial proceedings also identify information needs that are then incorporated in the research program. U.S. and international scientists work together to identify means to fill information gaps needed to manage both U.S. and high-seas fisheries of interest to the American public and industries. In all respects, this Plan is the ultimate integration of the broad fisheries research needs of American society and its legislative, executive, and judicial institutions.

Legislative Background

The United States Congress reauthorized the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), as amended by the Sustainable Fisheries Act (SFA), on October 11, 1996. Section 404 (Fisheries Research) of the MSFCMA requires the Secretary of Commerce to develop and publish in the *Federal Register* a strategic plan for fisheries research for the five years immediately following such publication. The Act stipulates that the plan:

- 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 fishers 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 that the comprehensive program contain the following areas of research:

- Research to support fishery conservation and management, including but not limited to:

  biological research concerning the abundance, trends, and life history of stocks of fish,
  the interdependence of fisheries or stocks of fish and their ecosystem,
  the identification of essential fish habitat,
  the impact of pollution on fish populations,
  the impact of wetland and estuarine degradation, and
  other factors affecting the abundance and availability of fish.

- Conservation engineering research, including:

  the study of fish behavior,
  the development and testing of new gear technology and fishing techniques to minimize bycatch and any adverse effects on essential fish habitat, and
  the promotion of efficient harvest of target species.

- Research on the fisheries, including:

  the social, cultural, and economic relationships among fishing vessel owners, crew, fish processors, associated shoreside labor, seafood markets, and fishing communities.

- Information management research, including:

  the 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

Research Components

The Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) mandates strong action to conserve and manage fishery resources that contribute to the food supply, economy, and health of the Nation. MSFCMA provisions require NMFS to end overfishing, 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.

MSFCMA provisions require NMFS to end overfishing, rebuild all overfished stocks, and conserve essential fish habitat through research and consultations on Federal and state actions that may adversely affect such habitat.

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. Biologically, this includes species' responses to environmental changes, exploitation, and other human activities that affect them and their habitat. This information includes social, cultural, and economic behaviors and incentives that influence human/marine interactions. All of the agency's information must be comprehensive, objective, credible, and effectively communicated. It is used not just for current management decisions, but also to conserve resources and anticipate future trends, assure 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 thus the management decisions for which it provides the foundation, is understood and its validity accepted by user groups and other constituents. To accomplish this, the MSFCMA has mandated that we provide a role for commercial fishers in our fisheries research.

The research priorities of NMFS may be grouped into the four major areas with several sub-areas 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**

I. Research to support fishery conservation and management

Living marine resources (LMRs) currently support extensive commercial, recreational, and subsistence uses. In 2000, commercial landings by U.S. fishers were 9.1 billion pounds valued at $3.5 billion. The 2000 U.S. marine recreational fish catch was an estimated 429 million fish, taken on an estimated 76.0 million fishing trips (NMFS, 2001). These represent just some of the many benefits Americans derive from living marine resources.

However, many marine species are under stress from overexploitation or habitat degradation, or both. Over one-third of all fish stocks for which we have scientific population information are overutilized, and nearly half are below optimal population levels. Some populations are in danger of extinction, and many more are threatened by various human activities. There are many other species about which we have little information. Many factors, both natural and human-related, affect the status of fish stocks and their environment.

NMFS scientists are actively engaged in collaborative research to protect and enhance fishery resources. These research efforts include mapping, spatial analyses, geographic information systems (GISs), and fishery and ocean habitat modeling and characterization, as well as an evaluation of ecosystem approaches focusing on spatially-explicit models and further research into trophic relationships. Additionally, with the increasing need to seek new management approaches to enhance and conserve essential fish habitat (EFH), NMFS is conducting studies on adaptive/management techniques through the identification and use of potential areas of 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 MPAs to facilitate important experiments in marine ecology and to support recommendations made by the NRC (NRC, 2001). Further, NMFS is evaluating the potential negative/positive impact of fishing gear on habitat and fisheries production.

NMFS scientist receives instructions prior to launch of the *Deepworker* submersible in preparation for survey on deepwater fishes and their habitats in and around the Big Creek Ecological Reserve off California.

NMFS' research efforts incorporate the use of innovative new technologies and techniques. For example, NMFS, in cooperation with NOAA, is working to enhance survey capabilities through research and development of an omnidirectional hydroacoustic system. This new system will combine biomass assessments with the ability to acoustically identify species, utilizing airborne LIDAR (light detection and ranging) laser technology as a biomass assessment tool for near-surface pelagic species, and using underwater (laserline) technology for identification of habitat types and species identification. Additionally, NMFS employs manned submersibles and remotely-operated vehicles to directly evaluate deepwater species and their habitat.

It is NMFS' responsibility to provide fishery managers with the information needed to make scientifically sound decisions. In order to support fishery conservation and management, NMFS scientists are actively pursuing the following areas of research.

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

Activities in this area include collecting catch and effort data, biological sampling, and developing bio-statistical 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 complexity of any assessment is determined by the amount of available data (i.e., tiers of data completeness) and by the type of information required for scientific advice to fishery managers. Stock assessments can be roughly grouped in order of increasing levels of modeling effort and sophistication, each one incorporating the underlying data requirements of all preceding levels.

Assessment Levels:

- **Index Only:** a time series of relative index of stock abundance calculated as raw or standardized catch-per-unit-of-effort (CPUE) in commercial, recreational, or survey vessel data; or a one-time estimation of absolute abundance derived from tagging results, a depletion study, or some form of calibrated survey.

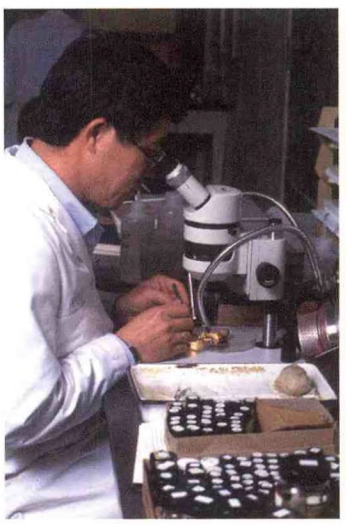
- **Simple Life History Equilibrium Models:** typically applied to life history information; for example, yield-per-recruit or spawner-per-recruit functions based on mortality, growth, and maturity schedules; catch curve analysis; survival analysis; or length-based cohort analysis.

- **Aggregated Production Models:** data input for equilibrium and non-equilibrium production models aggregated both spatially and over age and size classes; these include the classic Schaefer model and the Pella-Tomlinson model.

- **Size/Age/Stage Structured Models:** techniques that include cohort analysis, virtual population analysis, age-structured production analysis, CAGEAN, stock synthesis, size or age-structured Bayesian models, modified DeLury methods, and size or age-based mark-recapture models.

- **Ecosystem Models:** assessments incorporating ecosystem considerations with spatial and seasonal analyses. Ecosystem components include one or more of the following: (1) one or more time-varying parameters, either estimated as constrained series, or driven by environmental variables; (2) multiple target species as state variables in the model; or (3) living ecosystem components other than target species included as model variables.

The biology and life history of species have become more significant with respect to management of the Nation's living marine resources. Describing and understanding migration and distribution patterns, 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 employed, including aging using otoliths, 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 an in-



NMFS scientist examines the stomach contents of Alaskan walleye pollock.

creasing need to identify and characterize discrete stocks. This will enable scientists to correctly structure stock assessments and design stock-specific management measures.

I.B. Social and economic factors affecting abundance levels

NMFS also recognizes the social, cultural, and economic diversity of the fisheries, and the importance of recognizing those differences in creating effective conservation measures. For instance, one critical factor affecting stock abundance is the level of fishing effort. Type and location of both commercial and recreational fishing effort vary across different fishing fleets, groups of anglers, and communities. Also, these groups will differ in their responses to alternative strategies of effort control such as days-at-sea, closed areas, limited access, and bag-limits. NMFS will need new data and models, and modifications to existing models, to capture fully this diversity and its interaction with biological diversity.

NMFS will therefore develop bio-socio-economic models and increase the collection of data necessary to meet conservation goals and maximize net economic and social benefits to the Nation from living marine resources. For commercial fishing, these data include vessel and plant level cost and earnings data; ex-vessel prices; and data on social and institutional constraints such as open access regimes or differing ethnicity-based labor practices. For recreational and subsistence fishing, these data include information on expenditures, trip characteristics, demographic descriptors, and social and cultural influences on fishing behavior. Given that some of these data are newly emphasized, national coordination and funding of these activities will be especially important.

Coordinated bio-socio-economic research and analysis will add the element of human behavior to stock variability, thus bringing the parameters of our models closer to real world conditions. This, in turn, will improve the predictive power of stock assessments and incorporate fishers' incentives into the precautionary approach.

I.C. Interdependence of fisheries or stocks of fish

Living and non-living parts of an ecosystem are linked to each other through physical and biological relationships — for example by food chains or shared habitat use. This information is very important if we are to successfully manage our living marine resources in a holistic manner. The health 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 a report to Congress (EPAP, 1999). The abundance, productivity, and spatial distribution of a fish stock depends on a number of factors, including environmental conditions, habitat quantity and quality, the abundance and health of its competitors, predators, and prey, as well as its symbiotic relationships.

The objective of the 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 of fish as well as the spatial and temporal variability in abundance and habitat use. We will develop recruitment and multi-species 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 compensatory population mechanisms on long-term stability, production, and structure of fish communities under different harvest strategies and environmental regimes. Research activities include the following:

- Marine food web research through field and laboratory studies of fish consumption rates, feeding selectivity patterns, food preference, and nutritional values of various foods.

- Density-dependent and predator-prey dynamics.

- Fisheries oceanography research to determine how varying environmental conditions create variability in biological components of the ecosystem.

- Food-web-based dynamic mathematical models to examine how abundance of fish stocks, marine mammals, and other ecosystem components react to changes in environmental conditions and alternative fishery management measures.

A current meter (an instrument that measures current, temperature, conductivity, and pressure) is recovered by an operations specialist aboard the R/V *Miller Freeman* from a sub-surface oceanographic instrumentation mooring deployed in the Bering Sea by FOCI/PMEL in support of Steller sea lion habitat studies.

To examine human activities in an ecosystem perspective, research is required on the behavior of consumptive (e.g., commercial and recreational fishers) and non-consumptive (e.g., whale watchers and non-harvest divers) users of the resource. Some fishers target a single species or species assemblage exclusively. Others fish for a variety of different species by season (an annual round), sometimes switching fishing gears to do so. Yet other fishers are part-time participants only, working in land-based occupations for some portion of the year. Other users of the ecosystem who, for example, swim with sharks or view coral reef communities, benefit from a rich and diverse habitat. Still others who never see the resource value knowing that it exists.

Different fishing behaviors, based on the use of different gear types or vessel sizes among commercial or recreational fishers, appear more likely to interact with the ecosystem differently and can negatively impact the net benefits the ecosystem generates for a non-consumptive user group. These different behaviors and the relative values attributed to the ecosystem by different user groups imply different levels and types of fishing effort applied to a resource stock and have differing effects on their various target species, and are therefore important to ecosystem management. For example, the development of a wetland for industrial or residential purposes may impact water quality and thus require that a water treatment plant be constructed to replace the wetland's natural filtering action, so that an offshore coral reef is preserved. Some critical research areas include:

- The suite of fishing and non-fishing activities available to commercial and recreational fishers for which they are qualified.

- The geographic range within which various consumptive and non-consumptive user groups operate.

- The identification of all user groups, including but not limited to consumptive and non-consumptive as well as those that value the existence of the resource.

- Determination of the existence value of fishery resources in the ecosystem by habitat type.

- Determination of the non-market value of fishery resources in the ecosystem by habitat type for recreational and other non-consumptive user groups.

- Determination of the market value of fishery resources in the ecosystem by habitat type for commercial and other consumptive user groups.

- Determination of the market incentives that direct behavior by consumptive and non-consumptive user groups.

- Development of models that incorporate ecosystem relationships into bio-economic models.

- Identification of the demographic, sociological, and anthropological characteristics of different user groups who value fishery resources and how they differ between groups.

- The effect of point and non-point specific sources of pollution on the ecosystem to determine trade-offs in costs and benefits of improving ecosystems; e.g., hypoxia in the Gulf of Mexico.

- Establishment of safe minimum standards for fishery and other resources in the ecosystems.

- Identification of the role of coastal settlements on ecosystems and stocks of fish.

- Identification of the role of ecosystems and stocks of fish on communities.

- Determination of the interactions and links between user groups and fish stocks.

- Establishment of a national bio-socio-economic 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.D. Identifying, restoring, 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. Others, however, are apparent. We know, for example, that dams for hydroelectric power generation and water diversion for agriculture have severely reduced some valuable anadromous fish runs, and chemical contaminants cause neoplasm 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 continual changes in fish communities, and that environmental variability, such as El Niño, changes the latitudinal distribution, abundance, and recruitment dynamics of several species on the west coast. It has become apparent that many changes to the habitat are not only the result of natural processes, but also the direct result of human interactions with the environment.

NMFS scientist uses a transmission electron microscope to study the bioaccumulation of chemical contaminants in fish.

The Sustainable Fisheries Act of 1996 requires fishery management councils (FMCs) to describe and identify EFH in FMPs, 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. It also 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, analyze data, and provide consultation necessary to: (1) identify estuarine, coastal, and oceanic habitats and their utilization by various life stages of living marine resources for spawning, growth, and production, through comparative studies of similar habitats in stressed and unstressed environs as well as comparative studies of different habitats; (2) document the life history of managed fish and determine factors that influence resiliency or sensitivity to fishing; (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) determine the best methods for restoring LMRs 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; and (8) work cooperatively with fishers to gain information on existing fishery habitats. The information resulting from these activities will be used by fishery managers to identify, describe, conserve, and enhance EFH.

The NMFS Centers' staff work closely with Regional Offices, FMCs, NOS research facilities, the NOAA Damage Assessment and Restoration Program, and other Federal and state agencies to provide timely habitat information. NMFS works with the NOAA line offices and other agencies in developing 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, and circulation.

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

- Develop a comprehensive and coordinated base-funded habitat research program in NMFS that interacts with and provides information to habitat managers, the FMCs, and the 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 species.

- Improve stock assessment capabilities and reduce uncertainty.

- Improve habitat conservation, protection, and enhancement capabilities and improve assessment of threats to EFH and managed fishery 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 that enhance recovery of biodiversity and value to fisheries.

- Map EFH for managed species in each region, and develop a national GIS database on essential habitat.

- Provide GIS identification and mapping of habitat subject to adverse impacts from fishing gear.

- Restore degraded habitat using restoration options that have a scientific base.

- Cooperate with fishers in gathering information on habitat.

- Research current incentives for habitat protection, including literature reviews of incentives for non-fishery activities such as land-based non-point-source pollution.

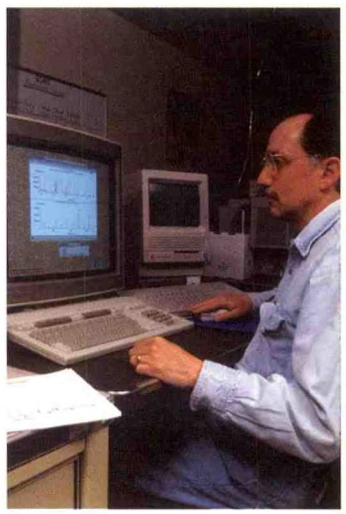
I.E. Impact of anthropogenic factors and environmental changes on fish populations

Changing conditions of the biotic and physical environment occupied by fish, whether natural or anthropogenic, affect population productivity through mechanisms ranging from sub-lethal effects to outright mortality. 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 must conduct research to unravel these complex relationships and better understand their role in the sustainability of marine fish populations.

There is recognition in the scientific community that toxic contaminant discharges to the coastal oceans can have a significant impact on the viability of important fish populations. Contaminants can disrupt an organism's early life stage development and growth that in turn can affect their reproductive potential as adults. Such nonlethal effects are not easily identified or characterized, and therefore, are difficult to relate to the sustainability of the fishery populations. The quantification and identification of deleterious changes is further complicated by natural and uncontrolled variability within and between fishery populations and their supporting food webs.

NMFS will continue to study the potential effects of contaminants on important fishery species as well as the sources of variability. To assess the risk to fish populations from different combinations of stressors there must be a linkage made between understanding toxic effects of contaminants to individual organisms and the factors, both anthropogenic and natural, that influence fishery 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, affecting 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 will continue to study similar habitats in stressed and unstressed anadromous streams, estuarine, and ocean environs in order to understand the effects of pollution on LMRs and their habitats.

