Our Living Oceans

REPORT ON THE STATUS OF U.S. LIVING MARINE RESOURCES • 6th EDITION




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Our Living Oceans

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Front cover photographs, clockwise from top left: black rockfish, Steve Lonhart, Monterrey Bay National Marine Sanctuary; nesting leatherback sea turtle, Canaveral National Seashore, U.S. National Parks Service; giant trevally, Pacific Islands Fisheries Science Center, NMFS; spotted seal, Brent Stewart, Hubbs-SeaWorld Research Institute.

Our Living Oceans


John Butler, SWFSC

Report on the status of U.S. living marine resources • 6th edition

October 2009
NOAA Technical Memorandum NMFS-F/SPO-80

U.S. Department of Commerce

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Secretary of Commerce

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Foreword

This new edition of *Our Living Oceans* serves as a major yardstick to measure the success of managing our Nation's living marine resources since the last report was released in 1999. In addition to detailing the status of the Nation's living marine resources, this report also focuses on the steps that the National Marine Fisheries Service (NMFS) has taken to end overfishing and reduce bycatch, and spotlights what is known and what still remains unknown about fishery stocks and protected resources.

The passage of the Magnuson-Stevens Reauthorization Act of 2006 (MSRA) has changed the landscape of fisheries management. In addition to its requirement to end overfishing by 2010, the Act requires expanded fishery management tools (including market-based management approaches, e.g. "catch shares"), a larger role for science in the fishery management process (including improved recreational data collection and strengthened peer-review processes), and enhanced international cooperation (to address illegal, unreported, and unregulated fishing and bycatch of protected species). The keys to achieving sustainable fishery stocks, and local communities dependent upon them, are ending overfishing and rebuilding overfished stocks. The agency and the Nation we serve face new and emerging challenges: setting effective and accurate annual catch limits, conserving and rehabilitating the marine and freshwater habitats needed to sustain fishery stocks, recovering endangered species and protecting those at risk of becoming endangered, creating successful limited access privilege programs that help provide for sustainable and safe fisheries, and designing ecosystem-based management plans that consider multiple uses of marine ecosystems, including fisheries and a wide range of other societal needs.

NMFS has been working to anticipate and meet emerging management and conservation challenges. The NMFS Strategic Plan for Fisheries Research, published in 2007, describes the agency's research priorities for the next 5 years and provides a framework for targeting NOAA's resources to best meet science and management needs. The NOAA Fleet Recapitalization Plan, released in October 2008, outlines NOAA's plans to replace its aging fleet of sea-going vessels, the primary platforms for collecting fishery-independent data, which is vital for assessing stocks and managing fisheries. Updating the NOAA fleet will give us the tools to build capacity and collect more, and more comprehensive, data to better manage living marine resources. NMFS is also working with industry and academic partners to develop advanced sampling technologies that will further enhance data collection and the fisheries management that depends on those data.

In order to better meet the Nation's stewardship responsibilities for the oceans, coasts, and Great Lakes, the Obama Administration established an Interagency Ocean Policy Task Force (OPTF) to be led by the Chair of the Council on Environmental Quality. On 10 September 2009 the Obama Administration released the interim Ocean Policy Task Force report. The OPTF report provides proposals for a comprehensive national approach to uphold stewardship responsibilities and ensure accountability. It outlines a more balanced, productive and sustainable approach to managing ocean resources focusing on an integrated and science-based approach to ecosystem protection and restoration strategies. It calls out as a priority the importance of the "protection, maintenance, and restoration of populations and essential habitats supporting fisheries, protected species, ecosystems, and biological diversity."

The United States has some of the strongest marine resource legislation in the world, and passage of the MSRA gives NMFS critically needed tools to effectively manage our Nation's living marine resources for the sustainable use and enjoyment by this and future generations. This report serves as a report card to the Nation on the status of our living marine resources, but it will also serve as a baseline for measuring future progress under the MSRA mandates and meeting the requirements and initiatives of the OPTF. While we will eliminate known overfishing on Federally managed stocks in 2010, we know that it will take time to restore those populations—but recover they will of we are vigilant in keeping fishing mortality within sustainable limits. We expect that comparisons of future reports with this one will show continued improvements in the status and health of stocks, as well as increases in knowledge about those stocks.

Steve Murawski, Ph.D.
Director of Scientific Programs
National Marine Fisheries Service
Silver Spring, Maryland
October 2009

Quarterly updates on the status of populations can be found at:
http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm.

Preface

This is the sixth edition of *Our Living Oceans. Report on the Status of U.S. Living Marine Resources* to be released since the inaugural edition was published in November 1991. These publications serve as a series of National status reviews by the National Marine Fisheries Service. The reports are neither mandated nor intended to fulfill any legal requirement. Instead, the purpose of *Our Living Oceans* from the beginning has been to provide a report card to the American public on the biological health of U.S. living marine resources. Additional reports in this series were released in 1992, 1993, 1995, and 1999. Over time, this reporting effort has evolved from a 1-year cycle to a multiyear cycle so as to better reflect the extended time periods often requireds to observe and document change in biological populations and the marine environment.

Building on the reception of the biological report card, *Our Living Oceans. The Economic Status of U.S. Fisheries* was released to the American public in December 1996. This companion report defined and characterized economic sustainability in the Nation's fisheries, and presented a preliminary assessment of their economic health. An update to the 1996 Economics report is currently underway. Work on a third report that will present an initial assessment of the status and health of marine and coastal habitats important to living marine resources is nearing completion. When *Our Living Oceans: Habitat. Status of the Habitat of U.S. Living Marine Resources* is released in the near future, the envisioned *Our Living Oceans* series covering stock status, economics, and habitat will be in place.

Our Living Oceans 6th Edition presents new data analyses focusing on the principal fishery resources, marine mammals, and sea turtles that are under the management jurisdiction of the National Marine Fisheries Service. Living marine resources in this report are discussed in terms of seven regional ecosystems around the United States: Northeast Shelf, Southeast Shelf, Gulf of Mexico, Caribbean Sea, California Current, Alaska Ecosystem Complex, and Pacific Islands Ecosystem Complex, plus Highly Migratory Species. The information reported is drawn from stock assessment reports, field surveys, biological and physical studies, and independent monitoring of recreational, subsistence, and commercial fisheries. As with previous editions of *Our Living Oceans*, this publication and the data presented are the result of the collective efforts of National Marine Fisheries Service staff from around the country. The principal contributors to this report are listed in Appendix 1.

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Part 1
National Overview

Photo on previous page: Gray snappers find shelter beneath a coral reef ledge. Photo courtesy of Florida Keys National Marine Sanctuary.

National Overview

INTRODUCTION

The National Marine Fisheries Service (NMFS) is dedicated to the stewardship of living marine resources (LMR's). This is accomplished through science-based conservation and management, and the promotion of healthy ecosystems. As a steward, NMFS has an obligation to conserve, protect, and manage these resources in a way that ensures their continuation as functioning components of healthy marine ecosystems, affords economic opportunities, and enhances the quality of life for the American public.

In addition to its responsibilities within the U.S. Exclusive Economic Zone (EEZ), NMFS plays a supportive and advisory role in the management of LMR's in the coastal areas under state jurisdiction and provides scientific and policy leadership in the international arena. NMFS also implements international measures for the conservation and management of LMR's, as appropriate.

NMFS receives its stewardship responsibilities under a number of Federal laws. These include the Nation's primary fisheries law, the Magnuson Fishery Conservation and Management Act. This law was first passed in 1976, later reauthorized as the Magnuson-Stevens Fishery Conservation and Management Act in 1996, and reauthorized again on 12 January 2007 as the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act (MSRA). The MSRA mandates strong action to conserve and manage fishery resources and requires NMFS to end overfishing by 2010 in all U.S. commercial and recreational fisheries, rebuild all overfished stocks, and conserve essential fish habitat.

Additional stewardship responsibilities come from the following statutes:

- The Endangered Species Act (ESA) provides for the conservation of species that are endangered or threatened throughout a significant portion of their range and the conservation of the ecosystems on which they depend.

- The Marine Mammal Protection Act (MMPA) regulates interactions with marine mammals and establishes a national policy to prevent marine mammal species and population stocks from declining beyond the point where they cease to be significant functioning elements of the ecosystems of which they are a part.

- The National Environmental Policy Act (NEPA) requires Federal agencies to analyze the potential effects of any proposed Federal action that would significantly affect historical, cultural, or natural aspects of the environment.

- The Federal Power Act (FPA) allows NMFS to minimize the effects of dam operations on anadromous fish, such as by prescribing fish passageways that bypass dams.

- The Lacey Act prohibits fish and wildlife transactions and activities that violate state, Federal, Native American tribal, or foreign laws.