NMFS will also research 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 LMRs. This information helps assess the true impact of human-induced factors.



NMFS scientist in the Biochemical Effects of Contaminants Laboratory, NWFSC, uses a PhosphorImager to analyze DNA damage in fish exposed to environmental chemical carcinogens.

Habitat loss and degradation affects riverine, estuarine, and coastal ecosystems. The primary threats come from physical destruction of wetland and other habitats, alteration of freshwater flows, eutrophication, and destructive fishing methods. For example, logging contributes to siltation and can destroy salmon spawning habitat upriver and impede their migratory paths. Construction of marinas and docking facilities as well as dredging and the 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 that are important to adults and juveniles of many marine and anadromous species. Propeller damage to shallow vegetated and non-vegetated habitats not only causes a direct loss of habitat, but results in destabilization of these areas, resulting in increased habitat loss and increased sediment re-suspension and turbidity. Diminution in freshwater volume and flow rates stems from damming and diversions of major rivers, impacting nearshore ecosystems adapted to seasonal discharges of freshwater. Destructive fishing methods can damage EFH and 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 populations (Gulf of Mexico dead zone off the Mississippi River and western Long Island Sound) and loss of inshore habitat (replacement of eelgrass beds by macroalgae or loss of eelgrass beds due to shading by epiphytes or phytoplankton in Chesapeake Bay, Waiquiot Bay, and Lake Pontchartrain). In addition, changes in nutrient dynamics can create harmful algal bloom events that can lead to wild fish kills, shellfish harvest closures, and mass mortalities of farmed salmon in the Northwest. Fishing activities, if they alter food web structure, could 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 on harmful algal blooms events is also not known.

NMFS will engage 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, including:

- Examining the effects of mobile fishing gears, such as bottom trawls, which disturb the sea bottom and damage fragile corals and other benthic habitat.

- Determining the cumulative effects of watershed and regional land cover and changes in that land cover on EFH.

- Ecosystem monitoring for habitat degradation and resource surveys by satellite remote sensing and shipboard and moored instrumentation.

- Developing rationales/methodologies to detect and quantify habitat loss.

- Establishing a GIS database to document and track habitat loss.

- Researching natural environmental variability at temporal and spatial scales pertinent 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 genetic techniques to assess the 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 existing environmental and fishery data that are available on fishery habitat types and fishery populations.

- Researching to separate the effects of natural versus human-induced climate change.

- Developing methods to identify, map, and forecast harmful algal blooms.

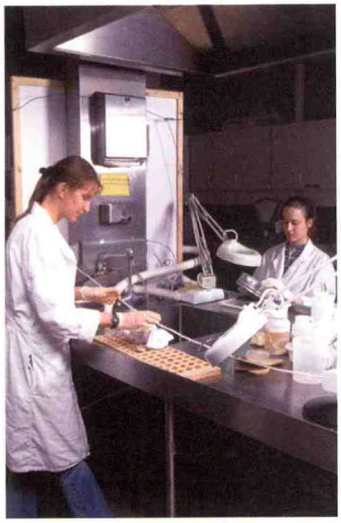
- Determining the effect of fishing on ecosystem trophic structure and population dynamics of harmful algal species.

- Cooperating with fishers in assessing habitat changes over the past decade.

- 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 by decreasing fishing costs, bycatch mortality, and habitat destruction. It is also intended to improve the data provided by scientific surveys of fish populations. This area includes research on gear performance and fish behavior used in the development of selective fishing gear to reduce bycatch. Bycatch is responsible for the death of millions of juvenile finfish, including red drum, red snapper, weakfish, Spanish mackerel, and king mackerel. For example, prior to the implementation of bycatch reduction devices (BRDs), it has been estimated that between 15 to 50 million red snapper were annually taken and discarded in the offshore shrimp fishery in the Gulf of Mexico. The Food and Agriculture Organization (FAO) estimates that one-third of the world's 16 billion lbs. of bycatch comes from shrimp fishing. The most recent studies of bycatch estimate that the ratio of bycatch to shrimp landed is 4:1 in the Gulf of Mexico. The worldwide bycatch ratio for all fisheries is 0.35 lb to 1 lb. of target species.



NMFS contract workers examine the contents of marine mammal scat collected in Alaska, AFSC.

Since few discarded fish from trawls survive, bycatch constitutes a problem for fishery managers because it represents both an unaccounted mortality in fisheries and an economic loss to harvesters and the Nation. For instance, fishers in another fishery might target the discarded species, or fishers in the same fishery might be able to keep those same fish when they are older or larger. 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 will encourage research on ways to increase the survival of recreational releases. Bycatch reduction, then, is critical for the continued existence of healthy fisheries, and is especially critical when the bycatch includes protected species. Additionally, NMFS conducts research at several of its laboratories on populations of ESA-listed species and marine mammals. Stocks of listed species and marine mammals interact with species managed under the MSFCMA (e.g., competition for food, bycatch). As such, research conducted to support requirements of the Magnuson-Stevens Act also make an important contribution to the conservation and management requirements of the Endangered Species Act (ESA) and the Marine Mammal Protection Act (MMPA). Along with incentives and other management strategies, one solution to bycatch reduction is to design and operate selective fishing gears, using knowledge of species behavior, gear hydrodynamics, and fishing practices.

NMFS observer measures a dogfish.

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 there are initiatives underway 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 all regional FMCs. Even when apparent solutions are found, the dynamics and abundance of marine species change in time and area, which 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. This approach is known as "conservation engineering" and NMFS will work in cooperation with the fishing industry and gear manufacturers to find designs that meet conservation needs while recognizing the financial constraints of fishers.

To determine when gear modifications are the most appropriate response to bycatch problems, NMFS will study existing programs such as the turtle excluder devices (TEDs) in the Gulf of Mexico and BRDs to exclude finfish from Gulf shrimp trawls and from northern shrimp trawls in New England. 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 field work on board fishing vessels working under actual fishing conditions. Most trawl gear evaluation includes an alternate tow approach, varying which net is fishing with the experimental gear and comparing the catch results using statistical tests. Underwater cameras allow for examination of the behavioral mechanisms and gear variations that would account for the catch differences.

NMFS gear specialist prepares test nets for trials aboard NOAA fishery research vessels, Pascagoula, MS.

Growing controversy over the impact fishing gear is having on EFH has resulted in a need to evaluate the impacts. 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. Experiments are being designed to assess the potential effects of all fishing gear types used in waters described as EFH. These studies will include the use of remote underwater cameras, divers, abundance studies, and perhaps research closure areas for comparison. If an adverse effect is identified and determined to be an impediment to reaching target long-term production levels, then the research needed to quantify and mitigate that effect would be the next logical step.

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 this plan. It includes proposed 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. The latter is intended to serve as a benchmark from which progress in bycatch reduction can be measured.

NMFS is committed to maximizing the research contribution of the fishing industry and other non-government participants in the fisheries. Across the NMFS regions, the industry is providing advice in research planning, in formal reviews of research programs, and, where possible, in research operations. Examples of research involvement includes: (1) provision of chartered vessels and crew for surveys and bycatch gear development; (2) keeping logbooks of species catches, including bycatch; and (3) industry efforts to develop gear, gear modifications, and fishing practices to reduce bycatch.

The Saltonstall-Kennedy Grant Program has had direct industry involvement and investment since its inception decades ago. Industry members submit proposals, usually with strong 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 nearly all species.

III. Research on the fisheries

In its fifth edition, *Our Living Oceans* (NMFS, 1999) reported (from 1995-97 data) that of 160 U.S. Exclusive Economic Zone (EEZ) fisheries whose biological status could be assessed, 34% were classified as overutilized and 47% were fully utilized. Nationwide an additional 43 fishery stocks were characterized as having "unknown" status. New management measures, based on the Sustainable Fisheries Act (Public Law 104-297), have been implemented to halt the decline in stock levels in many of these fisheries. Causes typically cited for the declines include overfishing, deteriorating environmental conditions, loss of habitat, and changing oceanographic conditions.

III.A. Social and economic research

Social and economic information has become increasingly important in addressing fishery conservation and management issues. Federal law, Executive Orders, and NMFS policy require social and economic assessments of proposed regulatory or policy changes. The U.S. fishing industry, however, is quite diverse. Competition within and between consumptive users of living marine resources, such as commercial and recreational fishers, and non-consumptive users, who value the existence of living marine resources, greatly complicates the resource allocation decisions fishery managers face. Significant diversity exists between firms within the commercial fishery, and can be seen by the variation in the sizes and types of vessels between fisheries as well as between geographic areas. In addition, oftentimes no clear distinction in an actual fishery exists between commercial fishing firms and individual recreational fishers. Instead, a continuum of activities separate two extreme forms of fisheries exploitation including recreational fishers who sell their catch, headboat and charterboat operations, meat fishers, and catch-and-release fishers. Equally important are individuals who value knowing a particular fish species exists or value the existence of species dependent on a fish stock or stocks; e.g., whales, Steller sea lions, and marine turtles. One consequence of the size and diversity of the users of living marine resources is that the goal of managing U.S. fisheries to maximize the present value of net benefits to the nation is difficult to achieve.

The application of this broad-based policy to individual fisheries is difficult because each fishery has unique biological, economic, and sociological characteristics that require different types of regulatory approaches. For example, vessel sizes, gear types, crew sizes, and processing, marketing, and distributional arrangements vary significantly among fisheries and geographic areas. Educational levels, household dependence on fishing, preferred target species, and fishing patterns differ across fisheries and fishing communities. Levels and types of social, cultural, and economic dependence on fisheries vary by community and region.

Management decisions must reflect the values as well as needs of many different groups, including commercial and recreational fishers, subsistence fishing communities, non-consumptive users, Pacific Islanders, and Native American tribes

(many of which have treaties with the United States guaranteeing certain fishing rights).

Management by NMFS must be done within an economic framework that considers economic efficiency and provides equity or fairness to all resource users. This economic framework considers the transition time associated with a proposed regulation to minimize adverse economic impacts on fishing dependent communities, firms, and individuals. Adequate consideration of these factors requires that NMFS collect and analyze sufficient information about fishing communities, commercial and recreational fishing firms or individuals, and other consumptive and non-consumptive users of our living marine resources. Without sufficient data and analyses, we will have inadequate social and economic assessments and will be unable to determine if our management policies are achieving their intended objectives.

To produce quality assessments will require new data and models on a number of sectors, including the following:

- **The U.S. commercial harvesting sector:** Detailed social and economic analyses of the majority of U.S. fisheries will be conducted in conjunction with stock assessments to determine current social and economic costs and benefits in the harvest of living marine resources, and determine methods to maximize net benefits through innovative management alternatives.

- **The U.S. recreational harvesting sector:** The recreational and commercial fishing sectors are interdependent and have much in common. Policies aimed at regulating one group almost always impact the other and often affect other sectors of the marine fishing industry. NMFS will assess the net economic and social benefits from various allocation scenarios using estimates of anglers' consumer surplus, commercial fishers' producer surplus, and, theoretically, the consumer surplus for commercial catch as well.

- **The U.S. subsistence and traditional use fisheries:** NMFS will conduct data collection to support empirical research using both qualitative and quantitative techniques of fisheries economics, including alternative sources of protein and cultural and ritual uses of the harvested living marine resources, to model and assess social, cultural, and economic factors related to community dependence on the fishery.

- **The U.S. seafood processing/wholesale sector:** The processing and wholesale sectors are an integral part of the seafood industry. As in the harvesting sector, technological innovations advance the processing and distribution of seafood. NMFS will continue to collect annual data to determine the total number of processing and wholesaling plants, the number of people employed, and the total volume and value processed. NMFS will also increase data collection to support research on social and economic relationships among fishing firms, processors, and wholesalers to better understand the cultural and other institutional influences on the

structure of seafood markets (e.g., to develop econometric models of the processing sector to determine the effect of common property resources on capital investment).

- **The U.S. trade sector:** The U.S. plays a major role in the international seafood market, importing and exporting billions of dollars worth of seafood each year. The U.S. seafood trade market in part determines conditions in its domestic fisheries. NMFS will conduct an annual survey to determine our share of the international seafood trade market from which econometric analyses of supply and demand conditions in international markets can be developed to determine how trade agreements impact our Nation's competitiveness in this arena.

- **Retail demand for seafood:** Social and economic forces in the United States over time have influenced the current makeup of the seafood industry. Population, real per capita income, and the prices of substitutes are three factors that economic theory suggests should explain the aggregate demand for seafood. NMFS will conduct studies to gain a greater understanding of the responsiveness of consumers to changes in prices, quantities, and product quality, their willingness to substitute among various seafood products and other protein sources, their readiness to purchase imported products, and the responsiveness of fish and fishery product prices to changes in harvest levels.

- **Fishing communities:** NMFS will collect or acquire from other sources qualitative ethnographic, demographic, and economic data important for the social and economic profiling of fishing communities, including opportunity costs, social structure, and ethnohistorical data, and other data needed for the estimation of net benefits for use in input-output models and analyses of distributional effects of alternative management policies.

- **Economic impact analyses:** NMFS will collect economic data to meet the requirements of Executive Order 12866, the National Environmental Policy Act, regulatory flexibility analyses (RFAs), and fiishery impact statements for the MSFCMA.

- **Social impact assessment (SIA):** NMFS will collect ethnographic, economic, and biological data related to fishing decision-making processes of captains; investment decision-making processes of owners; information flows within the fishery; and the differential effects of management policies on various subsets of the fishing industry such as absentee owners, captain-owners, and crew members, full-time and part-time fishers, fishers with different household compositions, large vessels and the undertonnage fleet, those who target single species or complexes, and those who fish different gears and species by season.

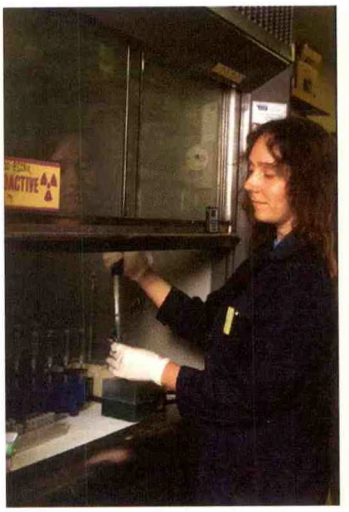
- **Overcapacity:** NMFS will assess current levels of capacity of U.S. commercial and recreational fishing fleets (i.e., charter/party vessels), deter-

mine optimal levels, and develop approaches to solving the problem of overcapacity.

- **Fisheries management:** NMFS will seek to integrate the existing biological, economic, and other social sciences information into a single bio-socio-economic framework from which information can be generated to aid fishery managers in making decisions about our living marine resources.

III.B. Seafood safety research

Intra and extramural seafood science research is aimed at continuing the integration of trophodynamic investigations 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 are focused on identifying and determining the characteristics of marine pathogens; improving methods to detect, forecast, and evaluate the ecological significance of harmful algal blooms; as well as 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, such as that needed to perform a Risk Assessment to wild shrimp stocks resulting from imported aquacultured shrimp products being infected with various shrimp viruses or re-evaluating the human exposure rate from mercury in seafoods. These research efforts are conducted primarily at the National Seafood Inspection Laboratory in Pascagoula, MS, as well as at the Northwest and Southeast Fisheries Science Centers.



NMFS scientist studies marine biotoxins in the Utilization Research Division, NWFSC.

III.C. Marine aquaculture

The importance of marine aquaculture (mariculture), both in the U.S. and throughout the world, is widely recognized. The production limits of wild stock are being reached and most of the increased global production of fisheries products for the last decade has come from aquaculture. In many countries aquaculture is progressing more rapidly than in the U.S., and one-third of the global supply of food fish now come from aquaculture (FAO, 2001). The annual U.S. trade deficit in edible fishery products is $7 billion. In the U.S., aquaculture production (1999 statistics) has reached over 380,000 metric tons per year, with a value of $987 million, but only about one-third of this is for marine species. In addition, an estimated 150,000 metric tons of commercially and recreationally caught fish with a value of about $100 million originate from marine stock enhancement, primarily for Pacific salmon species. Although aquaculture accounts for 28% of the value of the total U.S. landings, it makes up only 9% of the landed volume. There is significant potential to increase U.S. marine aquaculture production. However, there are technical, environmental, and socio-economic impediments that need to be addressed by basic and applied research and through an examination of policies. NMFS has scientific expertise that can be applied to all of these

NMFS scientist uses image analysis to measure gut contents in larval fish. Larval feeding studies are an important component of aquaculture research.

issues. NMFS has had 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. Also, NMFS has environmental stewardship responsibilities and the expertise to assess the appropriate role of mariculture and its potential impacts on wildstocks and habitat quality. Finally, NMFS has responsibilities for permitting aquaculture projects, and it is important to use good science as a basis for establishing a clear policy for permitting decisions.

In addition to food production, aquaculture can also play a role in enhancing wildstock populations, assisting in recovery plans for protected species, and can be used to produce non-food products such as ornamental fish, baitfish, and pharmaceuticals. Expanded mariculture production in the U.S. has the potential to reduce the pressure on wildstock harvest and help in the rebuilding efforts for those stocks.

To ensure that mariculture progresses in an environmentally sound manner, NMFS will concentrate its mariculture research activities in the following broad areas:

- Develop and evaluate commercially viable husbandry technologies for new candidate species.
- Conduct research on the effects of marine aquaculture on habitat and evaluate the risk to wild stocks from the introduction of cultured stocks.
- Establish, with the help of stakeholders, uniform requirements for aquaculture development in the U.S. EEZ under a Code of Conduct for its implementation.
- Develop effective enhancement strategies for aquatic species to help in the recovery of wild-stock fisheries and endangered species.
- Integrate aquaculture development with the management of wild stocks, particularly threatened and endangered species.
- Develop environmentally safe protocols for disease prevention.
- Assess the effectiveness of aquaculture as an alternative employment source for fishers in over-exploited fisheries.
- Accelerate industrial implementation of aquaculture technologies through demonstration, training, and extension projects for producers, tribes, and community groups.
- 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 with scientific analysis and assessment of risk.

IV. Information management research

Title IV (Fishery Monitoring and Research) Section 401 (Registration and Information Management) of the MSFCMA required the Secretary of Commerce to deliver a proposal to Congress that recommended an implementation strategy for the creation of a "...standardized fishing vessel registration and fisheries information system." This report was completed and delivered to Congress in December 1998, and outlined an approach that integrated all fisheries information required under all applicable National Marine Fisheries Service (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 under state authority for those states willing to participate. This report was developed in consultation with the U.S. Coast Guard, the states, the regional FMCs, the interstate Marine Fisheries Commissions, other key governmental and non-governmental organizations, and interested stakeholders. Drafts of the proposal were published in the *Federal Register* for public comment.

The proposed fisheries information system included information from both commercial and recreational fisheries (the vessel registration component was recommended to apply to only commercial vessels). The current development of the fisheries information system is based on integrating data collection and data management systems required by NMFS, and linking them with existing state/Federal cooperative statistics programs around the country (i.e., the Atlantic Coast Cooperative Statistics Program (ACCSP); Gulf coast (GulfFIN); Pacific coast (Pacific RecFIN and PacFIN); Hawaii and Pacific islands (WestPacFin); and Alaska (AkFIN)). Linking regional systems will identify and satisfy mutual information needs for states and the Federal government. In addition, gaps in information needs not yet met by these programs will be identified through consultation with industry and policy makers. The proposal recommended the following:

- Standardization of vessel registration and information collection systems contents as required by SFA and other state and Federal enabling legislation, to include:

  Establishing standardized units of measurement, nomenclature, and formats for the collection, submission and management of data;
  establishing procedures for requiring commercial and recreational fishers and ex-vessel purchasers to participate in collection and reporting of fisheries information;
  Inclusion of all species and all commercial fishing vessels (including charter fishing vessels) within the geographic areas of authority of the FMCs; and

  Assessing the desirability or necessity of creating a vessel registration system for recreational fishing vessels (not including charter fishing vessels).

- Integrating information collection programs under existing FMPs and integrating other state, tribal, and Federal fishery information systems to reduce/avoid duplication and minimize paperwork and other burdens on affected parties.

- Improving stakeholder and industry participation in effectively implementing new, integrated systems.

- Identifying costs and possible funding mechanisms and schedules associated with implementing the recommendations for the system.

- Modifying several statutory impediments to enable implementation of the system.

Major Fishery Research Goals and Objectives

All Federal agencies operate in an environment of increasing demands competing for limited resources. To meet this challenge, NMFS is increasing its partnering activities with other NOAA line offices and their programs (e.g., Sea Grant, National Undersea Research Program, Coastal Ocean Program), 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.

The major fishery research goals and objectives are driven by the goals and objectives in the *NOAA Fisheries Strategic Plan* (FSP), published in May 1997. To facilitate cross reference, the corresponding FSP strategy or foundation number follows each fishery research objective found below.

GOAL 1: Provide scientifically sound information and data to support fishery conservation and management. (Ongoing)

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. (FSP Strategy 1.1.1)

Objective 1.2: Use stock assessments to predict future trends in stock status. Forecasts will take into account projected biological productivity, climatic information, economic markets, and other social forces that will affect levels of fishing effort. (FSP Strategy 1.1.2)

Objective 1.3: Determine and reduce the level of uncertainty associated with stock assessments through improved data collection and advanced analytical techniques. (FSP Strategy 1.2.1)

Objective 1.4: Use stock assessment workshops, peer reviews, and other fora to ensure that our information and advice are developed through an open and collaborative process. (FSP Strategy 1.2.2)

Objective 1.5: Communicate our scientific information and advice, along with the associated uncertainties, to the Councils, other management authorities, and the public. (FSP Strategy 1.1.3)

Objective 1.6: Collaborate with the Councils and other management authorities to explore and develop fishery management regimes and alternative governance systems that will effectively control exploitation and promote sustainability. (FSP Strategy 1.1.4)

Objective 1.7: Provide guidelines to assist the Councils in assessing and specifying Maximum Sustainable Yield (MSY) for managed fisheries. (FSP Strategy 1.1.5)

Objective 1.8: 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. (FSP Strategy 2.1.1)

Objective 1.9: For each stock which is overfished or approaching an overfished condition, we will develop, in collaboration with the Councils, measures to eliminate or prevent the overfishing. (FSP Strategy 2.1.2)

Objective 1.10: Conduct additional research to provide needed information to refine initial EFH designations and to help the Councils minimize the adverse effects of fishing on EFH, as mandated by the SFA. (FSP Strategy 2.3.1)

Objective 1.11: Establish an inventory of living marine resource habitats (tied to *Our Living Oceans* series) and implement measures to monitor the trends in habitat availability. (FSP Strategy 7.3.3)

Objective 1.12: Support recommendations provided by the NRC (NRC, 1999a) 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. (FSP Strategy 7.3.2)

Objective 1.13: 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 evaluating the quality and productivity of restored habitats, as well as improved restoration and creation technologies, including contaminant remediation, to ensure that created habitats are beneficial to fish populations. (FSP Strategy 7.3.1)

Objective 1.14: Incorporate assessments or indices of climate variability into stock assessments.

Objective 1.15: Monitor climate change on inter-annual, decadal, and centennial scales and its impact on currently sustainable fisheries.

GOAL 2: Through conservation engineering research contribute to efforts to reduce bycatch and adverse effects on EFH, promote efficient harvest of target species, and to improve the data from fishery surveys. (Ongoing)

Objective 2.1: Identify and assess the magnitude of incidental takes of protected marine species. (FSP Strategy 6.1.1)

Objective 2.2: Establish sustainable levels of takes for all protected marine species and continue to improve the estimates of these levels through ecologically sound research. (FSP Strategy 6.1.2)

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. (FSP Strategy 6.1.3)

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. (FSP Strategy 6.1.5)

Objective 2.5: Establish a standardized reporting methodology to assess the amount and type of bycatch occurring in each fishery covered by an FMP. (FSP Strategy 3.4.1)

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. (FSP Strategy 3.4.2)

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. (FY 2003)

Objective 3.1: Collect data and develop integrated bio-socio-economic models to measure net benefits to the Nation from living marine resources. (FSP Strategy 3.1.1)

Objective 3.2: Assist the Councils in reviewing optimum yield (OY) levels for consistency with economic theory and with the revised definition in the Sustainable Fisheries Act. (FSP Strategy 3.2.1)

Objective 3.3: Develop an integrated multi-disciplinary scientific framework to collect sufficient economic, biological, and social data to support recommendations made by the NRC on developing a national policy for individual fishing quota programs (NRC, 1999b). (FSP Strategy 3.3.3)

Objective 3.4. 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. (FSP Strategy 4.1.1)

Objective 3.5: Determine the bio-economic requirements for the siting of aquaculture operations in the U.S. EEZ. (FSP Strategy 4.4.1)

Objective 3.6: Work with the aquaculture industry to develop, identify, evaluate, and transfer technologies that are appropriate to both economically efficient aquaculture production and environmental protection. (FSP Strategy 4.5.1)

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: Improve the fishery information system. (FY 2003)

Objective 4.1: Develop implementation strategy and annual operational plans for creation of a national fisheries information system as described in the December 1998 Report to Congress (NMFS, 1998b). (FSP Strategy 3.3.2)

Objective 4.2: Develop implementation strategy and annual operational plans for executing the days-at-sea requirements identified in the NMFS Data Acquisition Plan (NMFS, 1998c).

GOAL 5: Improve the effectiveness of external partnerships with fishers, managers, scientists, conservationists, and other interested groups. (Ongoing)

Objective 5.1: Promote a cooperative network of partners in the coordination of fisheries research.

Objective 5.2: Develop infrastructure for long-term, continuous working relationships with partners to address fisheries research issues.

Objective 5.3: Sponsor symposia and conferences for partners to exchange information and identify major fisheries research initiatives.

Objective 5.4: Solicit partners' views on fisheries research needs.

APPENDIX A. NMFS Scientific Enterprise

The National Marine Fisheries Service is the NOAA line office responsible for the stewardship of the Nation's living marine resources. NMFS has five regional Science Centers, composed of about 30 laboratory facilities nationwide and over 1,500 scientific and support personnel, which conduct a comprehensive, interdisciplinary science program. The scope of their work is broad in time, space, and discipline. These Science Centers provide the scientific knowledgebase on which NMFS formulates stewardship policies through to its five Regional Offices. Research at NMFS laboratories supports resource managers in NOAA, fiishery management councils, interstate fishery commissions, and other agencies in making informed marine resource management decisions for sustainable fisheries, protected resources, endangered species, and habitat.

Because fisheries are managed on a regional basis, the focus of NMFS research programs varies among the regional Science Centers. Each Science Center Director and his/her Division Chiefs develop annual research priorities, based upon regional and national needs, through dialogue with his/her Regional Administrator, councils, the Program Offices in NMFS headquarters, and with user groups and other interested parties. Within each Science Center, teams of researchers work together to develop research plans.

NMFS' longer-term integrated research program is coordinated by headquarters' Office of Science and Technology. The Science Board, composed of the five Science Center Directors and 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 function to provide the agency with information that is comprehensive, objective, credible, and effectively communicated.

The NMFS science program has extensive collaborations with academia, many through cooperative agreements and grants. These partnerships enhance and extend NMFS' research capability. Many NMFS scientists serve as adjunct professors at nearby universities. This relationship offers intellectual stimulation and challenges for agency scientists to remain on the cutting edge, while expanding the teaching capability of the university and bringing NMFS expertise into the academic community. Academic scientists also play an important role in the periodic review and evaluation of the quality and relevance of NMFS research programs. The Science Centers work in cooperation with other Federal and state agencies, international entities, non-governmental organizations, and the private sector, including the 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 underway to reduce wasteful bycatch. Other research initia-

tives focus on needs of the FMCs and NMFS Habitat Conservation field offices to meet their scientific and management mandates under the EFH provisions of the MSFCMA.

Goals of the Scientific Enterprise

The mission of NMFS scientific enterprise is to ensure that the science products produced and disseminated by the National Marine Fisheries Service is of the highest quality. During the next five years NMFS will accomplish this by meeting the following goals and objectives:

Improve Scientific Capability

- Implement NRC recommendations (NRC, 1998) to ensure state-of-the-art resource assessments through our National Stock Assessment Improvement Plan (NMFS, In press). (Ongoing)

- Continue to incorporate economic and social factors into our decision-making. As part of this continuing effort, NMFS will publish the next edition of the *Our Living Oceans: The Economic Status of U.S. Fisheries.* The report will measure the economic health of U.S. fisheries relative to current conditions versus desired future conditions of long-term sustainability. (FY 2002)

- Increase our ability to predict natural living marine resource variation through improved data collection, improved understanding of how LMRs respond to environmental variability and climate change, and coordinated bio-socio-economic modeling, which will result in more accurate assessments and estimations of the uncertainty associated with them. (Ongoing)

- Increase our ability to identify, conserve, protect, and restore those habitats essential to managed fishery resources and to estimate the impact of pollution, wetland and estuarine degradation, and fishing gear on the abundance and availability of fish. (Ongoing)

Increase Science Quality Assurance

- Implement policies to ensure that our science programs, analyses, and products are sound, credible, and provide an objective basis for management. (Ongoing)

- Improve our professional standards for research and scientific advice by establishing national guidelines for technical program and staff performance evaluations, performance award programs, and professional career development opportunities. (Ongoing)

- Expand and improve our system for peer review of scientific advice by

establishing panels of knowledgeable scientists from both within and outside government. (Ongoing)

- Solicit input from external scientists in topical areas when identifying research initiatives for the various NMFS grant programs. (Ongoing)

Improve Fishery Research Capability

- Implement our fishery research vessel replacement plan (NMFS, 1998c) that integrates government, university, and industry vessel capabilities to provide the state-of-the-art facilities necessary for the accomplishment of our varied at-sea research programs. (FY 2008)

Improve Data Collection

- Implement NRC recommendations (NRC, 2000) to improve our data collection and analysis techniques and fishery data management systems. (Ongoing)

- Provide a core fishery statistics program based on our strategic and operational needs. (Ongoing)

Increase Outreach/Information Dissemination

- Involve constituents in research programs. To the extent practicable, NMFS will charter fishing vessels to participate in research projects, invite constituents to participate aboard NOAA research vessels during resource surveys, encourage frequent contact and cooperation between scientists and constituents, and develop methods to incorporate scientifically valid observations by fishers and others into fish stock assessments and other analyses related to living marine resources and their habitat. (Ongoing)

- Coordinate with the NMFS Constituent Affairs and Outreach Team to develop an Internet Web-centralized resource for neutral science-based information to educate the public and user groups and answer questions on various topics on the status of our nation's fisheries, including how NMFS research is conducted and how stock assessments are performed. (Ongoing)

- Develop a new series of reports and presentations to communicate scientific results in simplified language that is easier to understand than traditional scientific publications. (Ongoing)

Support International Fishery Science

- Participate in international scientific initiatives, such as the United Nations Intergovernmental Panel on Climate Change (IPCC), Program for the Conservation of Arctic Flora and Fauna (CAFF), Commission for the

Conservation of Antarctic Marine Living Resources (CCAMLR), Food and Agriculture Organization of the UN (FAO), Global Oceans Observing Program (GOOS), North Pacific Marine Science Organization (PICES), International Council for the Exploration of the Seas (ICES), International Whaling Commission (IWC), United Nations Atlas of the Oceans, and Global Ocean Ecosystems Dynamics (GLOBEC). (Ongoing)

- Participate in bilateral scientific initiatives with neighboring countries, Canada and Mexico, and in scientific exchange programs with foreign countries which are developing their fishery resources. (Ongoing)

NMFS Fisheries Science Centers

The National Marine Fisheries Service 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. 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 five NMFS Science Centers.

Alaska Fisheries Science Center (AFSC)

Alaska Fisheries Science Center, NOAA Western Regional Campus, Seattle, Washington.

The Alaska Fisheries Science Center (AFSC) has research facilities in Alaska (Auke Bay and Kodiak Island), Washington (Seattle), and Oregon (Newport). Organizationally, the AFSC consists of the Auke Bay Laboratory (ABL), the National Marine Mammal Laboratory (NMML), the Resource Assessment and Conservation Engineering Division (RACE), the Resource Ecology and Fisheries Management Division (REFM), and other administrative units. The major survey platforms supporting the AFSC include the NOAA fishery research vessels *Miller Freeman* and *John N. Cobb*, and chartered vessels from the industry. External cooperators include state and other Federal agencies, academic institutions, foreign research institutions, the fishing industry, and resource conservation organizations.

The Center has a permanent staff of about 325 employees who conduct fisheries and marine mammal research in the coastal and offshore waters off Alaska and the U.S. west coast. This marine region of nearly three million square miles includes over 50% of the U.S. coastline and over 70% 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. It is host to some of the world's largest populations of marine mammals and seabirds.

The Center conducts research on the following fishery resources that are under active management:

- The groundfish fishery in the Bering Sea-Aleutian Islands region involving 14 major species and 20 minor ones including walleye pollock, Pacific cod, Atka mackerel, sablefish, yellowfin sole and other flatfish species, Pacific ocean perch, and other rockfish species.