- The Migratory Bird Treaty Act requires the reduction of impacts of fishing gear on sea birds, in cooperation with the U.S. Fish and Wildlife Service.

- The Fish and Wildlife Coordination Act (FWCA) requires all Federal agencies to consult with and give strong consideration to the views of the U.S. Fish and Wildlife Service, NMFS, and state wildlife agencies regarding the impacts on fish and wildlife of projects that propose to impound, divert, channel, or otherwise alter a body of water.

Kip Evans

Black rockfish in a West Coast kelp forest.

The U.S. EEZ starts at 3 nautical miles (n.mi.) and extends to 200 n.mi.[1] seaward of the 48 contiguous states, Alaska, Hawaii, and U.S.-affiliated islands of the Caribbean and western Central Pacific Ocean (Figure 1). It is the largest EEZ in the world, covering 3.36 million square n.mi., or 1.7 times the area of the U.S. continental landmass (FAO, 2005). Jurisdiction over waters from 0 to 3 n.mi. offshore belongs to the coastal states, interstate fisheries management commissions (which coordinate state actions), and even counties or municipalities. International waters outside the U.S. EEZ are generally managed by applicable international laws and multilateral agreements among sovereign governments.

Eight regional Fishery Management Councils (FMC's; see Appendix 2) work in partnership with NMFS to manage LMR's and prepare Fishery Management Plans (FMP's). FMC's represent diverse interests through their members, who are nominated by state governors in each region and appointed by the Secretary of Commerce. The Secretary of Commerce oversees the FMC's and their development of fisheries regulations and is ultimately responsible for the management and conservation of LMR's in the U.S. EEZ; if the FMC's fail to act or are unable to act on an FMP or fishery problem in a timely manner, the Secretary must develop a Secretarial FMP. The Secretary of Commerce also has management authority for Atlantic highly migratory species and is responsible for the preparation of FMP's to manage these stocks; the Secretary also oversees implementation of international requirements related to fisheries.

Fishery management plans specify how fisheries will be managed, and are developed through extensive consultations with state and Federal agencies, affected industry sectors, public interest groups, and international science and management organizations where appropriate. The MSRA contains 10 National Standards to guide development of FMP's, taking into consideration the social, economic, biological, and environmental factors associated with fisheries. NMFS, state, and commission programs collect and analyze much of the fisheries data used by managers. Federal law requires that managers use the "best science available" to make management decisions.

Our Living Oceans 6th Edition (*OLO 6th Edition*) covers the majority of LMR's that are of in-

[1]The U.S. EEZ extends from 9 n.mi. to 200 n.mi. off the shores of Texas, the Gulf Coast of Florida, and Puerto Rico.

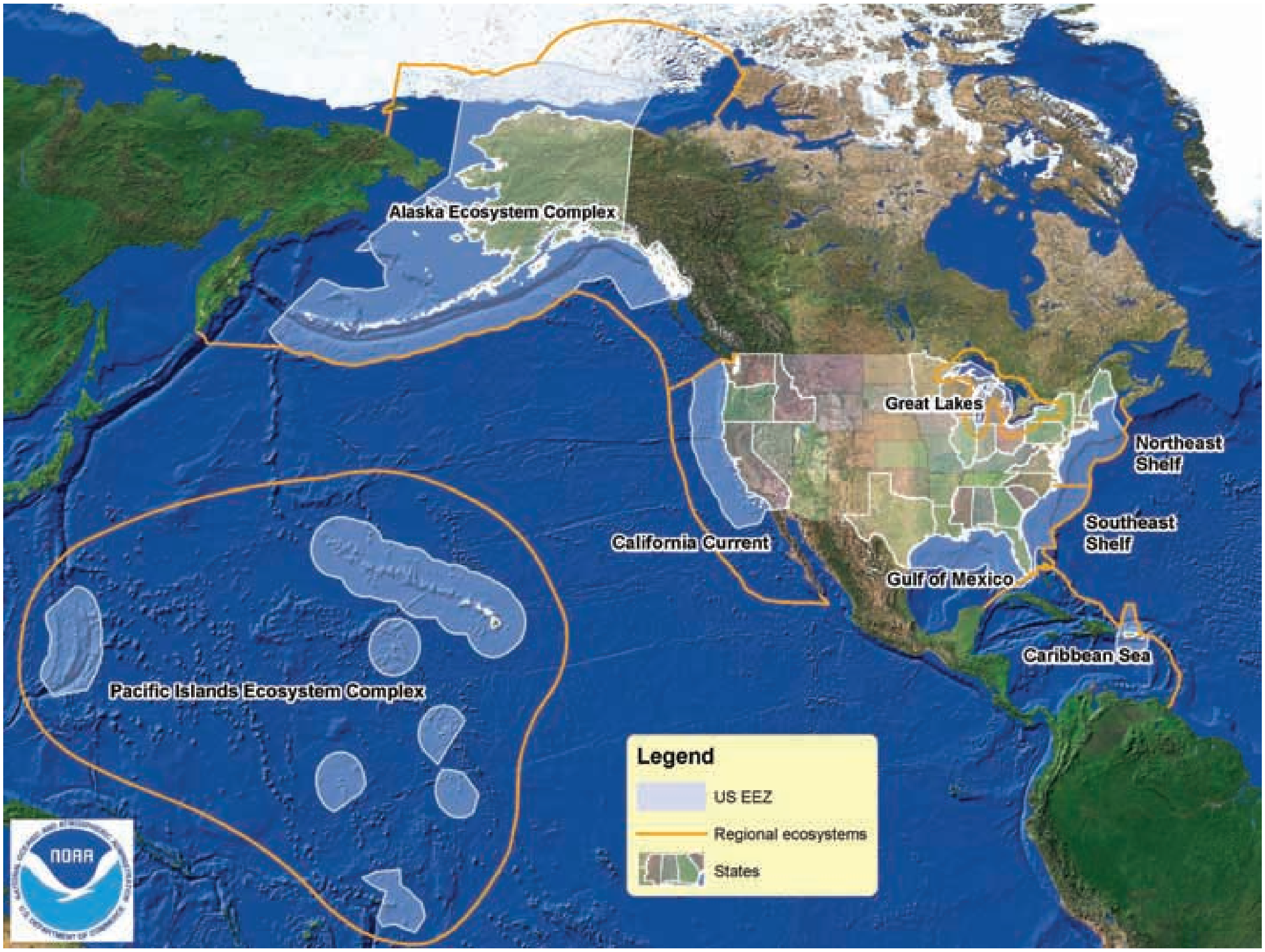


Figure 1

Our Living Oceans 6th Edition divides the U.S. Exclusive Economic Zone into seven Regional Ecosystems plus international/highly migratory species for the purpose of reporting the status of U.S. living marine resources. An eighth Regional Ecosystem designated by NOAA, the Great Lakes, is not covered. Map courtesy of Tim Haverland, NMFS.

terest to the United States for commercial, recreational, subsistence, and aesthetic or intrinsic reasons. The volume reports on the biological status of U.S. fishery resources, presents information on current and sustainable yields, in addition to current harvest rate and stock status relative to prescribed thresholds, and discusses significant management issues. Finally, the status of U.S. stocks of marine mammals and sea turtles is summarized.

Although a short discussion on the status of selected nearshore species has been included in previous editions of *Our Living Oceans*, no nearshore unit is included here. Many nearshore species provide the basis for locally important commercial and recreational fisheries, but these coastal and estuarine species are under the control of coastal states and their local governments, and NMFS does not have direct responsibility inshore of 3 n.mi. NMFS and the FMC's do coordinate with the states on the management of some large-scale fisheries, and certain nearshore resources such as anchovy, sardine, and some herrings are included in Federal FMP's. Because the composition of nearshore resources is diverse and management is shared among many coastal states and other local authorities, a comprehensive treatment of them has not been attempted in this report. However, some large-scale nearshore fisheries of national interest are reported.

Much of the information in this report comes from peer-reviewed stock assessment reports and publications. These sources form the scientific basis for management. Some stock assessments provide complete information necessary to judge stock status and the magnitude of current and sustainable fishery yield. When information is inadequate, the stock or fishery status is classified as unknown. In such cases, current and sustainable yield may be estimated from the most recent catch statistics. More detailed information can be obtained from regional reports produced by NMFS fisheries science centers (Appendix 3) and from state natural resource agencies.

Reauthorization of the Magnuson-Stevens Act

The Magnuson Fishery Conservation and Management Act (1976 Act) was first adopted in 1976 to govern fishing activities in Federal waters. Most notably, the 1976 Act aided in the development of the domestic fishing industry by phasing out foreign fishing, and it created the system of regional fishery management councils to govern domestic fishing activities and conservation efforts. The 1976 Act was reauthorized in 1996 (MSA) and gave NMFS the initial legal tools necessary to begin slowing fisheries expansion and stop the overcapitalization of U.S. fisheries. Since then, progress has been made towards rebuilding overfished stocks, but NMFS needed stronger laws to enable it to stop overfishing and accelerate rebuilding.

The Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006 (MSRA) was signed into law by President George W. Bush on 12 January 2007. The MSRA guides U.S. ocean and fisheries policy and gives NMFS the authority to manage the Nation's $62 billion fishing industries. Passage of the bill followed many years of hard work and much debate and compromise between the House, Senate, Administration, conservation groups, and the fishing industry to find common ground in their shared goal to maintain strong fishing industries and healthy marine ecosystems. The legislation is an important step for the United States to rebuild our Nation's fisheries and will allow our fishermen to utilize all available tools to fish safely and economically.

The MSRA will end overfishing in the United States, help rebuild overfished stocks, and advance international cooperation and ocean stewardship. One of the centerpieces of the legislation is a firm deadline to end overfishing in the United States by 2010. This is achieved by directing the regional FMC's to establish Annual Catch Limits (ACL's) by 2010 for Federally managed fish stocks currently undergoing overfishing and by 2011 for all other Federally managed fish stocks. ACL's are required to be set within the range of scientific recommendations—currently, most fishery managers abide by this principle, but this is not always the case. See Feature Article 1 for more information on ending overfishing.

MSRA GOALS

- End overfishing
- Help rebuild overfished stocks
- Promote market-based management approaches
- Advance the state of fisheries science and its role in decisionmaking
- Enhance international cooperation and ocean stewardship
- Strengthen enforcement of fisheries laws
- Improve monitoring of recreational fisheries

The MSRA also supports a number of other priorities to move towards sustainable fisheries in the United States. Among these is the use of market-based incentives to sustainably manage U.S. fish stocks: the MSRA aims to double the number of limited access privilege programs by the year 2010. Increasing the number of these programs will end the race for fish, improve the quality of catches, raise profits for fishermen, and increase safety. Strengthening enforcement of U.S. fishing laws is also a key piece of the new legislation. The MSRA expands cooperation between state and Federal officials to ensure that fishing laws are fully enforced and encourages the use of the latest technology in vessel monitoring to aid in real-time tracking of fishing boats. In addition, ecosystems are an important part of the MSRA, which improves information and decisions about the state of ocean ecosystems by creating several programs to improve the quality of information used by fishery managers.

Ecosystem Approaches to Management

As problems associated with decreasing natural populations and marine biodiversity become better defined and recognized, increasing calls are being made for new approaches to management. Although traditional fisheries management has worked well in some situations, a need exists for managers to move past single-species resource management and consider the many needs and interconnections between biodiversity and human uses. Ecosystem-based management fills this need by using an integrated approach to management that considers all elements of an ecosystem, including the role of humans. In the marine environment, an ecosystem approach to fisheries management (EAFM) extends the conventional principles and practices of fisheries management to cover the ecosystem as a whole.

John Butler, SWFSC

Healthy habitat is important to the health of many living marine resources.

Ecosystems are geographically specified systems of organisms, their environment, and the processes that control their dynamics. Humans, their institutions, and the benefits they derive from the ocean are all integral parts of marine ecosystems. Thinking of the ocean and its life as an ecosystem provides a more realistic view of the underlying causes and effects of changes in living marine resources. To understand a marine ecosystem, many factors need to be considered, including climate and oceanography, species habitat requirements, the biology of all of the organisms in the system from the phytoplankton at the base of the food web to the top predators, and the connections that link all of these parts.

An ecosystem approach to management is a geographically specified and adaptive process that takes account of ecosystem knowledge and uncertainties, considers multiple external influences, and strives to balance diverse societal objectives. This kind of approach allows managers to consider the effects of multiple factors and their interactions. For management to be effective, relevant geographic management areas must be defined according to ecosystem rather than political boundaries. The goals of ecosystem-based management include conservation and management of species, minimization of bycatch (and discards), consideration of tradeoffs, accounting for feedback effects, maintenance of ecosystem productivity, balancing ecosystem structure, and accounting for climate variability. The benefits of ecosystem-based management are more sustainable fisheries, healthy marine ecosystems, and economically healthy coastal communities.

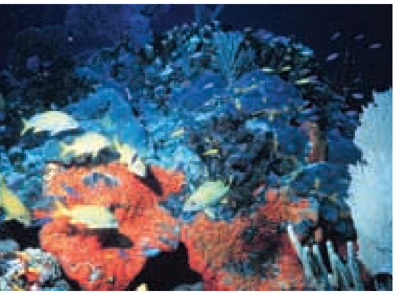
A wide variety of human activities may affect marine ecosystems, including fishing, coastal

GOALS OF ECOSYSTEM-BASED MANAGEMENT

- Conservation and management of species
- Minimization of bycatch (and discards)
- Consideration of tradeoffs
- Accounting for feedback effects
- Establishment of ecosystem boundaries
- Maintenance of ecosystem productivity
- Balancing ecosystem structure
- Accounting for climate variability

development, pollution, shipping, and oil and gas extraction. Human-induced climate change may also affect marine ecosystems. The ecosystem-level issues most relevant to fisheries management are the conservation and management of target and non-target species, maintenance of marine biodiversity, balancing competing uses between fisheries and other user groups, accounting for feedback effects (e.g. predator–prey interactions and habitat effects of fishing gear), maintaining ecosystem productivity and balanced trophic structure, and use of adaptive approaches in management. A comprehensive ecosystem approach to fisheries management (EAFM) requires managers to consider all interactions between a target stock and its predators, competitors, and prey species. Other factors such as the effects of weather and climate on fisheries biology and ecology, the effects of fishing on fish stocks and their habitat, and the complex interactions between fishes and their habitat must also be considered. However, the approach does not need to be endlessly complicated—an initial step might require only that managers consider how the harvesting of one species may impact co-occurring species in the ecosystem. Such steps have already been taken in the management of many U.S. LMR's.

Important building blocks for an EAFM already exist within the current NMFS management structure. These include provisions for protecting essential fish habitat (EFH), reducing bycatch, and elements related to overall conservation goals under the MSA and for protecting non-target species under the MMPA and ESA. Although a number of provisions of the MSA are directly related to the objectives of an EAFM, its measures may be more relevant to the management of recovering resources but less so for optimizing among multiple conflicting uses of rebuilt ecosystems. Passage of the MSRA strengthens existing ecosystem provisions in previous mandates and additionally authorizes FMP's to include measures to conserve both target and non-target species as well as habitats, considering the ecological factors affecting fishery populations.



NOAA

An ecosystem approach to fisheries management takes into account multiple factors in addition to the abundance of target stocks, such as species interactions and habitat quality.

NMFS and the FMC's have already made significant progress in integrating ecosystem considerations into fisheries management. NOAA has designated eight Regional Ecosystems (RE's) to guide and coordinate research and management decisions (Figure 1). Additionally, NMFS has begun working with the FMC's to develop voluntary Fisheries Ecosystem Plans (FEP's). FEP's are umbrella documents that provide Council members with a clear description and understanding of the fundamental physical, biological, and human/institutional aspects of ecosystems within which fisheries are managed, and direct how that information should be used in FMP's. A single FEP developed by each Council for the ecosystem under its jurisdiction will set policies for the development and implementation of management options. Because issues of optimality, particularly for rebuilt resources and ecosystems, are less well described under the MSRA due to its focus on rebuilding, FEP's appear to have utility in addressing some issues that are not addressed fully under existing management measures. They may help FMC's achieve the maximum cumulative societal benefits from ecosystems by considering the interactions among stocks (while fishing all stocks at their single-species optima may not result in overfishing of target stocks, the resulting suite of cumulative benefits from an ecosystem may not be maximized).