- The groundfish fishery in the Gulf of Alaska region involving 14 major species and 37 minor ones including walleye pollock, Pacific cod, sablefish, flatfish species, Pacific ocean perch, and a variety of slope and shelf rockfish species.

- The king, tanner, and snow (*C. opilio*) crab fisheries in the Bering Sea-Aleutian Islands region.

- The Pacific halibut fishery of Canada and the U.S.

- The scallop fishery off Alaska.

- The salmon fisheries off Alaska.

In addition to fishery research, the NMML conducts research on marine mammals to determine their status, conservation needs, and potential impacts of fishing activities on the populations. The Alaska region has 37 stocks of more than 25 species of marine mammals that may be grouped as:

- Seals, sea lions, and walruses that include bearded seal, harbor seal, northern fur seal, ribbon seal, ringed seal, and northern sea lion.

- Whales, dolphins, and porpoises that include beaked whale, beluga whale, bowhead whale, Cuvier's beaked whale, fin whale, gray whale, humpback whale, killer whale, minke whale, northern right whale, sperm whale, Pacific white sided dolphin, Dall's porpoise, and harbor porpoise.

Recent Accomplishments and Research Priorities for FY 2001-2006

I. Research to support fishery conservation and management

Recent Accomplishments:

Major research cruises conducted by the AFSC included: (1) a winter hydroacoustic survey by the NOAA R/V *Miller Freeman* that estimated the biomass and distribution of pollock in Steller sea lion critical habitat on the Bering Sea shelf and in the Bogoslof area; (2) a spring hydroacoustic survey by the NOAA R/V *Miller Freeman* to determine the distribution and biomass of spawning pollock within

Research scientist monitors survey trackline during an acoustic/trawl survey of pollock aboard the NOAA R/V *Miller Freeman* in the Gulf of Alaska.

the Shelikof Strait area of the Gulf of Alaska; (3) 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; (4) a summer bottom trawl survey of Aleutian Islands groundfish with two chartered fishing vessels to estimate the biomass and distribution of groundfish and to collect other biological data; (5) a summer hydroacoustic survey by the NOAA R/V *Miller Freeman* to determine the distribution and biomass of pollock on the Bering Sea shelf; (6) a summer bottom trawl survey of eastern Bering Sea shelf with two chartered fishing vessels to estimate distribution and abundance of crab and groundfish stocks, (7) a summer bottom trawl survey of Bering Sea continental slope groundfish and crab with a chartered fishing vessel; and (8) a fall bottom trawl survey of the west coast continental slope by the NOAA R/V *Miller Freeman* to determine distribution of groundfish.

The AFSC runs an ongoing Fisheries Observer Program to collect data from the fishing industry. The data include the incidental takes of all protected marine species such as marine mammals, seabirds, and prohibited species of groundfish. The data collected by these observers were used for stock assessments and real time management of the fisheries.

Sorting a catch of groundfish collected with a bottom trawl during a research cruise aboard the NOAA R/V *Miller Freeman* in the eastern Bering Sea.

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. The Center also provided analysis of the Pacific hake resource off the Pacific Coast.

The AFSC, in cooperation with the Pacific Marine Environmental Laboratory (PMEL), conducted some Fisheries Oceanography Coordinated Investigations (FOCI) as part of GLOBEC and the Southeast Bering Sea Carrying Capacity programs. These studies examine the environment and biological factors affecting the recruitment of pollock in the Gulf of Alaska and Bering Sea. Forecasts of future year class recruitment strength are made for pollock stocks and in predicting future stock levels.

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

The AFSC conducted restoration studies related to the *Exxon Valdez* oil spill in Prince William Sound.

The NMML conducted research to determine the status, conservation needs, and potential impacts of fishing activities on marine mammal populations. The NMML worked closely with the Alaska Scientific Review Group (ASRG) concerning recommendations regarding the status of marine mammal stocks in Alaska. The ASRG had representatives from industry, the tribal community, and the environmental community.

The AFSC (ABL) completed a three year radio-tagging study on Yukon River fall chum salmon that documented spawning location, migration rates, and estimated numbers crossing the border into Canada. This laboratory also developed a ge-

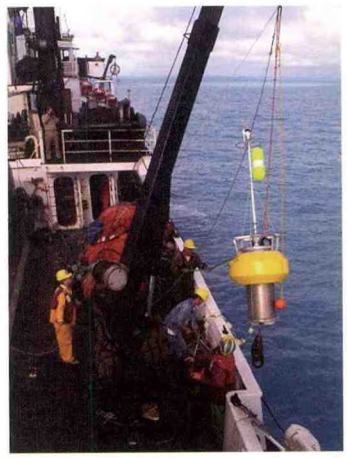
netic baseline information base on salmonids to identify stocks or country of origin. AFSC scientists have been key partners in Coastal Fish Habitat Restoration design and application of new aquatic habitat restoration technology and in developing the database needed to test the effectiveness of those restoration designs.

Research Priorities, FY 2001-2006:

I.A. Biological research concerning the abundance and life history parameters 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 midwater trawl-acoustic surveys to assess off-bottom component of pollock stock in the Bering Sea every two years (2002, 2004, 2006) and the Gulf of Alaska (2003, 2005) with the NOAA R/V *Miller Freeman*.
- Conduct an Eastern Bering Sea slope survey on groundfish every two years (2002, 2004, 2006) with a chartered fishing vessel.
- Conduct an annual March survey on spawning pollock resources in the Bogoslof Island area by the NOAA R/V *Miller Freeman* or with cooperating foreign research vessels.
- Conduct an annual spring survey of pollock resources in the Shelikof area by the NOAA R/V *Miller Freeman*.
- Conduct a summer bottom trawl survey on groundfish in the Gulf of Alaska with chartered fishing vessels every two years (2001, 2003, 2005).
- Conduct a summer bottom trawl survey on groundfish in the Aleutian Islands region with chartered fishing vessels every two years (2002, 2004, 2006).
- Conduct an annual summer longline survey on sablefish resources in the Gulf of Alaska by a chartered vessel.
- Conduct a triennial summer bottom trawl survey on shelf groundfish off the Pacific West coast with two chartered vessels in 2001.
- Conduct an autumn bottom trawl survey on slope groundfish off the Pacific west coast with the NOAA R/V *Miller Freeman* in 2001.
- Conduct a triennial summer hydroacoustic-bottom trawl survey on Pacific whiting off the Pacific west coast with the NOAA R/V *Miller Freeman* in 2001.
- Conduct an annual April FOCI egg-larvae survey in the Gulf of Alaska and a May survey on late-larvae by the NOAA R/V *Miller Freeman*.



Deployment of a specially-developed acoustic buoy from the NOAA R/V *Miller Freeman*. This free-floating buoy contains a scientific acoustic system which can be used to assess local abundance of pelagic fish and observe reactions of fish to disturbance.

In addition to the above surveys, the AFSC is also planning to conduct many field operations to study marine mammal-fish interactions, with particular emphasis on sea lion-pollock/cod/atka mackerel interactions in the Gulf of Alaska to the Bering Sea areas.

The following observer programs are planned for the groundfish fisheries that occur off Alaska:

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

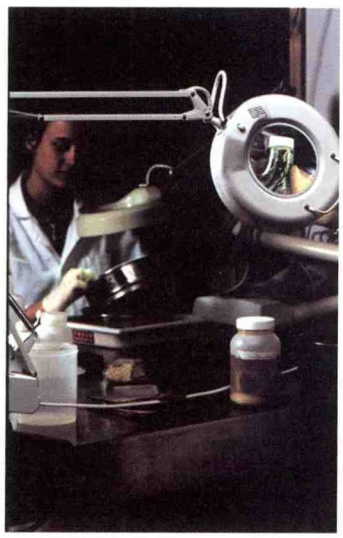
The AFSC will assess the status of stocks, estimate their biological production potentials (MSY, acceptable biological catch (ABC), overfishing levels), bycatch requirements, and other parameters required for their management. The following stocks will be assessed annually and be published in stock analysis and fishery evaluation (SAFE) reports:

- All Bering Sea-Aleutians and Gulf of Alaska groundfish stocks, including pollock, cod, sablefish, atka mackerel, yellowfin sole, rock sole, flathead sole, Greenland turbot, other flatfish, Pacific ocean perch, and other rockfish species.
- King and tanner crabs in the Bering Sea.

Steller sea lion, Middleton Island, Gulf of Alaska.

The NMML will assess the population dynamics, ecosystem interactions, and abundance of marine mammal stocks and their incidental take requirements. Some specific programs and activities that will be pursued are:

- Implement the Steller Sea Lion Recovery Plan.
- Implement the Steller Sea Lion — Fishery Interactions Research Plan.
- Implement the Northern Fur Seal Conservation Plan.
- Implement the Alaska Harbor Seal Research Plan.
- Analyze existing aerial survey data and harvest monitoring data on Alaskan ice seals.
- Analyze data collected during the international Antarctic Pack Ice Seal (APIS) cruise.
- Implement the Humpback Whale Recovery Plan.
- Implement the Northern Right Whale Recovery Plan as it pertains to the North Pacific.
- Implement an extended five-year research and monitoring plan for the eastern North Pacific gray whale.
- Analyze data collected during the 1997-1999 small cetacean surveys in Alaska.
- Implement the west coast pinniped-salmonid research plan.
- Monitor the Makah gray whale harvest.



NMFS scientist investigates dietary components of Steller sea lions and other marine mammals in Alaska.

I.B. Social and economic factors affecting abundance levels

- Expand sociological and economic research and incorporate results into the fishery management process.

- Conduct research on vessel over-capitalization and impacts of their fishing effort levels on fisheries.

- Compile and analyze data on harvesting and processing sector behavior.

I.C. Interdependence of fisheries or stocks of fish

- Collect biological specimens of spawning pollock throughout its range for genetic marker studies through DNA and other genetic techniques. Cooperation with foreign scientists is required for sampling non-U.S. waters.

- Analyze survey and observer data to determine spatial distributions of different species clusters that would indicate separation or interdependence of stocks.

- Develop genetic baseline information on salmonids to identify stocks or area of origin.

- Conduct winter surveys to estimate distribution and abundance of pollock (acoustic) and Pacific cod (bottom trawl) in Steller sea lion critical habitat areas in southeast Bering Sea, Shumagin Islands, and Kodiak Island to determine dependence of sea lions on localized food supplies and assess feasibility of annual time series.

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

- Conduct studies on the impacts of logging, urbanization, and mining on coastal salmon resources in southeast Alaska. NMFS will work with the Corps of Engineers and local organizations to restore an urban impacted salmon stream.

- Conduct restoration studies related to the *Exxon Valdez* oil spill in Prince William Sound. The research will build upon the results reported in the accomplishments section, including a study of the effects of oil on the biology, homing, and survival of pink salmon.

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

- Investigate mortality and pathogens of shellfish and groundfish.

- Conduct Fisheries Oceanography Coordinated Investigations (FOCI): 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.

- Assess effects of fishing on EFH and develop ways to minimize adverse impacts.

II. Conservation engineering research

Recent Accomplishments:

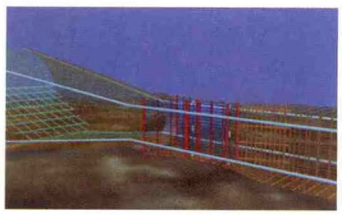
The AFSC conducted research to measure the direct effects of bottom trawling on seafloor habitat in eastern and central Gulf of Alaska, eastern Bering Sea, and the Aleutian Islands. Some of the major accomplishments were: (1) the assessment of changes to the seafloor caused by chronic long-term trawling in soft-bottom areas in the Gulf of Alaska; (2) the examination of possible adverse effects of bottom trawls on soft-bottom benthos in the eastern Bering Sea; (3) the evaluation of acoustic technology for seabed classification; (4) the assessment of impacts to habitat areas of particular concern (HAPC) such as gorgonian corals; (5) the documentation of the effects of trawling on hard bottom habitat in the Aleutian Islands and Gulf of Alaska; and (6) the mapping of the areas by sediment types.

The AFSC worked cooperatively with the industry's Groundfish Forum by chartering two fishing vessels to test a flexible grate system in bottom trawls designed to reduce the bycatch of Pacific halibut in trawl fisheries for Pacific cod. Preliminary results are very promising that this technology will be successful in reducing bycatch of halibut. AFSC has also worked with industry and the North Pacific Fishery Management Council (NPFMC) to develop other bycatch management measures that would provide substantial incentive for the development of more selective gear types.

A workshop on fishing gear impacts and seafloor mapping was hosted by the ABL of the AFSC and the NMFS Alaska Regional Office. The focus of the workshop was to improve cooperation with other NOAA research conducted by the U.S. Geological Survey, the National Undersea Research Program, and the National Ocean Service. Plans for coordination were developed at the workshop.

The NMML worked closely with the Northwest Regional Office and the Makah tribe to develop methods for deterring the incidental mortality of harbor porpoise in salmon gill nets. The recent development of an acoustic pinger has resulted in a significant reduction in marine mammal bycatch.

Live fish experiments at the Hatfield Marine Science Center in Newport, OR, test 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.



Schematic drawing of a commercial bottom trawl that has been modified to reduce bycatch of flatfish in the Alaskan fishery for Pacific cod.

Research Priorities, FY 2001-2006:

- Continue to conduct research to measure direct effects of bottom trawling on seafloor habitat according to a five-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.

III. Research on the fisheries

Recent Accomplishments:

The AFSC conducted socio-economic research to support fishery management actions, particularly those of the NPFMC. The Center's principal accomplishments on socio-economic research were as follows:

- Developed a report on the economic status of the Alaska groundfish fisheries and incorporated it as part of the SAFE reports for the Bering Sea/Aleutian Islands (BSAI) and Gulf of Alaska (GOA) groundfish fisheries.
- Identified and assessed economic consequences associated with alternatives for the programmatic supplemental environmental impact statement (SEIS) for the BSAI and GOA groundfish fisheries.
- Analyzed economic consequences of fishery management actions including additional restrictions on the atka mackerel, pollock, and Pacific cod fisheries to provide additional protection for sea lions through the use of trip limits, stacking groundfish permits, and changing time/area closures to assess interactions between pollock fisheries and sea lions.
- Published research on the decision of fishers to choose fishing locations, marine protected reserves, valuing recreational fisheries, and behavioral modeling of Alaska groundfish fisheries.

The AFSC completed a qualitative assessment of excess fishing capacity in federally managed fisheries off Alaska, assisted in a NMFS national effort to define and measure excess capacity, and revised the guidelines for economic analysis of fishery management actions.

Full utilization of groundfish is mandated by regulation in Alaska. The AFSC contributed to research that led to a ban on roe-stripping and the proper utilization of young fish. The research efforts now concentrate on developing and incorporating aspects of uncertainties associated with stock assessments and ecosystem interactions of the major component species to assess the status, population dynamics, and biological productivity of most of the major groundfish species managed by FMP's in the BSAI and the GOA regions. For example, the effects of variable recruitment and predation needs of marine mammals have been incorporated to provide risk analyses of different exploitation strategies on the Gulf of Alaska pollock stocks so that the stocks are properly utilized.

The AFSC also maintains a fish lab at the Hatfield Marine Science Center at Newport, OR, that conducts research with live fish. The focus of the research is to measure mortality resulting from the capture process of Pacific halibut, sablefish, and juvenile pollock taken as bycatch in trawl and longline fisheries. While the research is focused on impact analyses of human activities on the fish, some of the lessons learned may be useful for aquaculture research. For example, growth and survivorship studies are conducted to study the influence of water temperature on growth of young fish.

Research Priorities, FY 2001-2006:

III.A. Social and economic research

- The AFSC has initiated a data collection program that will collect cost, earning, and employment data for the Alaska groundfish fishery and has worked with the NPFMC, Alaska Department of Fish and Game, and the Alaska Fisheries Information Network (AKFIN) to identify the elements of a broader program to collect economic and social data. This project is continuing to build upon the economic database that is now available.

- Assess the economic impact of different fishing and conservation strategies that are proposed throughout the year by NMFS and the Councils.

- Compile the economic status of Alaska's groundfish fisheries as part of the annual Groundfish SAFE reports.

- Assess economic performance of the Alaska groundfish and halibut fisheries and research to improve these assessments.

III.C. Marine aquaculture

- Study the growth, distribution, behavior, and early marine survival of salmon; and conduct research on salmon biology and enhancement technology in Alaska.

IV. Information management research

Recent Accomplishments:

The AFSC communicates its scientific information and advice, along with the associated uncertainties, to the Councils, other management authorities, 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 Memos and Center Processed Reports.

The AFSC and other research units of NMFS used stock assessment workshops, peer reviews, and other fora 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.

The AFSC provided guidelines to assist the Councils in assessing and specifying MSY for managed fisheries. The AFSC (REFM Division) 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 manage exploitation of the stocks within biologically safe levels.

The AFSC (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 and the Alaska regional office took the lead in developing a comprehensive Bering Sea ecosystem research plan. Two workshops were held in Anchorage to bring together research experts from NMFS, other elements of NOAA, different units from the Department of the Interior, the Environmental Protection Agency, the Alaska Department of Fish and Game, the University of Alaska, the University of Washington, Alaska Native Groups, and other fisheries organizations to share in the planning efforts. This comprehensive research plan can be found at the Bering Sea and North Pacific Ocean Theme page under Interagency Information Exchange at *www.pmel.noaa.gov/bering/pages/inter-agency/*. Additionally a meta-data base of all the research of the different research agencies now resides at *www.pmel.noaa.gov/bering/mdb/*.

Research Priorities, FY 2001-2006:

- Continue to build data infrastructure and resources for easy access and data processing. The AFSC's key data bases are its survey data bases from the 1950's (or earlier) and the scientific observer data base 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.

Northwest Fisheries Science Center (NWFSC)

The Northwest Fisheries Science Center (NWFSC) conducts basic and applied research to support the management, conservation, and development 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 and from five research stations located in Manchester, Mukilteo, and Pasco, WA, and at Newport and Pt. Adams (Hammond), OR. The Center conducts both field and laboratory research in coastal and estuarine environments of Washington and Oregon, as well as in inland freshwater habitat populated by anadromous species in Washington, Oregon, Idaho, and Montana. The Center also supports annual and triennial groundfish surveys off the west coast.

Northwest Fisheries Science Center's historic 1931 Montlake Laboratory, Seattle, WA.

NOAA R/V *Miller Freeman*.

The NWFSC has several small vessels for conducting field studies. The R/V *Harold Streeter* serves Puget Sound and the R/V *Sea Otter*, R/V *Nerka*, and the R/V *Columbia* serve Columbia River basin projects. The NWFSC relies on the NOAA R/V *Miller Freeman* for some of its research survey data, and also relies on privately chartered vessels and academic research ships to supplement its research capability.

The NWFSC provides the scientific basis to conserve and recover declining Pacific salmon and groundfish populations as well as to address overarching issues such as the impacts of climate shifts, biotoxins, including harmful algal blooms, and toxic chemical pollution on anadromous and marine fishery resources. The NWFSC conducts multi-disciplinary research involving fisheries science, marine biology and ecology, genetics, biochemistry, molecular biology, oceanography, and aquaculture.

Center scientists conduct stock assessments, investigate the impact of bycatch, describe essential fish habitat, and develop new seafood technologies to reduce waste and maximize returns to fishers and processors. Center scientists also develop quantitative models, genetic tools, electronic monitoring devices, hatchery and captive-broodstock rearing techniques, and strategies for safe migration of salmon to the sea. The NWFSC's innovative and original research has helped establish new aquaculture endeavors, seafood processing, dam passage equipment and techniques, methods to detect and evaluate harmful algal blooms, and technology to integrate and track important fisheries dependent data, including fish catch and fish ticket data. The NWFSC's pioneering work on evolutionarily significant units (ESUs) helped define the science of salmonid stock identification under the Endangered Species Act (ESA).

NWFSC research supports critical management decisions on the conservation and recovery of Pacific salmon and groundfish populations, contaminant management, and seafood safety issues. Center scientists are leading west coast recovery efforts for salmon listed under the ESA, providing the scientific information necessary to determine whether certain salmon and groundfish species should be listed as endangered or threatened, understanding crucial links between habitat conditions and species productivity, developing plans to rebuild overfished groundfish stocks, and delivering the science necessary to develop or revise national policies on contaminants, bycatch, fisheries dependent data collection, fishery closures, harmful algal blooms, and other issues. Center scientists are also conducting social and economic studies to support the fishery management process.

Center research is used by the Pacific Fishery Management Council (PFMC) to build and maintain sustainable fisheries through the development of regional fishery management plans and subsequent amendments. NWFSC scientists relay applicable research results through their participation in committee meetings of the PFMC, Pacific Salmon Commission, and the Pacific States Marine Fisheries Commission (PSMFC), as well as other national and international fora, including National Stock Assessment panels and workshops. NWFSC research also supports national and international efforts, including the U.S. GLOBEC program.

The NWFSC nurtures and maintains strong collaborative relationships with other Federal agencies, industry, environmental groups, Native American tribes, individual fishers, universities, and other research and academic institutions. The NWFSC conducts annual groundfish surveys in collaboration with industry and provides west coast specific research needed by other line offices within NOAA (e.g., National Ocean Service) as well as other Federal agencies (e.g., the Bonneville Power Administration and the Army Corps of Engineers). The NWFSC, working with the Northwest Indian College (NWIC), the Department of Commerce, and NOAA, established the National Indian Center for Marine and Environmental Research and Education (NICMERE). NICMERE provides training at the NWIC and NWFSC for students from the 40 tribes served by the NWIC, and also to students from Tribal Colleges and Universities (TCUs) throughout the nation through a distance learning network. The Center also sponsors numerous students in marine research, technology, and library science through cooperative research agreements with regional universities and technical schools.

Recent Accomplishments and Research Priorities for FY 2001-2006

I. Research to support fishery conservation and management

Recent Accomplishments:

Comprehensive research plans for west coast groundfish and Pacific salmon were developed to ensure that all relevant scientific information is available to regional managers and policy makers. Scientists outside the agency, as well as other NMFS Centers, reviewed and provided comments on these documents.

The NWFSC conducted extensive assessments of west coast groundfish species and analyzed the potential for rebuilding species classified as overfished.

A new observer program for west coast groundfish was established. In partnership with the PSMFC, this program is the first new coastwide observer program launched from the NWFSC and implements a new electronic system for capturing and communicating fishery-dependent data. NWFSC also has begun management of the ongoing Pacific whiting observer program.

Salmon Technical Recovery Teams (TRTs) were established in three geographic regions—Puget Sound, Willamette/Lower Columbia River, and the Columbia Basin. TRTs are developing biological criteria for delisting salmon populations and will assist in the development of recovery plans. TRTs are chaired by NWFSC researchers and are composed of scientists from Federal, state, county, city, tribal organizations, and universities. The NWFSC also created a Recovery Science Review Panel, composed of renowned external scientists, to help ensure integrity and consistency in the scientific aspects of recovery planning.

Research Priorities, FY 2001-2006:

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

- Develop biologically-based delisting goals for listed salmon and steelhead. This action will be carried out by the Puget Sound, Willamette/Lower Columbia River, and Columbia Basin TRTs for ESUs of Pacific salmon that are listed as threatened or endangered under the ESA.

- Evaluate the direct and indirect effects of nutrients derived from salmon carcasses on salmon populations.

- Apply extinction risk estimates to salmonid populations to establish rationally based priorities for recovery goals.

- Analyze data from trawl surveys, fishery catch, and life history studies to produce reliable assessments of the status of groundfish species.

- Explore and quantify the ecological linkages of salmon distribution and survival in estuarine and near shore environments by studying juvenile Pacific salmon in the Columbia River plume and at Oregon's Cape Blanco.

- Improve west coast groundfish resource surveys and the scientific assumptions on which assessments are based. This will ensure stock assessments more accurately reflect population trends and provide for economic viability of coastal communities, while preventing overfishing.

I.B. Social and economic factors affecting abundance levels

- Expand sociological and economic research and incorporate results into the fishery management process.

- Develop new economic models and analyses to support management decisions.

I.C. Interdependence of fisheries or stocks of fish

- Conduct Genetic Stock Identification (GSI) studies to help determine stock allocation under the Pacific Salmon Treaty, analyze the composition of chinook salmon fisheries in California, help elucidate the ocean migration patterns of listed salmon stocks, and compare different methods of stock identification through computer simulations.

- Develop quantitative and qualitative methods of classifying risk for species of conservation concern through computer modeling and data analysis.

- Assess both the positive and negative effects of hatcheries on wild salmon populations by measuring the relative fitness of hatchery fish and their descendants when they spawn in the wild, developing and applying better models of phenotypic and genetic evolution in hatchery influenced populations, characterizing the genetic consequences of inbreeding within and interbreeding between salmon populations, and developing and applying methods for addressing ecological risks associated with artificial propagation programs.

- Better understand and quantify the importance of genetic diversity within and among salmon populations. Research projects include: (1) measuring the effects of in-breeding in Puget Sound chinook salmon; (2) creating genome maps of chinook and coho salmon and identifying chromosomal regions associated with traits important to adaptation and fitness in species; and (3) determining the usefulness of molecular tools for measuring natural selection and local adaptation.

- Further develop molecular techniques that identify salmon species using DNA markers to identify individual populations within salmon species.

- Use genetic analysis to further investigate the predator/prey relationship between harbor seals and salmon as it relates to recovering some listed salmon populations.

- Estimate the degree of genetic divergence among spawning populations of Pacific hake in Puget Sound and the Strait of Georgia to support decisions to determine the status of distinct population segments for Puget Sound Pacific hake under the ESA, and conduct, if necessary, additional genetic work to better elucidate the population structure of these species.

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

- Evaluate the effectiveness of habitat restoration efforts in Washington and Oregon, including evaluating the extent to which placement of structural elements in streams improves habitat quality and increases salmon abundance.

- Develop statistical 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.

- Develop monitoring and evaluation strategies to help determine the rate and success of salmon recovery.

- Determine what aspects of estuarine conditions are critical to salmon survival.

- Define essential fish habitat and assess the impact of fishing gear on stocks

by answering three questions: (1) which habitats are susceptible to gear impacts; (2) what is the relationship between differing levels of fishing activity and habitat degradation; and (3) how can current fishing practices be modified to minimize risks to habitats.

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

- Investigate the links between industrial waste, mining activity, pesticide use, and other physical and chemical alterations of coastal and urban habitats on decreased fisheries productivity. Establish threshold values for contaminant effects so biological effects on species can be predicted.

- Investigate the impact of ocean and marine climate variations on salmon by studying salmon distribution, abundance, food habits, and predator-prey relations.

- Determine the impacts of non-indigenous species on salmon by developing new statistical techniques, implementing food web modeling, and conducting field studies and experiments.

- Investigate the effects of chemical contaminants on the growth, development, reproduction, and survival of marine fish and mammals.

- Investigate how natural environmental variations and exposure to contaminants affect juvenile salmon during their passage through estuaries in Washington and Oregon, focusing on how natural and human induced stresses alter growth, neurological function and behavior, and induce disease-related mortality.

- Quantify how salmon use stream and river habitats by collecting descriptive information as well as assessing population responses to different watershed conditions.

- Explore how land use practices such as logging, farming, urban development, and other human activities impact the recovery of threatened and endangered Pacific salmon.

II. Conservation engineering research

Recent Accomplishments:

The adult return of endangered Redfish Lake sockeye salmon was significantly increased. Using captive broodstock technology, juveniles produced from all returning fish (16) during the 1990s were reared and released. Over 250 adults returned this year from the first year class.

A genetic marker for differentiating among strains of bacterial kidney disease (BKD) was identified. Used in combination with other molecular methods, this marker will be a powerful new tool for investigating sources of infection and routes of transmission in both wild and captive salmon.

Passive integrated transponder (PIT) tag technology was expanded in the Columbia River Basin. As a result, it will be possible to install adult salmonid PIT-tag detection systems in all fish ladders at Bonneville Dam by 2002, allowing scientists to make precise estimates of ocean survival of salmon and steelhead.

A collaboration with the net pen industry was established to conduct a two-year risk-benefit assessment of the Puget Sound net pen industry.

Research Priorities, FY 2001-2006:

- Develop conservation hatchery technology to aid recovery of ESA-listed stocks of Pacific salmon. Further develop the Natural Rearing Enhancement System (NATURES), a system for culture of Pacific salmon in raceways that simulate natural environments to develop salmon with characteristics and behavior more like their wild counterparts.

- Develop broodstock technology to restore depleted Pacific salmon stocks. Improve captive broodstock rearing techniques and gauge the potential of hatchery salmon to alter the genetics of wild populations.

- Develop methods to identify and control pathogenic microorganisms, including BKD, that threaten fishery resources, by conducting genetic studies of the bacterial pathogens, characterizing host-pathogen interactions, and developing highly sensitive molecular techniques.

- Determine both the direct and indirect effects of hydropower operations on salmon populations.

- Continue advancing PIT-tag technology to promote safe and efficient fish passage through hydropower systems, and other unnatural barriers, and to gain understanding of migration patterns upsteam and downstream.

III. Research on the fisheries

Recent Accomplishments:

Over 5,000 juvenile lingcod were produced through culture techniques for early life history and habitat preference research.

A new method was developed for producing surimi for human consumption from fillet trimmings of cod, pollock, and underutilized species such as arrowtooth flounder.

A regional aquaculture initiative was drafted to establish codes of conduct and best management practices in coastal waters and the EEZ.

Research Priorities, FY 2001-2006:

III.A. Social and economic research

- Analyze current and historical operating costs and activity patterns in the fishing industry and indicate how each group would be economically impacted by changes in fishing gear use and area restrictions, limits on individual catch, and/or direct allocation between user groups.

NMFS scientist stands near incubation unit for culturing phytoplankton for marine biotoxin studies, Phytoplankton Culturing Laboratory, NWFSC.

III.B. Seafood safety research

- Explore more complete utilization of marine resources by developing methods to recover more flesh from targeted fish species and to identify and control naturally occurring microbial pathogens that limit shellfish harvests.

- Develop methods to identify and analyze marine toxins and the algae that produce them. Ascertain how these toxins are transmitted and their effect on target organisms. Determine the health risks that biotoxins pose for fish and shellfish.

III.C. Marine aquaculture

- Develop laboratory aquaculture techniques for targeted marine species, by studying aquaculture engineering, fish physiology, nutrition, pathology, and developmental biology to relieve pressure on severely depressed wild marine stocks.

IV. Information management research

Recent Accomplishments:

The Alpha-level Electronic Fish Catch Logbook Project (EFCL) system was demonstrated to the states of California, Oregon, and Washington and to fishers and fish processors. Fishers requested that the NWFSC develop an electronic system to allow better use of data that fishers and processors are already required, by state law, to collect. Users wanted to be able to enter fish catch landing data electronically and to use computers to communicate and track fishing locations in real time, or near-to-real time. This system can improve fisheries management and support better fishing practices.

A salmon data team was created and launched to improve Pacific salmon data management, data access, and data sharing between parties and institutions.

Research Priorities, FY 2001-2006:

- Complete the current development effort of the EFCL with on-vessel beta testing.

- Integrate all data on salmon stocks in Washington, Oregon, and California generated by ESA status reviews with data maintained in the StreamNet database. The NWFSC has created an interagency salmon data team to develop a comprehensive management model. The model's purpose is to anticipate multi-species impacts resulting from changes in environmental and fishing regimes and to support tribal fishery managers with data and analysis that focuses on maintaining long-term viability and genetic diversity of local breeding populations.

- Develop statistical approaches to improve monitoring and evaluation of threatened or endangered species.

- Improve Cumulative Risk Initiative web-based reporting system outputs by strengthening links to raw data and other information sources.

- Provide support for area school systems interested in implementing salmon genetics curricula as well as vocational programs for training technicians.

Southwest Fisheries Science Center (SWFSC)

The Southwest Fisheries Science Center (SWFSC) headquarters is located in La Jolla, CA, and research is conducted at laboratories in La Jolla, Santa Cruz, and Pacific Grove, CA, and Honolulu, HI. The current staffing level involved in MSFCMA-related activities is at about 156 full-time equivalents (FTEs). An estimated 65% of total SWFSC resources are assigned to direct MSFCMA activities. NOAA research vessels assigned to fisheries research in the SWFSC are the NOAA R/V *Townsend Cromwell*, assigned to the Honolulu Laboratory, and the NOAA R/V *David Starr Jordan*, which has San Diego, CA, as its homeport. In addition about two-thirds of the NOAA vessel *McArthur*'s time is used by the Center.

Southwest Fisheries Science Center, La Jolla Laboratory and Headquarters, La Jolla, CA.