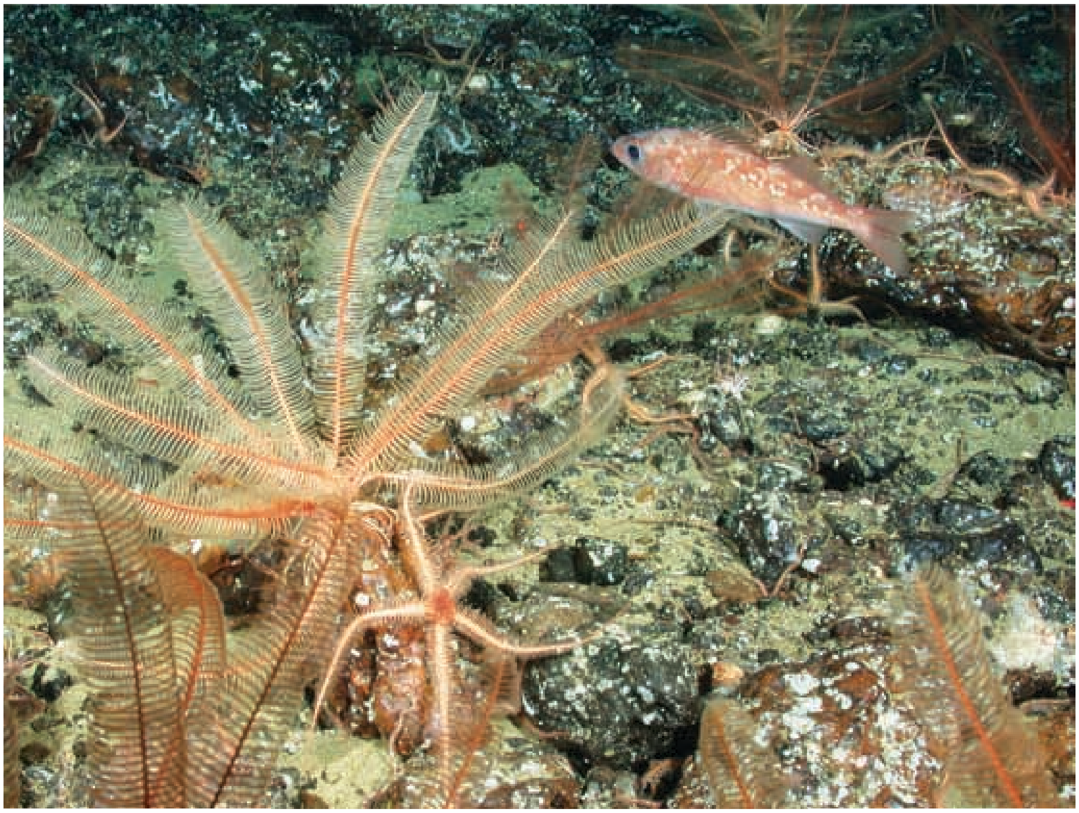
A number of cases from around the country emphasize the importance of considering ecosystem-level issues, as well as provide examples of the work that NMFS is doing to advance an EAFM. In Alaska, the North Pacific FMC already accounts for many ecosystem considerations in its management approach, including environment and climate regimes, the effects of fishing on habitat, non-fishing impacts on living marine resources, bycatch management, management of protected resources, uncertainty and risk in fishery management decisions, and research needs. To support the management needs of the North Pacific FMC, scientists at the Alaska Fisheries Science Center (AFSC) conduct annual or biennial stock assessments for both target and some non-target stocks and stock complexes. Stock assessments include ecosystem considerations such as investigations of the relationship between catchability and environmental factors; the effect of regime shifts on stock recruit relationships; results of ecosystem models; linkages between species; and habitat characteristics. Stock assessment reports for North Pacific stocks also include a full review of ecosystem status and trends, including climate, human influences, and biological trends. Additionally, the AFSC conducts a large amount of ecosystem research to support the shift to EAFM. For example, multidisciplinary research in the Bering Sea uses wind transport models to explain and predict recruitment patterns of winter-spawning flatfish species. The AFSC researches the effects of climate on fishery production; this research is currently expanding to consider the role of sea ice on population productivity and the consequences of reduced sea ice coverage due to climate change.

CMDR John Bortniak, NOAA Corps

A sablefish tagging research cruise in Alaska to support ecosystem research and sablefish stock assessments.

The Northeast Fisheries Science Center (NEFSC) also conducts a great deal of ecosystem-based research. The NEFSC has had an integrated ocean observation system in place for many decades, as a basis for understanding changes in marine ecosystems in response to natural and human-related factors. The NEFSC Observing System is a broad-based monitoring program that draws on many different instruments and sampling systems and encompasses the physics, chemistry, and biology of the seas as well as the human dimension. Data from the observing system as well as from other NEFSC scientific studies support the New England and Mid-Atlantic FMC's and their programs to conserve and manage living marine resources of the Northeast Shelf Ecosystem. In particular, NEFSC ecosystem research has been useful in supporting the New England FMC's Ecosystem Pilot Project, which is introducing EAFM concepts to the Council and public, and exploring options for developing an FEP for the Northeast Shelf Ecosystem. Additionally, the NEFSC is leading an effort to develop a suite of ecosystem indicators that can be used across regions to track the health and status of ecosystems.

There is also much ecosystem-related research in the Northwest Region. The Science for Ecosystem-Based Management Initiative at the Northwest Fisheries Science Center (NWFSC) examines the ecological interactions and processes necessary to sustain ecosystem structure, composition, and function where fish and fisheries coexist. By understanding the factors that sustain the ecosystem, scientists will be able to provide managers with the scientific advice needed to inform an EAFM for groundfish in the Pacific Northwest. The research initiative at the NWFSC addresses five research foci to guide EAFM: 1) interactions of target species with predators,



One focus of ecosystem research at the Northwest Fisheries Science Center is on the interactions between fish and their habitat.

competitors, and prey species; 2) effects of weather and climate on target species and their ecological communities; 3) effects of fishing on marine ecosystems and fish habitat; 4) interactions between fish and their habitat; and 5) use of marine protected areas (MPA's) as a fishery conservation and management tool.

The move to an EAFM is an incremental and ongoing process, and NMFS continues to support the effort through research, scientific support, proposed legislation, management efforts, and outreach. As ecosystem information and understanding improves over time, the shift from traditional single-species fisheries management to a more holistic EAFM will become more possible and accepted. NMFS continues to work with the regional FMC's to apply ecosystem principles to the management process, and to adopt precautionary and proactive management plans. The significant ecosystem research currently being conducted by NOAA, including expanding ocean observation systems, will support these efforts.

CONTENTS

Part 1 of this report is a national overview of significant LMR's and their fisheries. It includes this introduction, a brief review of common fisheries terms, LMR summaries and trends organized by Regional Ecosystem (RE), and a discussion of issues of national concern and near-term outlook.

Part 2 contains four feature articles—a discussion of overfishing and NMFS' efforts to end overfishing in U.S. fisheries, a look at how NMFS scientists are improving fisheries science with advanced sampling technologies, an assessment of the deep sea coral communities of the United States, and an examination of NMFS' cooperative and proactive approaches to implementation of the Endangered Species Act.

Part 3 presents in greater detail the biological status of LMR's in 24 units that describe important species linked geographically, ecologically, or by characteristics of their fisheries.

Part 4 consists of appendices containing acknowledgements; a list of regional FMC's and their FMP's; a list of the principal NMFS facilities; a summary of stock assessment principles and terms; a list of scientific and associated common names of species covered in this report; a list of acronyms and abbreviations; and a list of species under NMFS jurisdiction currently protected under the ESA.

COMMON TERMS

Explanations of most of the technical terms and phrases used in this report can be found in Appendix 4; the most important are briefly described here.

Stock ideally refers to a biologically distinct group of organisms that are genetically related or reproductively isolated from other segments of a larger population. However, a stock unit defined for management purposes may not necessarily correspond to a discrete genetic unit and can include all the individuals of a species or several co-occurring species within a geographical area as one fishery stock when it is impractical to differentiate between them.

Recent average yield (RAY) is the total catch, including commercial landings, recreational landings, and discards, averaged over the most recent 3-year period of workable data, usually 2004–06 unless otherwise noted.

Current yield (CY)[2] is the potential catch that can be taken, depending on current stock abundance and prevailing ecosystem considerations. CY is analogous to acceptable biological catch (ABC) that is specified in some FMP's. ABC, where specified, usually represents the upper limit of CY.

Maximum sustainable yield (MSY)[2] is the maximum long-term average catch that can be achieved from the resource.

NOAA

Henry B. Bigelow, the second of four technologically advanced fishery survey vessels currently being added to the NOAA fleet. These new vessels feature a low acoustic radiated noise profile to help scientists quietly monitor fish and protected species without affecting their behavior, scientific sonar systems to measure fish biomass in the water column, dynamic ship positioning to maintain a fixed station location in the ocean, and multibeam sonar systems to map and provide information about the seafloor.

[2]For some stocks, CY and MSY may be unknown. For the purpose of reporting total CY and MSY across resources within the various fishery units and for the Nation as a whole, if CY was unknown RAY was substituted when calculating a unit, regional, or national total CY. If MSY was unknown, CY was substituted, or failing that, RAY was substituted in calculating totals.

Juvenile yellowfin tuna captured for physiological studies of heart function.