The SWFSC is a world-class research organization which conducts integrated, multi-disciplinary research programs in biology, mathematics, oceanography, and economics for the purpose of developing scientific technology and information to support the management and allocation of Pacific coastal, central and western Pacific insular, coral reef, and high-seas fishery resources. These activities support the scientific, statistical, and economic needs of the Western Pacific and the Pacific Fishery Management Councils 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).
- Crustaceans of the central Pacific (lobster).
- Precious corals of the central Pacific.
- Bottomfish and seamount species of the western Pacific.
- Groundfishes of the west coast (Pacific hake, rockfishes, lingcod).
- Small coastal pelagic species of the west coast (northern anchovy, sardine, mackerel, squid).
- Salmon of the west coast.
- Antarctic krill, crabs, squid, finfish including Patagonian toothfish.

The Southwest Fisheries Science Center 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, billfish, tunas and sharks, and California salmon. The Center maintains and utilizes 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-participant in the State-Federal California Cooperative Fisheries Investigations, a comprehensive long-term study of the biology and oceanography of the California Current. In the oceanic Pacific, the Center is the leading source of stock assessment expertise on tropical island and oceanic resources, especially bottomfishes, lobster, tunas, sharks, and billfishes and cooperates with the University of Hawaii and the Western Pacific Fishery Management Council (WPFMC) in undertaking the Western Pacific Pelagics Research Program. The SWFSC is also leading a multi-partner research and long-term monitoring effort to assess the health of the Nation's largest coral reef resource and to mitigate the impact of marine debris on the coral reef ecosystem of the Northwest Hawaiian Islands (NWHI). 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 two NOAA CoastWatch nodes at its Honolulu and La Jolla laboratories.

NMFS scientist conducts *in situ* coral reef study.

SWFSC scientists have taken the lead in characterization of large- and small-scale habitats that support groundfish and bottomfish populations in deep water. This work requires an interdisciplinary approach from fishery biologists, geologists, and ecologists and couples the use of GIS with remote-sensing acoustic tools, *in situ* survey techniques using submersibles, and spatial analyses. This approach is being applied to the identification of EFH, the improvement of stock assessment

surveys, 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 fishers, leaders of environmental groups, participants of fishery management councils, 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 data bases 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: (1) Convention for the Conservation of Antarctic Marine Living Resource (CCAMLR), which manages the marine living resources of the Antarctic; (2) Inter-American Tropical Tuna Commission (IATTC), which deals with tuna and tuna-like fishes, and the tuna-dolphin issue of the eastern Pacific Ocean; (3) South Pacific Tuna Treaty (SPTT), which provides tuna fishing access to the western Pacific Ocean; (4) 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; (5) 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; (6) MEXUS-Pacifico, which promotes joint U.S.-Mexico research projects of mutual interest; (7) North Pacific Albacore Workshop (NPALB), which promotes stock assessment research for north Pacific albacore; (8) Commission on the Conservation of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean (MHLC), which will manage the highly-migratory fish resources of the western and central Pacific Ocean; and (9) International Whaling Commission (IWC), which promotes conservation of whale stocks. In addition, SWFSC scientists periodically work jointly with other scientists on projects sponsored by international organizations such as the UN Food and Agriculture Organization (FAO), Global Ecosystem Dynamics (GLOBEC), and the North Pacific Marine Science Organization (PICES).

The Southwest Fisheries Science Center maintains an exceptional 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 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 2001-2006

I. Research to support fishery conservation and management

Recent Accomplishments:

Studies on the basic biology, movement, and population status of North Pacific swordfish were completed to provide the WPFMC up-to-date information for the management of its longline fishery. Similar information was provided on the status of the blue shark; in both cases the stock assessments indicated these populations were being managed in a sustainable manner. Subsequent analyses are underway for blue and striped marlin, other tuna, and miscellaneous pelagic species. This work has involved collaboration with fisheries scientists from around the Pacific, particularly with Japanese scientists.

A multi-national synoptic survey of krill biomass of Antarctic Statistical Subarea 48 (Peninsula, S. Orkney, S. Georgia, and S. Sandwich) was completed. As a result of a five-year planning effort, one ship from the U.S., United Kingdom, Japan, and Russia each conducted a one-month acoustic/oceanographic survey of the above areas and the open-ocean areas between each island group. This was a CCAMLR-sponsored survey with the participation of scientists from the International Whaling Commission. The U.S. convened a CCAMLR workshop to complete analyses of survey data.

The Groundfish Program provided PFMC with stock assessments for bocaccio rockfish, widow rockfish, canary rockfish (south), and lingcod (south), as well as rebuilding analyses for bocaccio rockfish and Pacific ocean perch. SWFSC staff initiated and convened a review of harvest rates for west coast groundfish, resulting in significant revision of PFMC management policy. Midwater trawl surveys provided annual indexes of rockfish recruitment strength for use in stock assessments and analyses of environmental influences.

A recent analysis of atmospheric observations in the North Pacific revealed extensive decadal-scale variations in the mid-latitude winter surface wind stress. In the decade after the winter of 1976, eastward wind stress doubled over a broad area in the central North Pacific and the core of the North Pacific Current was displaced about 360 nautical miles southward. The result was that surface water entering the California Current was of more subtropical origin in the post-1976 decade. All factors considered contributed to a multi-decadal temperature pattern of warm, nutrient-poor surface waters in the California and Alaska current regions. In association with the 1976 climatic shift, marine fishery production in the Oyashio, California, and Alaska currents altered dramatically, suggesting that natural environmental variation significantly alters the long-term yields from many North Pacific fisheries.

Research Priorities, FY 2001-2006:

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 South Shetland Islands, Antarctica.
- Understand the stock dynamics and influence of environmental conditions on the NWHI spiny and slipper lobster.
- Complete assessments of the coral reef ecosystems of the central and western Pacific.
- Develop a new Bayesian method of stock assessment for application to data-poor groundfish species.
- Develop a groundfish survey using chartered commercial fishing vessels for the Southern California Bight.
- Develop a population genetic database of all 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 list species take.
- Publish *Rockfishes on the Northeast Pacific*, a comprehensive book on the identification, description, biology, distribution, conservation, and fisheries of 72 species of rockfishes recorded from Mexico to Alaska.
- Assist the California Department of Fish and Game in developing a system of marine protected areas for California nearshore waters.
- Implement an archival tagging program for North Pacific albacore in cooperation with the albacore fishing industry, Japanese fishery agencies, and other groups to trace their 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 (cabezon, Puget Sound and coastal brown rockfish, and other rockfishes).

- 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 species and protected resources in the central and western Pacific.

I.B. Social and economic factors affecting abundance levels

- Expand sociological and economic research and incorporate results into the fishery management process.

- Develop behavioral models of economic incentives affecting the level and allocation of fishing effort in FMP fisheries.

- Initiate an economic survey of salmon commercial troll fishery.

- Enhance existing salmon harvest models to better predict fishing effort response to changes in sport and commercial fishery regulations.

- Conduct RIRs and RFAs for management actions being considered for all FMP fisheries.

- Evaluate growth in productivity for purse seine vessels harvesting tuna in the western and central Pacific, paying special attention to the effects of fiish aggregating devices (FADs).

I.C. Interdependence of fisheries or stocks of fish

- Complete research program under the International Dolphin Conservation Protection Act to determine whether the chase and encirclement 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.

- Extend analysis of factors affecting longline-turtle and longline-sea bird interactions to include more detailed oceanographic, tagging, and behavioral analysis.

- Evaluate the foraging ecology of the Hawaiian monk seal in terms of its use of fishery resources such as lobsters and bottomfish.

- Initiate studies of trophic ecology and growth biology of billfish and miscellaneous pelagic species (e.g., mahimahi, ono, moonfish).

- Integrate central Pacific pelagic ecosystem monitoring with stock assessments.

- Use ecosystem models such as Ecopath with Ecosim to describe ecosystem structure and dynamics for pelagic and insular ecosystems.

I.D. 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.

- Conduct baseline assessments and map major habitats of the coral reef ecosystem in the central and western Pacific (American Samoa, Guam, Hawaii, the Northern Mariana Islands, and remote Pacific islands).

- Investigate sources and ecosystem impacts of marine debris and identify mitigation measures.
- Evaluate EFH and monitor marine resources in newly created "no-take" marine reserves planned for 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.E. Impact of anthropogenic factors and environmental changes on fishpopulations

- Estimate the impact of marine debris on the health of coral reef ecosystems.

- 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 central California coast by juvenile salmonids. Assess the effects of environmental variability, particularly sandbar dynamics and water quality, on growth, development, and survival.

- 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:

A carefully constructed experimental design for testing alternative methods to avoid longline interactions with sea birds was completed. It identified several key methods for mitigating such impacts. These results were combined with WPFMC-supported research aboard commercial longliners to gain industry support of mitigation techniques and have been proposed by the Council as management regulations.

A comprehensive multi-agency program was initiated to remove marine debris from the NWHI coral reef ecosystem as a means to reduce impacts on the corals and to reduce mortality of the Hawaiian monk seal. To date, hundreds of tons of debris have been removed and the program will continue for the next two years. The Habitat Restoration Cost Workshop was convened in Portland, OR, in November 2000 to evaluate the feasibility of developing and applying standardized methodologies for estimating salmon habitat restoration costs, which would then

be used for salmon recovery planning. Restoration topics covered by the workshop included road maintenance and road decommissioning, streambanks stabilization, instream treatment, fish passages and fish screens, and wetland creation and restoration. Presentations were made by engineers, biologists, hydrologists, geologists, foresters, and economists representing Federal, state, and local agencies and the private sector.

An analysis of acoustic backscatter from an acoustic Doppler current profiler (ADCP) and surface temperature and salinity continuously sampled in relation to the continuous underway fish egg sampler provided a description of the sardine spawning habitat. This detailed observational analysis shows, on a survey-by-survey basis, that eggs and larvae are found in waters that are transitional between those that are freshly upwelled and those of the California Current proper.

The SWFSC completed research to improve our understanding of fisheries impacts on marine ecosystems. The study pioneered the use of the combination of acoustic techniques, fishing information, and direct submersible research to directly evaluate deepwater fisheries habitat. Research published in the past year considered the potential of side-scan sonar to enumerate the frequency of trawl tracks on soft bottom environments, suggesting that acoustic remote sensing is a promising independent approach to evaluate fishing effort on a scale consistent with commercial fishing activities.

Research Priorities, FY 2001-2006:

- Undertake studies to determine the best methods to increase survival of protected, prohibited, or sensitive species caught by longline and troll vessels.

- 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).

- Investigate methods for reducing longline interactions with sea turtles, including at-sea experiments with the commercial longline fleet.

- Develop GIS applications for mapping the NWHI lobster and bottomfish habitat, as well as identifying inter-relationship of precious (gold) coral and Hawaiian monk seal habitat.

- Conduct baseline rapid environmental assessments of the condition and health of some of the most remote and pristine coral reef ecosystems of the U.S.-affiliated Pacific Islands.

- Assess and monitor, with remote sensing, the marine debris in the NWHI.

- Establish a program to monitor the health of coral reef ecosystems, including remote sensing.

- 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) species identification algorithms for acoustic surveys.

- Develop advanced technology for automatic shipboard data logging of bio-acoustic 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 organized and convened the first workshop on marine harvest refugia to conserve and manage rockfish and continued these discussions in a special symposium on marine protected areas for California. The published proceedings and reports are also being used by west coast states in evaluating marine reserves as a strategy to conserve and manage nearshore marine resources. Similar studies are underway in Hawaii to evaluate State of Hawaii area closures designed to rebuild populations of several commercially important bottomfish species.

General additive model (GAMs) were estimated from detailed observations gathered from NMFS-SWR observers and high-resolution environmental data, merged with fishery logbook data to assess the impact of time-area closure alternatives on the Hawaiian longline fishery. The results from these models were used in litigation concerning the impact of the Hawaiian longline fishery on sea turtles and to propose efficient regulatory alternatives. The analysis used a financial portfolio analysis to estimate the efficacy of various scenarios.

Coho salmon production in the Pacific Northwest reached historically low levels in the 1990s, which stimulated research examining whether changes in ocean conditions were responsible for inter-annual variability in the ocean survival of coho. Recent investigations focused on improving the measures of ocean conditions using remotely-sensed sea surface temperature (SST) data and by weighting upwelling indices with sea surface temperatures. The models generated from the analyses may have the potential to be used for coho survival forecasting. Related research evaluated how spatial patterns of environmental variability may differentially affect parts of the coho populations.

Trawl-caught California market squid.

The SWFSC completed an analysis of harvesting capacity in the Pacific coast CPS limited entry finfish fishery. The Center also collaborated on an analysis of harvesting capacity in the Pacific coast market squid fishery.

Multifan CL was applied to develop stock assessments for highly migratory species.

Research Priorities, FY 2001-2006:

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 RFAs in an efficient and timely basis. Augment these templates to include the basic demographic information required to initiate preliminary SIAs.
- 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 activity impacts of management actions being considered for each of the FMP fisheries and fishing communities.
- Develop methods to assess the efficacy of various MPAs, ecosystem preserves, and other time-area closures in restoring fish stocks and increasing sustainable yields.

CTD array is deployed off NOAA R/V *Miller Freeman* to take conductivity, temperature, and depth measurements.

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's Pacific Fisheries Environmental Laboratory (PFEL) provides environmental data for fisheries research and management. Environmental variability has been identified as a key feature in fish and marine mammal population dynamics. PFEL's data holdings and related data products provide fisheries relevant data that cover the entire spectrum of the ocean environment—from surface or near-surface wind and pressure data that can affect the ocean, to surface and subsurface measurements of important oceanographic parameters. Over the last year, PFEL has developed a system to make this information readily accessible to fisheries scientists. Scientists can now obtain over the Internet most of the PFEL's data holdings,

NMFS scientist measures wire angle to deploy CTD array.

for any location in the world. The data can be sorted in both space and time, visualized on-line, and downloaded in a variety of formats. Data and expertise were provided to researchers working on salmon survivorship, hake catches and negotiations with Canada, harmful algal blooms, rebuilding overfished fish stocks, benthic fauna patterns in sanctuary areas, and marine mammal population dynamics.

Data collected and processed from U.S. purse seiners fishing in the central-western Pacific was computerized, edited, and submitted to the Forum Fisheries Agency (Treaty Manager) as required under the SPTT. This information was reported at the Annual Treaty meeting of the Forum Fisheries Agency in Nuie and also presented at the meeting of the Standing Committee of Tunas and Billfish in New Caledonia for use in stock assessments of central-western Pacific skipjack, yellowfin, and bigeye tuna stocks.

The SWFSC fielded three observers aboard U.S. troll vessels to collect length measurements of albacore and bycatch estimates to verify and supplement data taken by port samples and in logbook records. The data was computerized and presented to the North Pacific Albacore Workshop in Taiwan and used to assess the status of Pacific albacore stocks. This data was also analyzed and distributed to U.S. albacore fishers.

Conductivity, temperature, and depth studies at a series of stations along the NWHI were initiated in May 1999 to begin a long-term time series of vertical structures of the physical environment affecting fisheries. This information is being integrated in a GIS application with fisheries information and NOAA R/V *Townsend Cromwell* information to develop a series of applications for detailed location-referenced studies.

Federal logbook and permit data from the rapidly growing American Samoa longline fishery were developed into an integrated data management system by the WpacFIN program which has allowed rapid use of the information for assessing management measures considered for the fishery by the WPFMC. The information is collected and compiled by the government of American Samoa fisheries office where hands-on quality control and delinquency analysis can be conducted in conjunction with the NMFS Office of Enforcement. Data and statistics are then available through Internet connections to the Honolulu Laboratory.

Research Priorities, FY 2001-2006:

- Implement an Oracle-based integrated system for storing and distributing via the Internet all of the Honolulu Laboratory data holdings, including fisheries dependent, research cruise, remote sensing, laboratory, and video data.

- Develop automated systems for integrating data sets with common fields (e.g., longline logbook and observer reports, the NOAA R/V *Townsend Cromwell* cruise reports, and remote sensing).

- Develop GIS technology for mapping and spatial analysis of fisheries, oceanographic, and habitat information.

- 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.

Southeast Fisheries Science Center (SEFSC)

Southeast Fisheries Science Center Miami Laboratory and Headquarters, Miami, FL.

The Southeast Fisheries Science Center (SEFSC) is headquartered in Miami, FL. The SEFSC is responsible for scientific research on living marine resources that occupy marine and estuarine habitats of the continental southeastern United States, as well as Puerto Rico and the U.S. Virgin Islands. Research is conducted at laboratories located in Beaufort, NC (a joint NOS-NMFS facility); Miami, FL; Panama City, FL; Galveston, TX; and Pascagoula, MS, with a field station at the Stennis Space Center. Two NOAA vessels assigned to fisheries research are also homeported in Pascagoula: the NOAA R/V *Oregon II* and the NOAA R/V *Gordon Gunter*. SEFSC's current staffing level is 258 FTEs, with all positions involved in MSFCMA-related activities. Approximately 80% of all SEFSC resources are assigned to MSFCMA activities.