Harvest rate[3] describes a stock's harvest level relative to a prescribed fishing mortality (harvest) threshold defined in the FMP. This rate is expressed as overfishing, not overfishing, unknown, or undefined. A stock is experiencing overfishing when it is being harvested above the prescribed fishing mortality rate threshold (defined as less than or equal to F_{MSY}, the fishing mortality rate that would produce MSY); a stock is undefined when no threshold has yet been defined in the FMP.

Stock status[4] defines a stock's size relative to a prescribed biomass threshold. Status is expressed as overfished, rebuilding, not overfished, approaching overfished, unknown, or undefined. A stock is overfished when its biomass is below the prescribed threshold amount (defined as $½B_{MSY}$ in many FMP's). Stocks classified as approaching overfished are estimated to become overfished within 2 years. Rebuilding stocks have recovered to above their overfished threshold level under a stock rebuilding plan and are no longer considered overfished, but are still below the biomass target level. A stock status is undefined when no threshold has yet been defined in the FMP.

Stock level relative to B_{MSY}[5] is a measure of the stock's biological status. The current abundance level of the stock is compared to the biomass that, on average, would support the MSY (B_{MSY}). This level is expressed as below, near, above, or unknown relative to the abundance level that would produce MSY. The concept of B_{MSY} is similar to the Optimum Sustainable Population (OSP) level used in marine mammal stock assessments.

Threatened or **endangered** are terms specifically defined under the ESA. A species is considered endangered if it is in danger of extinction throughout a significant portion of its range; it is threatened if it is likely to become an endangered species within the foreseeable future.

Potential biological removal (PBR) is a concept that establishes a quantitative process for setting levels of take such that marine mammal stocks will equilibrate within their OSP. PBR (calculated as number of animals) is the sustainable removal level defined by the MMPA 1994 Amendments. Stocks for which bycatch levels exceed PBR are classified as **strategic** (stocks listed as **depleted** under the MMPA, or threatened or endangered under the ESA, are also considered strategic regardless of the level of take).

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[3]Harvest rate in *OLO 6th Edition* aligns with the overfishing classifications in NMFS' *2008 Status of U.S. Fisheries, First Quarter Update* status tables (available online at http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm). Because the list of stocks considered and the stock units used for classifying harvest rate may differ from those used to officially track overfishing status, not all stocks included in this publication have a harvest rate status determination listed or are included in Table 3.

[4]Stock status in *OLO 6th Edition* aligns with the overfished classifications in NMFS' *2008 Status of U.S. Fisheries, First Quarter Update* status tables (available online at http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm). Because the list of stocks considered and the stock units used for classifying stock status may differ from those used to officially track overfished status, not all stocks included in this publication have a stock status determination listed or are included in Table 4.

[5]Although both compare current biomass levels to a biomass threshold to determine the health of the stock, there is not a one-to-one correspondence between the stock level relative to B_{MSY} and overfished stock status classifications. While the first metric (stock level) compares biomass directly to B_{MSY}, stock status compares biomass to a threshold defined in the FMP, which may be some fraction of B_{MSY} (if known), a fraction of the estimated unfished biomass, or some other level.

U.S. FISHERIES PRODUCTION AND STATUS

The United States is one of the most productive fishing nations, ranking third in the world for fisheries landings in 2004, the most recent year surveyed by the Food and Agriculture Organization (FAO) of the United Nations (FAO Fisheries and Aquaculture Department, 2007). The 2004 U.S. catch of 5.0 million metric tons (t) was just over 5% of the world's total production of capture fisheries products in that year. The United States is the fourth-largest exporter of fishery products, exporting $3.8 billion worth in 2004. Despite these large exports, the United States ranks second in value for world imports; the nearly $12 billion of fishery products imported in 2004 accounted for about 16% of the $75 billion world trade. The United States is also the tenth-largest aquaculture producer, producing 606,549 t in 2004 and showing an estimated 10.4% annual growth rate in production.

The productivity of Federally managed fishery resources utilized by the United States is expressed as RAY, CY, and MSY (Table 1; Figure 2). Some stocks range beyond the boundaries of the U.S. EEZ, and the United States shares productivity with other fishing nations. For these

Table 1
Productivity in metric tons (t) of fisheries resources utilized by the United States.

Unit number and fishery	Total productivity (t) over the entire range of the stock			Prorated productivity (t) within the U.S. EEZ	
	Total recent average yield (RAY)[1]	Total current yield (CY)	Total sustainable yield (MSY)	U.S. RAY	U.S. MSY
1. Northeast demersal[2]	162,034	192,926	306,234	147,168	263,977
2. Northeast pelagic	229,633	550,461	406,065	160,335	336,766
3. Atlantic anadromous[2]	16,633	16,633	17,127	16,633	17,127
4. Northeast invertebrate[2]	155,316	169,407	205,456	126,600	167,470
5. Atlantic highly migratory pelagic[2]	290,221	282,190	322,731	18,569	24,760
6. Atlantic shark[3]					
7. Atlantic and Gulf of Mexico coastal pelagic[2]	17,482	18,959	18,473	17,482	18,473
8. Atlantic, Gulf of Mexico, and Caribbean reef fish[2]	24,253	23,416	37,145	24,253	37,145
9. Southeast drum and croaker[2]	40,994	40,994	77,801	40,994	77,801
10. Southeast menhaden	652,000	652,000	909,000	652,000	909,000
11. Southeast and Caribbean invertebrate	127,961	127,961	128,712	127,961	128,712
12. Pacific Coast salmon	21,110	33,312	33,312	21,110	33,312
13. Alaska salmon	377,449	317,900	317,900	377,449	317,900
14. Pacific Coast and Alaska pelagic	279,177	295,930	448,933	216,742	372,438
15. Pacific Coast groundfish	388,403	458,660	682,238	288,605	531,607
16. Western Pacific invertebrate[2,4]	0	0	0	0	0
17. Western Pacific bottomfish and groundfish[5]	317	424	2,628	317	2,628
18. Pacific highly migratory pelagic[6]	2,926,372	2,960,401	4,422,354	145,596	258,628
19. Alaska groundfish	2,228,226	3,210,397	3,856,508	2,219,202	3,849,508
20. Alaska shellfish	26,101	30,853	192,138	26,101	192,138
Total	7,963,682	9,382,824	12,384,755	4,627,117	7,539,390

[1]2004–06 average, unless otherwise noted.

[2]Total MSY is unknown due to unknown values for individual stocks; value shown is based on CY values where available, or on RAY.

[3]RAY for Atlantic sharks is expressed in thousands of fish instead of metric tons and cannot be converted to weights, so totals for this Unit have been excluded from this and other National Overview summary tables.

[4]Lobster fishery in the Northwestern Hawaiian Islands has been closed since 2000.

[5]RAY is 2002–04 average for Hawaii and 2003–05 for other island areas.

[6]A majority of the U.S. RAY is caught outside of the U.S. EEZ.

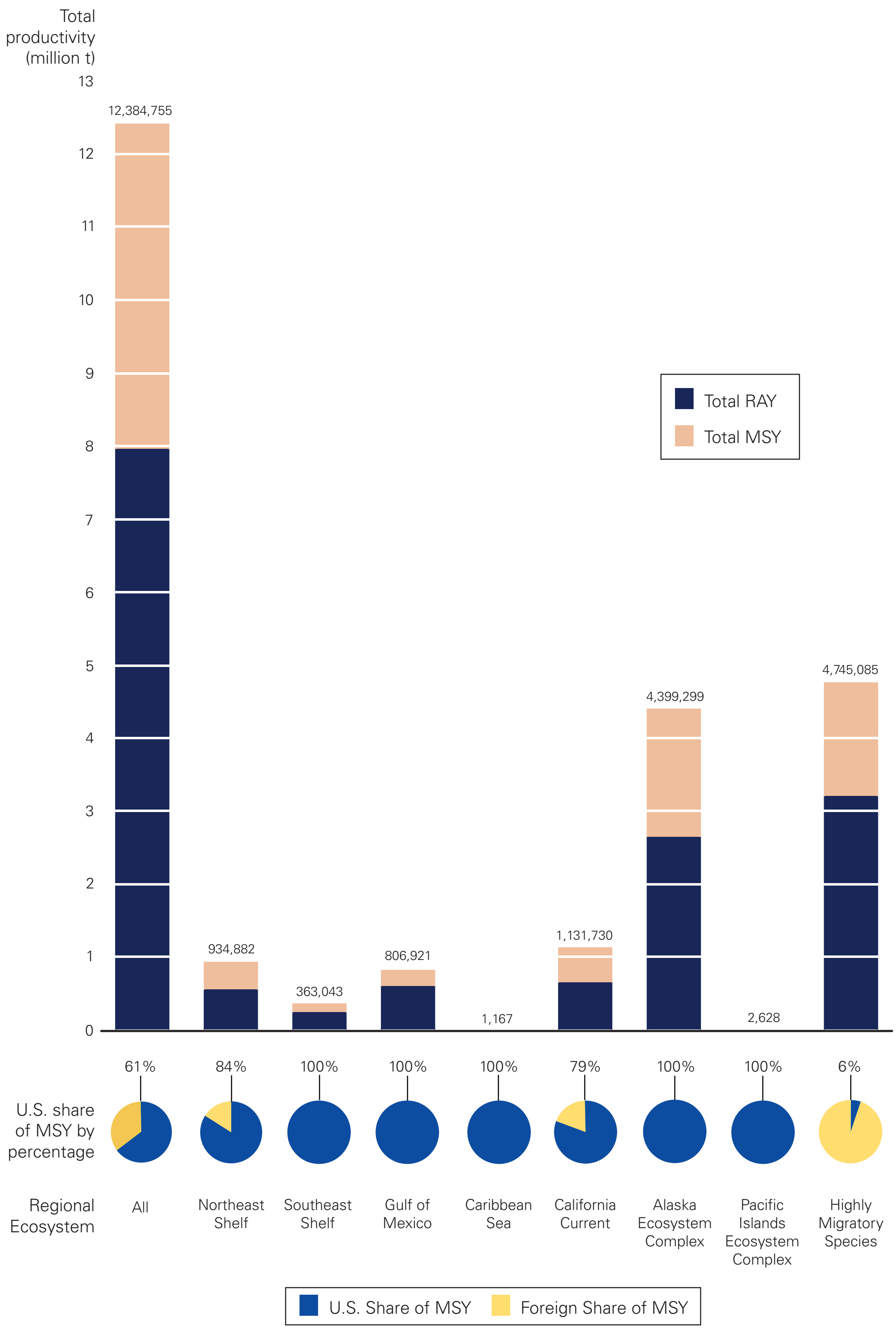


Figure 2

Total recent average yield (RAY, dark blue bars), maximum sustainable yield (MSY, peach bars), and U.S. prorated share of fisheries resources (blue pie slices), in metric tons (t) and by percentage.

transboundary stocks, *OLO 6th Edition* reports both total productivity and the prorated U.S. share of the stocks based on the ratio of the U.S. RAY to total RAY. The U.S. RAY for these stocks is primarily taken within the U.S. EEZ.

The total MSY of all U.S. fishery resources, across their entire range, is estimated to be 12,384,755 t (Table 1; Figure 2). Total CY is 9,382,824 t, indicating that the present productivity of U.S. stocks is about 24% below the long-term sustainable yield. The recent productivity (76% of MSY) is somewhat lower than the productivity reported in *Our Living Oceans 1999*[6] (86% of MSY; NMFS, 1999). Total RAY for 2004–06 (unless otherwise noted) was 7,963,682 t, or 36% below the MSY.

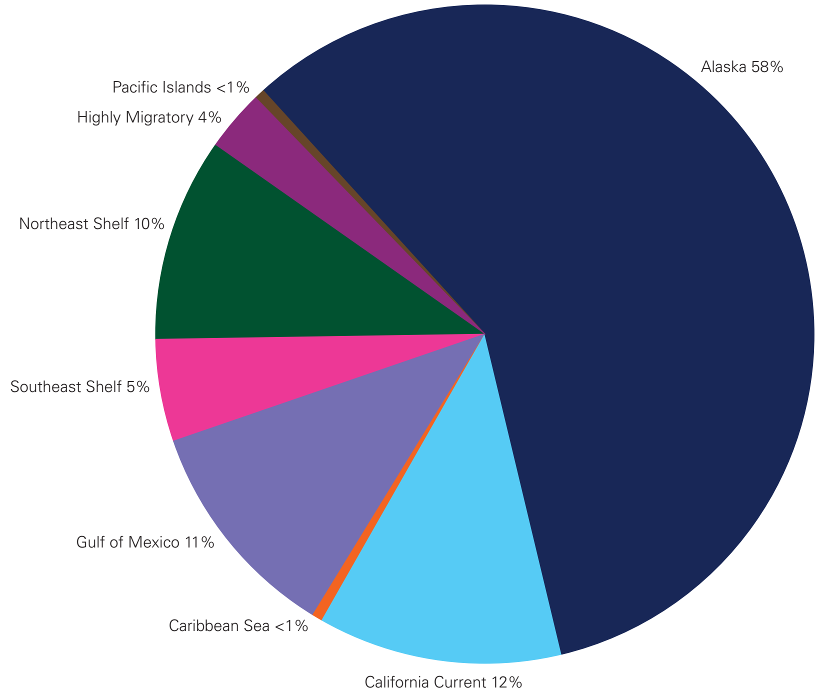


Figure 3

Apportionment of maximum sustainable yield, by Regional Ecosystem, of the U.S. prorated share of fisheries resources.

Considering only the U.S. prorated share of fisheries resources, the U.S. MSY (7,539,390 t) accounts for 61% of the total MSY. The distribution of U.S. MSY by Regional Ecosystem (RE) is 10% for the Northeast Shelf, 5% for the Southeast Shelf, 11% for the Gulf of Mexico, <1% for the Caribbean Sea, 12% for the California Current, 58% for the Alaska Ecosystem Complex, <1% for the Pacific Islands Ecosystem Complex, and 4% for Highly Migratory Species (Table 2; Figure 3).

[6]*OLO '99* used slightly different terminology than the current edition: current potential yield (CPY), equivalent to CY; and long-term potential yield (LTPY), equivalent to MSY. See the Recent Trends for Fisheries section on p. 35 for more information.

Table 2

Productivity, by Regional Ecosystem and in metric tons (t), of fisheries resources utilized by the United States.

	Total productivity (t) over the entire range of the stock			Prorated productivity (t) within the U.S. EEZ	
Regional Ecosystem	Total recent average yield (RAY)[1]	Total current yield (CY)	Total sustainable yield (MSY)	U.S. RAY	U.S. MSY
Northeast Shelf	563,616	929,427	934,882	450,736	785,340
Southeast Shelf[2]	255,939	256,554	363,043	255,939	363,043
Gulf of Mexico[2]	605,584	605,609	806,921	605,584	806,921
Caribbean Sea	1,167	1,167	1,167	1,167	1,167
California Current	658,030	756,039	1,131,730	486,773	897,604
Alaska Ecosystem Complex	2,662,436	3,591,013	4,399,299	2,662,436	4,399,299
Pac. Islands Ecosystem Complex	317	424	2,628	317	2,628
Highly Migratory Species	3,216,593	3,242,591	4,745,085	164,165	283,388
Total	7,963,682	9,383,824	12,384,755	4,627,117	7,539,390

[1]2004–06 average.

[2]Values exclude totals for Unit 6, Atlantic sharks; RAY for this Unit is expressed in thousands of fish instead of metric tons and cannot be converted to weights.

The U.S. RAY is 4,627,117 t, or 61% of the estimated U.S. MSY. The missing 39% was not realized due to a combination of some underutilized stocks, some overfished stocks that cannot be fished at MSY levels due to low population abundance, and some stocks that are rebuilding from past overfishing and are therefore not currently producing at their MSY levels. By RE, 10% of U.S. RAY comes from the Northeast Shelf, 6% from the Southeast Shelf, 13% from the Gulf of Mexico, <1% from the Caribbean Sea, 10% from the California Current, 58% from the Alaska Ecosystem Complex, <1% from the Pacific Islands Ecosystem Complex, and 4% from Highly Migratory Species (Table 2).

Harvest Rate

Harvest rate compares the current level of fishing pressure to a prescribed fishing mortality (harvest) threshold to determine if a stock is experiencing overfishing. Of the 217 *OLO* stocks that have harvest rates available,[7] 14% are classified as experiencing overfishing, 65% are not experiencing overfishing, 1% are undefined (i.e. have no fishing mortality threshold defined in their FMP's), and 19% are unknown[8] (Table 3, Figure 4). Known-status stocks account for 79%

[7] Not all stocks listed in *Our Living Oceans* have harvest rates available; those stocks that do not have a harvest rate available are omitted from harvest rate calculations.

[8] Although the harvest rates listed in *OLO 6th Edition* match the overfishing determinations listed in NMFS' *2008 Status of U.S. Fisheries, First Quarter Update* status tables, the list of stocks considered differs between the two publications and the summary calculations listed in the National Overview may not match those listed in the *First Quarter Update* or those appearing in the feature article on ending overfishing that is in this report.

Table 3

Harvest rate of U.S. fisheries resources (see text footnote 8).