In general, 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 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.

Each SEFSC laboratory is responsible for conducting research in specific subject areas, however, there is extensive cooperative research between SEFSC laboratories. Research activities conducted by the various laboratories are as follows:

Beaufort Laboratory: habitat research; fishery biology and stock assessments, especially for reef fish; population dynamics of menhaden, weakfish, red drum, etc.; protected species research.

Miami Laboratory: stock assessments for species such as snapper-grouper, mackerels, highly migratory species (e.g., sharks, swordfish, tunas, and billfish), sea turtles, marine mammals, and other endangered or threatened species; research on coral reefs, MPAs, and the South Florida ecosystem restoration program.

Panama City Laboratory: fishery biology and life history characteristics and essential fish habitat research.

Mississippi Laboratories: fishery-independent surveys; gear development (TEDs and BRDs); environmental remote sensing; bycatch; and endangered species research.

Galveston Laboratory: fishery biology and stock assessment of shrimp populations; gear and bycatch evaluation studies; habitat research and restoration; and endangered species.

SEFSC provides scientific support for NMFS' fishery management activities for 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. 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 ACCSP and exercises fishery management responsibilities through the Atlantic Coastal Fisheries Cooperative Management Act. In addition, 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 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 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). SEFSC responds to the information needs of fishery management councils and has a formal procedure (Council Operations Plan) for matching its research program to fishery management plan requirements.

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.

Recent Accomplishments and Research Priorities for FY 2001-2006

I. Research to support fishery conservation and management

Recent Accomplishments:

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.

The development of the red snapper rebuilding plan was based on SEFSC scientific efforts.

The Center 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.

SEFSC completed baseline data collection essential for the successful establishment of marine reserves in the Tortugas region for the Florida Keys National Marine Sanctuary and for the Dry Tortugas National Park.

Research Priorities, FY 2001-2006:

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

- Further efforts to improve the effectiveness of fishery resource management programs by refining the definition of stocks (including the "management unit" within species), and to determine data needs and analytical methods required for applying refined definitions.

- 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 finfish species (e.g., jewfish and Nassau grouper).

NMFS scientist measures fish, aboard R/V *Oregon II*.

- 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 stocks in support of management for the Councils (SAFMC, GMFMC, and CFMC) and Commissions (ASMFC, GSMFC).

I.B. Social and economic factors affecting abundance levels

- Expand sociological and economic research and incorporate results into the fishery management process.

I.C. Interdependence of fisheries or stocks of fish

- Increase our understanding of the interactions of protected species (e.g., sea turtles, marine mammals: bottlenose dolphin and large whales) and finfish candidate species (e.g., jewfish and Nassau grouper) with ongoing fisheries in the Southeast Region.

- 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 multi-species or ecosystem approaches towards the management of fishery resources, and where appropriate, transition from single-species approaches.

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

- Define and characterize EFH and develop an understanding of natural and anthropogenic threats.

- 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 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.

I.E. 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 Florida Bay, Galveston Bay, and other 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, and providing support for the Coral Reef Initiative.

- 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 BRD design have been developed. For example, 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 2001-2006:

- 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 that aid increased harvest efficiency are continuing.

III. Research on the fisheries

Recent Accomplishments:

Economic information, analyses, and evaluations were provided for numerous proposed fishery management actions in the southeast.

SEFSC developed and assisted in the collection of economic data through special surveys of the commercial snapper-grouper and mackerel fisheries.

SEFSC, in conjunction with academic economists, contributed to the development of random utility and contingent valuation models of the South Atlantic and Gulf of Mexico recreational fisheries.

Research Priorities, FY 2001-2006:

III.A. Social and economic research

- Include socio-economic related questions in the log book program and increase the use of information such as cost and return data in fisheries management.

- Design and implement procedures to collect socio-economic data on a routine basis. Data would be used to better determine the effects of regulation on commercial and recreational fishers.

- Develop better models of commercial and recreational fisheries to evaluate proposed management alternatives, including limited access systems.

- Estimate economic relationships such as demand curves, production functions, import supply curves, and recreational benefit functions needed to support the evaluation of management decisions.

III.B. Seafood safety research

- Support research aimed at identifying and characterizing marine pathogens, especially viruses, in aquacultured 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:

SEFSC has developed and implemented a fully integrated Oracle-based fisheries logbook system.

Research Priorities, FY 2001-2006:

- Develop a fishery database and information management system that will allow the full use of information in support of effective fishery conservation and management.

- Fully integrate the logbook system with the regional permit database.

- Increase collection of observer-based data on bycatch and improved fishery-dependent data (e.g., via ACCSP's program with ASMFC).

- Secure access by constituents and the public to SEFSC information resources via web-based technologies.

Northeast Fisheries Science Center Woods Hole Laboratory, Woods Hole, MA.

Northeast Fisheries Science Center (NEFSC)

The Northeast Fisheries Science Center (NEFSC) has facilities in Woods Hole, MA; Narragansett, RI; Milford, CT; Sandy Hook, NJ (James J. Howard Marine Laboratory space rental from the state of New Jersey), and supports staff at the National Systematics Laboratory (housed at the Smithsonian Institution in Washington, DC.). The NOAA R/V *Albatross IV* and NOAA R/V *Delaware II*, berthed in Woods Hole, MA, support the majority of the Center's fisheries survey and research cruises. Periodically, the NOAA R/V *Gordon Gunter* and NOAA R/V *Oregon II* (berthed in Pascagoula, MS) are utilized as supplemental sources for either surveys or research cruises. Private fishing vessels and academic research ships have been utilized on a periodic basis to support ecosystem surveys on the northeast continental shelf.

James J. Howard Marine Laboratory, Sandy Hook, NJ.

The NEFSC research program runs the gamut from stock assessments on finfish populations during the Spring and Fall Bottom 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/cod and haddock larvae distribution and predation on Georges Bank. Additional fisheries surveys are conducted for ocean quahogs, surf clams, and sea scallops, and grant funds are provided to support surveys of Gulf of Maine northern shrimp and finfish surveys in state waters. Stock assessment workshops (SAWs) involving the participation of fisheries experts from state, academic, and non-government organizations (NGOs) use this survey data to develop consensus estimates of stock size for managed species of finfish and shellfish. The Mid-Atlantic Fishery Management Council (MAFMC) and the New England Fishery Management Council (NEFMC) then uses this advice.

Long-term changes in the ecosystem supporting fisheries are monitored through surveys of the Northeast Shelf Large Marine Ecosystem (LME) and research is underway to convert such data into indices on the health of the ecosystem. Additional process-oriented research projects focus upon the effects of pollution on winter flounder; recovery of herring and Atlantic mackerel populations; trophic interactions between Atlantic mackerel, juvenile cod, and haddock; biological characteristics of selected shark species in the Northeast; and descriptions of EFH for most coastal finfish species. The Center also conducts social and economic research in support of the fishery management process.

Reliable information, critical to the development of regional FMPs and subsequent amendments, and, ultimately, to the building and maintenance of sustainable fisheries, is produced through the Northeast Regional SAW process. This process is a cooperative effort of the NMFS/NEFSC and Northeast Region Office (NERO), NEFMC, MAFMC, and the ASMFC. In the northeast, peer review of stock assessments is conducted twice per year within the Northeast Regional SAW process. The SAW process is guided by the SAW Steering Committee (directors of NEFSC and NERO, MAFMC, NEFMC, and the ASMFC) which determines the species to assess during a particular SAW cycle and establishes the assessment terms of reference. Each SAW cycle begins and ends with the meeting of the

SAW Steering Committee and includes Working Group meetings (where analyses are prepared for review); a five-day Stock Assessment Review Committee (SARC) meeting (where analyses are peer-reviewed and advice for managers is developed); and a two-to-three-session Public Review Workshop held during planned meetings of the MAFMC, NEFMC, and ASMFC. Participants in this process include NMFS scientists and managers; representatives from fishery agencies outside the region; MAFMC, NEFMC, and ASMFC representatives; state fishery agency representatives from within the region; academic and NGO participants; industry members; and occasionally experts from the international community. SAW meetings are open to the public and are widely announced. NEFSC personnel also participate in various committee meetings of the Regional FMCs and the ASMFC.

Much of the recent gear research in the northeast has been accomplished through grants, with NERO oversight. These grants have gone to fishers, 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). A resolution to this problem will allow fishing to continue. The fishing industry aided this effort through its participation in the Gear Advisory Group to the Atlantic Large Whale Take Reduction Team to devise solutions, and by volunteering vessels and time for observations and testing. Also, NERO and the Center 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 2001-2006

I. Research to support fishery conservation and management

Recent Accomplishments:

Rates of growth, development, and survival have been estimated for the larval goosefish.

Rates of growth, development, survival, and how these vary with water temperature, have been estimated for the egg, larval, and juvenile stages of summer flounder and winter flounder.

The NEFSC has demonstrated that the technique of using scale texture for sexing winter flounder is invalid.

Measures of egg quality and parental effects on offspring condition have been quantified for summer flounder and winter flounder.

NMFS scientist deploys bongo nets with Seacat instrumentation to support studies on the growth and survival of fish larvae.

The influences of the timing and location of spawning of summer flounder on offspring fitness have been estimated.

Data have been gathered on the timing and location of goosefish spawning.

Field work in the U.S. GLOBEC program on Georges Bank has been conducted. The program is investigating the environmental and biological processes controlling the reproductive success of the cod and haddock stocks on the Bank.

Winter flounder courtship and spawning behavior has been described relative to estuarine habitats.

Development of a micro-constituent technique for stock identification of bluefin tuna and other species was completed.

NEFSC demonstrated that diet influences otolith micro-constituent composition in young-of-the-year bluefish.

The oceanographic conditions on the Northeast Shelf were measured and the inter-annual variability was documented in a report each year. The data were used in stock assessment activities and available to the scientific community via the World Wide Web.

NEFSC completed the second year of a sampling program in the inner New York Bight and lower Hudson-Raritan estuary studying the effects of environmental/habitat variables on settlement and early post-settlement processes of local fish species.

Bio-economic models were contributed to support fishery management decisions. These models are designed to measure and project demand conditions; evaluate direct impact of area-base management measures; and to assess other regulatory tools such as trip limits.

Reports on the level of qualitative and quantitative harvest capacity in the major fisheries of the region were completed.

Assistance in the design and evaluation of vessel buyback programs for the groundfish fishery in the region was provided.

Biological parameters that potentially regulate foraging competition in juvenile bluefish and striped bass were identified.

A series of 30 EFH Source Documents, summarizing life history, habitat, and distribution/abundance information, was provided to NEFMC and MAFMC.

NEFSC completed a study of diets of 16 fish species in lower Hudson-Raritan Estuary, as compared to other Middle Atlantic areas.

A study of functional equivalence of marshes replanted after EXXON Bayway Oil Spill in Arthur Kill (NY/NJ) to oiled, but unrestored, marshes and control marshes was completed.

The potential predation risks of juvenile summer flounder and winter flounder in inshore habitats were quantified.

NEFSC demonstrated that nominal habitat classifications are inadequate for defining and studying the functional value of those habitats.

NEFSC has conducted studies which demonstrated that habitats are dynamic, defined by complex interactions of changing environmental conditions, and yielding a space favorable to growth and survival that continually expands, contracts, and changes position.

Environmental conditions and physical habitat within a shallow coastal nursery area in Connecticut that supports young tautog were characterized. The distribution and abundance of these fish has been described and preliminary GIS-based spatial maps have been created. Young tautog have been marked with coded wire tags in an effort, through mark-recapture, to determining individual growth rates, population size, and the extent of site-fidelity. Diets of young tautog and food habits of predators have been investigated. These efforts will be valuable in future attempts to release hatchery-reared tautog as they become available from the Milford Aquaculture Program.

The effects of egg incubation temperatures on the development and survival of summer flounder, winter flounder, windowpane, cod, and haddock have been quantified through laboratory experiments.

A study was completed that indicated that the resuspension of contaminated sediments is the dominant process in distributing contaminants in the Hudson-Raritan and Navesink estuaries.

The uptake of trace metals and organic compounds into mussels from Arthur Kill Sediments, including those tainted by oil spills, was investigated.

Research Priorities, FY 2001-2006:

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

- Continue to develop improved biological parameter estimates.
- Determine biological, environmental, and habitat processes controlling the reproductive success of important fishery resources.
- Expand research in the development of micro-constituent chemical analysis techniques for stock identification.

- 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.

I.B. Social and economic factors affecting abundance levels

- Expand sociological and economic research and incorporate results into the fishery management process.

- Develop/refine models to evaluate the efficacy of area management tools across a broad range of fisheries. This includes research into alternative approaches to resource management such as area-based resource portfolio management and the development of cooperatives.

- Investigate the impacts of latent (non-utilized) effort as stocks recover, including the design, execution, and evaluation of latent effort buyouts, and the factors affecting the reactivation and new activation of latent effort pools.

- Continue to develop guidance on National Standard 8 and on social impact assessments (SIAs). This includes examining approaches to rapid assessment techniques and institutions as well as establishing coastal cooperation in the supply of updated information relevant to SIAs on a continuing basis.

- Investigate and develop design features to mitigate perceived failures of individual fishing quota (IFQ), ITQ, and CDQ fishery regulations.

I.C. Interdependence of fisheries or stocks of fish

- Continue to investigate the importance of trophic interactions between the populations of bluefish and striped bass.

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

- Identify and provide EFH information as required by the MSFCMA for FMPs for the NEFMC and ASMFC.

- Continue to conduct research to determine the functional value to estuarine and nearshore habitats, including restored sites, to the sustainability of fishery resources.

I.E. Impact of anthropogenic factors and environmental changes on fishpopulations

- Conduct research to determine the effects of climate variability on the sustainability of coastal and pelagic fishery resources.

- Investigate the transfer of contaminants within estuarine systems and their effect on the growth and sustainability of fish populations.

II. Conservation engineering research

Recent Accomplishments:

Through the recently established NEFSC Office of Cooperative Programs Coordination, approximately 1,600 research fishing days were conducted since the program's inception in September 2000. This multi-faceted program is designed to explore ways to improve data upon which fishery management decisions are made as well as to improve communications between fishers, scientists, and fisheries managers. One of the key elements of this program is in the area of conservation research (i.e., mesh selectivity, bycatch discard reduction, harvest efficiency, and gear development).

The NEFSC Fishery Observer Program has made recent strides in the development and deployment of more selective fishing gears by placing scientific observers aboard commercial vessels. Specifically, in the Gulf of Maine northern shrimp fishery, the Nordmore grate was tested and subsequently implemented as a method to reduce the take of juvenile groundfish. Sea sampling was used in the initial gear trials, and the at-sea observer program continues to monitor the fishery following full implementation of the grate requirement. The fishery observer data indicate significant reductions in finfish bycatch after introduction of the Nordmore grate in the shrimp fishery. Although reduced catches of important groundfishes are in part due to their decreased abundance in recent years, the grate has been effective in reducing the fraction of finfish caught in this fishery, thereby reducing fishing mortality on young groundfish.

Similar studies evaluating the effectiveness of acoustic alarms to deter harbor porpoise from entering groundfish sink gillnets have also been conducted through the Fishery Observer Program. These studies involved alarm-equipped and control nets, fished in the vicinity of harbor porpoise aggregations. Results from this work are currently being evaluated to determine the efficacy of this method in reducing harbor porpoise mortalities. Additionally, at-sea observers have been used in other gear-related studies such as in the New England groundfish fishery to evaluate the effectiveness of changes in trawl mesh size.

Fall groundfish survey in the Gulf of Maine is conducted on R/V *Albatross IV*.

Three cruises were recently completed to evaluate the effect of gear on habitat by comparing fish distribution/abundance and diets, benthic communities, and sediment features in areas of Georges Bank that had been closed to fishing for five years with conditions in adjacent open areas.

Research Priorities, FY 2001-2006:

- Conduct research to develop and enhance gear performance and characteristics.
- Conduct research aimed at reducing bycatch and marine mammal mortalities.
- Conduct studies to evaluate the effects of gears on habitats.

III. Research on the fisheries

Recent Accomplishments:

The NEFSC has recently completed development of a New England-wide Input-Output model in collaboration with the Woods Hole Oceanographic Institute's Marine Policy Center. This model is used to assess distributional impacts of fisheries regulations.

The NEFSC has conducted collateral research with the Massachusetts Institute of Technology's Center for Marine Social Sciences (CMSS). CMSS is currently collecting socio-economic data on fishers and fisheries-dependent communities. Information generated by this extensive project will be the baseline from which the social impacts of regulatory change will be measured. As a result, this project will help communities and fisheries managers anticipate potential impacts and plan accordingly.

The NEFSC has conducted Vessel Cost and Earning Surveys for all major fisheries in the region. These "snap-shot" surveys contributed to the design of the coast-wide pilot program for social science data used by the ACCSP.

The NEFSC has produced a variety of socio-economic publications on the fisheries to inform resource managers and the public. These works address such issues as property rights, allocations between recreational and commercial fisheries, rent-seeking behavior in fisheries, models of recreational fisheries, and estimates of forgone national benefits as a result of shortcomings in the management of groundfish. Additionally, in support of two regional FMCs, the NEFSC has provided RIR/RFA analyses for 17 FMPs and numerous amendments/framework actions.

The NEFSC's Office of Marine Ecosystem Studies has been active in the monitoring and assessment of changes within the U.S. Northeast Shelf ecosystem in relation to the recovery of depleted demersal fish stocks, including cod, haddock, and yellowtail flounder and the unprecedented population explosion of pelagic herring and mackerel stocks.

Several United Nations agencies are collaborating with the NMFS Office of Science and Technology and Fishery Centers to introduce ecosystem-based assessment and management practices leading to the recovery of depleted fish stocks in

Asia, Africa, Latin America, and eastern Europe. A five module strategic approach developed and tested by the NEFSC has been introduced to coastal countries bordering LMEs of the Yellow Sea (China and Korea), the Benguela Current (Angola, Namibia, South Africa), the Guinea Current (Benin, Cameroon, Ghana, Ivory Coast, Nigeria, and Togo), and Baltic Sea (Denmark, Finland, Germany, Sweden, Estonia, Latvia, Lithuania, Poland, and Russia). The five modules provide advanced methodologies for monitoring and assessing the: (1) productivity, (2) fish and fisheries, (3) pollution and health, (4) socio-economics, and (5) governance of the LMEs.

Grants from the Global Environment Facility have been allocated over the past five years to support the LME projects. In each of the LME projects, joint international surveys are carried out measuring the effects of changing ecosystem states on the recovery of depleted fish stocks and the long term sustainability of biomass yields, ecosystem health, and socio-economic benefits to the coastal communities. Participating countries have created, under UNCLOS, Commissions and other joint institutions to serve as governance bodies and to initiate more sustainable ecosystem-based management protocols than have been generally initiated and practiced during the past half century.

Tautog have been cultured successfully from egg to about 1-1.5 lbs, a size especially desired for the live-market trade. Egg hatching rates are high, but the larvae are extremely sensitive to handling. Research efforts have focused on culture techniques that involved little or no handling of these sensitive early stages. Once fish reach the juvenile stage, survival rates are high. Optimum diets are being developed.

An integrated, micro-algal, shellfish nursery/wastewater treatment system was designed, built, and tested. This land-based, pilot-scale nursery for production of molluscan shellfish seed was based upon seawater recirculation technology. This innovation in scientific and engineering accomplishments represents an important step in developing sustainable and environmentally-compatible shellfish aquaculture in the U.S. and throughout the world.

A manuscript was published describing several years of field research that investigated different strategies to enhance the bay scallop population in a shallow coastal estuary in Connecticut. Part of the project was a collaboration with volunteers from a local Shellfish Commission. Low dissolved oxygen concentrations were found within some eelgrass beds during midsummer, but environmental conditions were generally favorable to support scallop growth. It was determined that natural recruitment was too low to support spat collection-based enhancement efforts. A transplant of large seed scallops in late fall resulted in a spawning stock that released new larvae into the estuary the following year. Use of suspension culture gear to rear, overwinter, and provide spawner sanctuaries was also demonstrated.

The first biochemically-based feeding standards for molluscan shellfish seed were developed. Using a custom designed and built computer-controlled feeding apparatus, NEFSC scientists determined both qualitative and quantitative nutritional needs of bay-scallop seed for optimal growth and feed-conversion efficiency. Feed-

ing standards, analogous to those used routinely in animal agriculture, were developed for molluscan shellfish for the first time, marking a milestone in the development of shellfish aquaculture.

Research Priorities, FY 2001-2006:

III.A. Social and economic research

- Continue the development of ongoing coast-wide cost and earnings data collection systems. This research includes the design of a fixed cost sampling protocol and the exploration of wide-scale observer-supplied economic data systems.

- Continue the development of a socio-cultural information gathering system sufficient for National Environmental Policy Act, National Standard 8, and SIA requirements for fisheries, marine mammals, endangered species, critical habitat for designated species, and EFH designations.

- Conduct additional research into multi-species management options incorporating various levels of constituent species. Research will focus on differential area treatment of gears, vessels, and effort based on habitat and fishing mortality considerations as well as impacts of variously defined MPAs.

- Conduct further exploration of applicability and utility of GIS information on economic and socio-cultural assessments of area-based management options including development of socio-economic and governance modules for LMEs.

- Continue research efforts for price models, bio-economic models, rapid social assessments techniques, rights-based fishing modes, annual round fisheries, and other issues central to improving approaches to management and the design and assessment of alternatives. Of particular concern is the coming need for the estimation of non-use benefits and cost minimization research for EFH, ESA, and MMPA issues.

- Extend input-output models to mid-Atlantic states for the management of recreational fisheries. This expansion includes: (1) analysis of effort and participation in specific recreational fisheries to better assess impacts of regulations on recreational fishers; (2) development of participation models to predict levels of activity 5-10 years into the future; and (3) defining and exploring recreational/subsistence fishing communities and their dependency and vulnerability to standard management alternatives.

III.C. Marine aquaculture

- Continue to conduct Aquaculture and Enhancement Division activities.

IV. Information management research

Recent Accomplishments:

NEFSC oceanographic data sets are being served through a distributed oceanographic data system (DODS) compliant server. In addition, data collected as part of the U.S. GLOBEC program on Georges Bank are being served through the GLOBEC data system, which is a DODS compliant system.

Research Priorities, FY 2001-2006:

- Continue to develop and expand DODS compliant client and server libraries to support Internet access to NODC oceanographic data sets.

APPENDIX B. Response to Comments on Public Draft of the NMFS Strategic Plan for Fisheries Research

In August 2001, NMFS published a Notice of Availability in the *Federal Register* announcing the availability of the draft Strategic Plan for Fisheries Research. Comments were received from 11 organizations and individuals, representing a range of interests. The comments were helpful in revising the plan and preparing the final document. This appendix summarizes the comments and addresses each major comment. Some commenters also identified inconsistencies in the draft plan and suggested editorial or textual changes. These specific comments are not addressed here. However, the final plan document incorporated these suggestions as much as possible.

Comment: The Plan does not fully address stock assessment research. It lacks specificity with regard to the development of better models to estimate abundance, biomass, and mortality with limited data and does not adequately detail methods to collect better data.

Response: The NMFS Strategic Plan for Fisheries Research is designed to provide a common framework for research, not the specific details. The details are to be elaborated in other plans such as the soon-to-be-released NMFS Stock Assessment Improvement Plan.

Comment: The Plan should establish and outline research efforts to explore alternatives to an MSY-based management system for fisheries. Predictive management could be based on predator-prey relationships, oceanographic conditions, and ecosystem-based interactions, but not without supporting research.

Response: NMFS believes that the concept of maximum sustainable yield (MSY) is an integral component of the MSFCMA and that it is reasonable to retain as a key element of current fishery management programs. It is worth noting that NMFS does not consider MSY, or the fishing mortality rate that generates MSY, as a target for fisheries management. Rather, NMFS interprets MSY as an upper bound on optimum yield. This interpretation is shared by several intergovernmental and national fisheries organizations as a central feature of the precautionary approach to fisheries management. However, NMFS does agree with the need to expand fisheries management to an ecosystem-based approach and is working toward this end in several respects. The NMFS Strategic Plan for Fisheries Research cites two prestigious committee reports (EPAP, 1999; NRC, 1999a). The former contains recommendations for the development of fishery ecosystem plans—a document that would incorporate ecosystem principles, goals, and policies into current fisheries management structure. The agency has formed a work-

ing group that is evaluating the recommendations contained in these reports and will begin developing technical guidelines for their implementation in 2002.

Comment: The Plan should provide a regional mechanism for soliciting review of NMFS' research programs, with an emphasis placed on prioritizing, monitoring, and evaluating these programs and taking corrective action when shortfalls occur. It is also important for this Plan to outline how this mechanism would function and incorporate knowledgeable fishers into the peer review process.

Response: NMFS agrees that peer review is an important component of an effective science program. NMFS is in the process of formalizing its science guidelines and procedures through the development of its Science Quality Assurance program. This suggestion will be forwarded to the development team so it can be considered for incorporation into their plan.

Comment: For the SWFSC overview in Appendix A of this Plan, NMFS does not adequately address research efforts to conduct baseline assessments and map major habitats of the coral reef ecosystem in the western Pacific region, despite the fact that this region contains most of the U.S. coral reef areas. Additionally, the western Pacific region might serve as a "laboratory" to investigate the impacts of fishing on coral reefs, and in particular, research marine protected area impacts.

Response: NMFS agrees and has revised this section of the Plan to more accurately reflect current research activities and priorities on coral reefs and the research opportunities that MPAs provide in the western Pacific region.

Comment: For the SWFSC overview in Appendix A of this Plan, NMFS needs to expand on research efforts to evaluate the socio-economic impacts of recent management measures affecting fishing industries in the western Pacific region.

Response: NMFS agrees and has modified this section of the Plan to more fully represent socio-economic research efforts and priorities in the western Pacific region.

Comment: For the SEFSC overview in Appendix A of this Plan, NMFS needs to list observer programs as a priority for the Southeast region. Observer studies provide data that are not only critical to assessing bycatch, but are an important component of the information needed for reliable stock assessments.

Response: NMFS agrees and has revised this section and others in this Plan to recognize the important role observers play in providing data on species-composition of catch and bycatch, estimates of gear, vessel and gear characteristics, fishing locations, biological samples, and environmental parameters, all of which contribute to effective fisheries management.

Comment: The Plan should include a study to identify the small nucleus of anglers pursuing swordfish and gather their landing statistics, catch rates, and size distribution in order to acquire more accurate information on recreational landings by U.S. fishers for swordfish.

Response: NMFS is very interested in conducting surveys to estimate the landing of swordfish by recreational anglers. Identification of the anglers who fish for swordfish is a difficult task because such anglers are not required under any existing permit program to notify NMFS of their intent to fish for this species. Compilation of a list of the participants in the recreational swordfish fishery would be possible if those participants were required to provide such notification. NMFS is currently considering possible options for implementing such a requirement. Once NMFS obtains a comprehensive list of these anglers along with their telephone numbers and mailing addresses, it would certainly be possible to use that list to conduct efficient surveys that would accurately estimate their fishing effort, catch rates, and landings with respect to swordfish.

Comment: The Plan should include research regarding post-release mortality for billfish, sharks, and small swordfish caught on U.S. longlines.

Response: The NMFS Strategic Plan for Fisheries Research cites and supports research to implement the recommendations of the NMFS Bycatch Plan which includes research on post-release mortality of billfish, sharks, and small swordfish.

APPENDIX C. Abbreviations and Acronyms

ABC	acceptable biological catch
ABL	Auke Bay Laboratory
ACCSP	Atlantic Coastal Cooperative Statistics Program
ADCP	acoustic Doppler current profiler
AFSC	Alaska Fisheries Science Center
AKFIN	Alaska Fisheries Information Network
APIS	Antarctic pack ice seal
ASMFC	Atlantic States Marine Fisheries Commission
ASRG	Alaska Scientific Review Group
BKD	bacterial kidney disease
BRDs	bycatch reduction devices
BSAI	Bering Sea and Aleutian Islands
CAFF	Conservation of Arctic Flora and Fauna
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
CDQ	community development quota
CFMC	Caribbean Fishery Management Council
CMSS	Center for Marine Social Sciences
CPS	coastal pelagic species
CPUE	catch-per-unit-of-effort
DNA	deoxyribonucleic acid
DODS	Department of Defense standard
EEZ	Exclusive Economic Zone
EFCL	electronic fish catch logbook
EFH	essential fish habitat
ESA	Endangered Species Act
ESU	evolutionarily significant unit
FAD	fish aggregating device
FAO	Food and Agriculture Organization of the United Nations
FIN	Fisheries Information Network
FMC	fishery management council
FMP	fishery management plan
FOCI	Fisheries Oceanography Coordinated Investigations
FSP	Fisheries Strategic Plan, NOAA
FTE	full-time equivalent
GIS	geographic information system
GLOBEC	Global Ocean Ecosystems Dynamics
GMFMC	Gulf of Mexico Fishery Management Council
GOA	Gulf of Alaska
GOOS	Global Oceans Observing Program
GSMFC	Gulf States Marine Fisheries Commission
HAPC	habitat areas of particular concern
HMS	highly migratory species
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
IPCC	Intergovernmental Panel on Climate Change
ISC	Interim Scientific Committee
ITQ	individual transferable quota
IWC	International Whaling Commission
LIDAR	light detection and ranging
LME	large marine ecosystem
LMR	living marine resource
MAFMC	Mid-Atlantic Fishery Management Council
MHLC	Multilateral High Level Conference
MPA	marine protected area
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
NEFMC	New England Fishery Management Council
NEFSC	Northeast Fisheries Science Center
NERO	Northeast Regional Office
NGO	non-government organization
NICMERE	National Indian Center for Marine and Environmental Research and Education
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
NPFMC	North Pacific Fisheries Management Council
NRC	National Research Council
NWFSC	Northwest Fisheries Science Center
NWIC	Northwest Indian College
PacFIN	Pacific Fisheries Information Network
PFEL	Pacific Fisheries Environmental Laboratory
PFMC	Pacific Fishery Management Council
PICES	North Pacific Marine Science Organization
PIT	passive integrated transponder
PMEL	Pacific Marine Environmental Laboratory
PSMFC	Pacific States Marine Fisheries Commission
OY	optimum yield
RACE	Resource Assessment and Conservation Engineering Division, AFSC
RecFIN	Recreational Fisheries Information Network
REFM	Resource Ecology and Fisheries Management Division, AFSC
RFA	regulatory flexibility analysis
RIR	regulatory impact review
SAFE	stock analysis and fishery evaluation
SAFMC	South Atlantic Fishery Management Council
SARC	Stock Assessment Review Committee
SAW	stock assessment workshop
SEFSC	Southeast Fisheries Science Center
SEIS	supplemental environmental impact statement

SFA	Sustainable Fisheries Act of 1996
SIA	social impact assessment
SPO	Scientific Publications Office Seattle, WA, NMFS
SPTT	South Pacific Tuna Treaty
SST	sea surface temperature
SWFSC	Southwest Fisheries Science Center
TED	turtle excluder device
UNCLOS	United Nations Convention on the Law of the Sea
WPFMC	Western Pacific 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.

Acoustic Doppler current profiler (ADCP): An acoustic sensor that measures the Doppler shift of acoustic scatterers in the water column and estimates the magnitude and direction of 3-D motions of the "water" versus depth, using the assumption that the scatterers are passive tracers of the water mass. Fisheries scientists have applied this sensor to look for biological constituents (i.e., eggs and larvae) in the water column.

Adaptive management: A combination of stock assessments with prior knowledge of the fishery coupled with quantitative modeling and empirical management experimentation.

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

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

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.

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 non-target 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.

Commercial fishing boat.

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 Endangered Species Act 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.

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 represents a distinct population segment under the Endangered Species Act that (1) is substantially reproductively isolated from nonspecific populations and (2) represents an important component of the evolutionary legacy of the species.

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 probability that a given fish will die during the year because of fishing.

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 dependent data: Data collected on a fish or a fishery from sport fishers, commercial fishers, and seafood dealers.

Fishery independent data: Data collected on fish by scientists who catch the fish themselves, rather than depending on fishermen or seafood dealers.

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: A 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 fishers or brought to shore by recreational fishers 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.

Mark-recapture: The tagging and releasing of fish to be recaptured later in their life cycles. These studies are used to study fish movement, migration, mortality, and growth, and to estimate population size.

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.

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.

Opportunity cost: An amount a fisher could earn for his/her time and investment in another business or occupation.

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.

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.

Recovery Science Review Panel (RSRP): A panel of scientists established to ensure the consistency of salmon recovery efforts throughout the western United States.

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 U.S. fishing industry. The Saltonstall-Kennedy Act, as amended [15 U.S.C. 713 (c) (3)], is the program's statutory authority.

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.

Subadult: A developmental life stage when fish exhibit most but not all traits of an adult fish.

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

Technical Review 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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