Unit number and fishery	Harvest rate of the resource				
	Overfishing	Not overfishing	Undefined[1]	Unknown	Total
1. Northeast demersal	10	17	1	4	32
2. Northeast pelagic	0	4	0	0	4
3. Atlantic anadromous	0	3	0	2	5
4. Northeast invertebrate	0	7	0	0	7
5. Atlantic highly migratory pelagic	5	3	0	1	9
6. Atlantic shark	3	5	0	5	13
7. Atlantic and Gulf of Mexico coastal pelagic	0	6	0	0	6
8. Atlantic, Gulf of Mexico, and Caribbean reef fish	9	6	0	1	16
9. Southeast drum and croaker	1	1	0	1	3
10. Southeast menhaden	0	1	0	0	1
11. Southeast and Caribbean invertebrate	1	10	2	2	15
12. Pacific Coast salmon[2]	0	0	0	0	0
13. Alaska salmon	0	1	0	0	1
14. Pacific Coast and Alaska pelagic	0	3	0	1	4
15. Pacific Coast groundfish	0	22	0	1	23
16. Western Pacific invertebrate	0	1	0	0	1
17. Western Pacific bottomfish and groundfish	0	4	0	1	5
18. Pacific highly migratory pelagic	2	7	0	11	20
19. Alaska groundfish	0	30	0	0	30
20. Alaska shellfish	0	11	0	11	22
Total	31	142	3	41	217
Percentage of total	14%	65%	1%	19%	
Percentage of 173 "known"stocks	18%	82%			

[1] Stocks categorized as "undefined" have no overfishing limit defined in their Fishery Management Plan.

[2] Harvest rates are determined for individual runs of Pacific Coast salmon and are not available for the coast-wide stocks.

of the total; of these, 18% are classified as experiencing overfishing, while a majority (82%) are not experiencing overfishing. The fisheries with the most instances of overfishing are Unit 1 (10 stocks of Northeast demersal species), Unit 5 (five stocks of Atlantic highly migratory pelagic species), and Unit 8 (nine stocks of Atlantic, Gulf of Mexico, and Caribbean reef fishes), although overfishing is occurring in a number of other fisheries as well.

Stock Status

Stock status compares current stock biomass to a prescribed biomass threshold defined in the FMP to determine a stock's health (i.e. if it is overfished or not). Classifications for the 217 *OLO* stocks with stock status determinations available[9] are summarized in Table 4. Of these, 19% are overfished, 6%

[9]Not all stocks listed in *Our Living Oceans* have a stock status available; those stocks that do not have a stock status available are omitted from calculations.

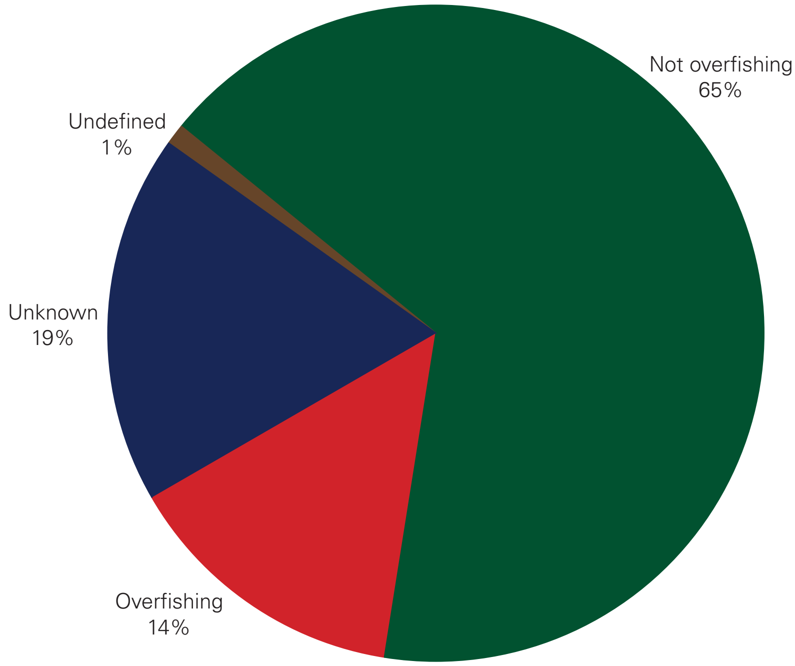


Figure 4

Stocks classified by their harvest rate (see text footnote 8).

Table 4

Stock status of U.S. fisheries resources (see text footnote 10).

	Stock status of the resource						
Unit number and fishery	Overfished	Rebuilding[1]	Not overfished	Appr. overfished	Undefined[2]	Unknown	Total
1. Northeast demersal	17	5	8	0	0	2	32
2. Northeast pelagic	1	1	2	0	0	0	4
3. Atlantic anadromous	2	0	1	0	0	2	5
4. Northeast invertebrate	0	0	5	0	0	2	7
5. Atlantic highly migratory pelagic	5	2	0	1	0	1	9
6. Atlantic shark	3	0	5	0	0	5	13
7. Atlantic and Gulf of Mexico coastal pelagic	0	1	5	0	0	0	6
8. Atlantic, Gulf of Mexico, and Caribbean reef fish	5	0	3	1	2	5	16
9. Southeast drum and croaker	0	0	0	0	1	2	3
10. Southeast menhaden	0	0	1	0	0	0	1
11. Southeast and Caribbean invertebrate	2	0	6	0	3	4	15
12. Pacific Coast salmon[3]	0	0	0	0	0	0	0
13. Alaska salmon	0	0	1	0	0	0	1
14. Pacific Coast and Alaska pelagic	0	0	2	0	1	1	4
15. Pacific Coast groundfish	4	3	14	0	0	2	23
16. Western Pacific invertebrate	0	0	0	0	0	1	1
17. Western Pacific bottomfish and groundfish	1	0	4	0	0	0	5
18. Pacific highly migratory pelagic	0	0	9	0	0	11	20
19. Alaska groundfish	0	0	20	0	10	0	30
20. Alaska shellfish	1	2	3	0	16	0	22
Total of units 1–20	41	14	89	2	33	38	217
Percentage of total	19%	6%	41%	1%	15%	18%	
Percentage of 146 "known" stocks	28%	10%	61%	1%			

[1]Stocks categorized as "rebuilding" have rebuilt to above the overfished threshold but not yet rebuilt to their targets under the rebuilding program.

[2]Stocks categorized as "undefined" have no biomass threshold defined in their Fishery Management Plan.

[3]Stock status is determined for individual runs of Pacific Coast salmon and is not available for the coast-wide stocks.

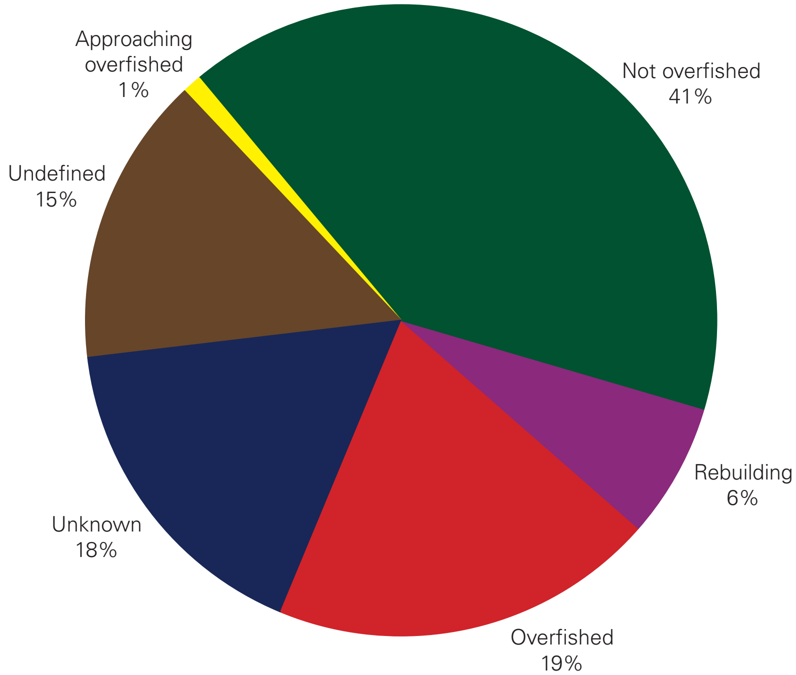


Figure 5
Stocks classified by their stock status (see text footnote 10).

are rebuilding, 41% are not overfished, <1% are approaching overfished, 15% are undefined, and 18% are unknown[10] (Figure 5). Of the 146 known stocks, 28% are overfished, 10% are rebuilding, 1% are approaching overfished, and 61% are not overfished. The majority of overfished stocks occur in Unit 1 (5 rebuilding and 17 overfished stocks of northeast demersal species), Unit 5 (two stocks rebuilding and five overfished among Atlantic highly migratory pelagic species), Unit 8 (five stocks overfished and one approaching overfished among Atlantic, Gulf of Mexico, and Caribbean reef fishes), and Unit 15 (three stocks rebuilding and four overfished among Pacific Coast groundfishes). A majority of the stocks classified as overfished are currently under rebuilding plans but have not yet been rebuilt to above the overfished threshold.

[10]Although the stock statuses listed in *OLO 6th Edition* match the overfishing determinations listed in NMFS' *2008 Status of U.S. Fisheries, First Quarter Update* status tables, the list of stocks considered differs between the two publications and the summary calculations listed in the National Overview may not match those listed in the *First Quarter Update*.

William B. Folsom, NMFS

Several stocks of Atlantic highly migratory species are classified as overfished, including the blue marlin.

FISHERY RESOURCE STATUS RELATIVE TO FISHING MORTALITY AND BIOMASS TARGETS

Stock Level Relative to B_{MSY}

One of the metrics used to measure the health of fisheries stocks is the current level of a stock's biomass relative to the biomass that would produce the MSY (B_{MSY}). The 283 stocks[11] covered in *OLO 6th Edition* are 22% below, 14% near, 20% above, and 43% unknown relative to B_{MSY} (Table 5, Figure 6). Although a large number (122) of stocks are classified as unknown,[12] many of these are not dominant in fisheries or ecosystems and this category contributes only a small proportion of the U.S. RAY.

Of the 161 known stocks, a relatively high percentage (39% or 63 stocks) are below levels that would produce the MSY. Many of these low-abundance cases are in Unit 1 (23 stocks of Northeast demersal species) and Unit 8 (eight stocks of Atlantic, Gulf of Mexico, and Caribbean reef fishes). A few cases of low abundance can be found in all regions. The remaining stocks (98 of 161 known-status stocks) are classified as 25% near and 35% above B_{MSY}. Assuming that stocks near or above B_{MSY} are healthy, about 60% of known-status stocks are at healthy abundance levels.

[11]This is the total number of stocks and stock groups listed in Units 1–20.
[12]Stocks that did not have a reported stock level were counted as unknown.

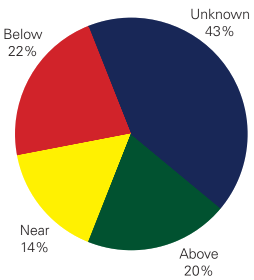


Figure 6
The percentage of stocks that are above, near, below, or unknown relative to the biomass level that would produce the maximum sustainable yield (B_{MSY}).

Table 5
Stock levels relative to the biomass producing the maximum sustainable yield (B_{MSY}) of U.S. fisheries resources.

Unit number and fishery	Stock level relative to B_{MSY}: Below	Near	Above	Unknown[1]	Total
1. Northeast demersal	23	2	3	8	36
2. Northeast pelagic	2	0	2	0	4
3. Atlantic anadromous	4	0	0	1	5
4. Northeast invertebrate	0	0	3	5	8
5. Atlantic highly migratory pelagic	3	4	0	3	10
6. Atlantic shark	3	0	6	5	14
7. Atlantic and Gulf of Mexico coastal pelagic	1	1	0	4	6
8. Atlantic, Gulf of Mexico, and Caribbean reef fish	8	1	0	24	33
9. Southeast drum and croaker	3	0	0	4	7
10. Southeast menhaden	0	0	1	1	2
11. Southeast and Caribbean invertebrate	1	8	0	7	16
12. Pacific Coast salmon	0	5	0	0	5
13. Alaska salmon	2	0	3	0	5
14. Pacific Coast and Alaska pelagic	0	2	2	4	8
15. Pacific Coast groundfish	5	6	11	5	27
16. Western Pacific invertebrate	0	0	0	1	1
17. Western Pacific bottomfish and groundfish	2	3	2	3	10
18. Pacific highly migratory pelagic	1	3	5	12	21
19. Alaska groundfish	3	6	19	12	40
20. Alaska shellfish	2	0	0	23	25
Total of units 1–20	63	41	57	122	283
Percentage of total	22%	14%	20%	43%	
Percentage of 161 "known" stocks	39%	25%	35%		

[1]Category includes stocks whose status is listed as "undefined" or "variable."

Fishing Mortality and Resource Biomass Relative to Target Levels

Another metric used to measure the condition of fisheries stocks compares the status of living marine resources relative to general fishing mortality and biomass targets. Current fishing mortality rates (F) are compared to the fishing mortality rate that would produce the MSY (F_{MSY}), and current biomass (B) is compared to the biomass necessary to produce the MSY (B_{MSY}). This analysis is similar to looking at harvest rate and stock status definitions, but allows for a more quantitative examination.

When comparing F and B targets in tandem, there are four states in which a stock can exist[13] (Figure 7):

1) currently experiencing overfishing ($F/F_{MSY}>1$) but not overfished at this time ($B/B_{MSY}>0.5$);
2) not experiencing overfishing ($F/F_{MSY}<1$) and not overfished ($B/B_{MSY}>0.5$);
3) not experiencing overfishing ($F/F_{MSY}<1$) but overfished ($B/B_{MSY}<0.5$); and
4) experiencing overfishing ($F/F_{MSY}>1$) and overfished ($B/B_{MSY}<0.5$).

[13]These are general definitions and may not match the legal overfished and overfishing status determination criteria specified in the FMP.

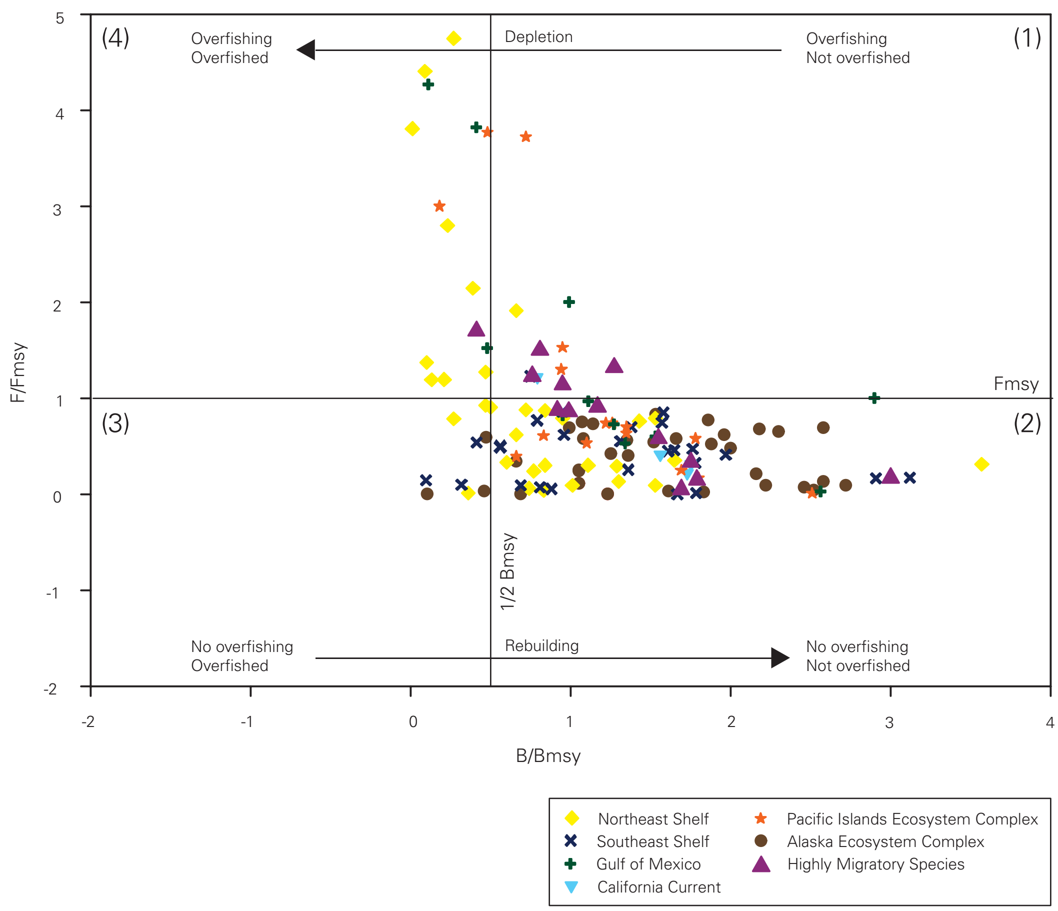


Figure 7

Current status of U.S. living marine resources relative to fishing mortality and biomass targets, by regional ecosystem.

States 1 and 3 are transitional in nature. Stocks can rarely persist in State 1 because stocks cannot support continued overfishing without experiencing negative effects on population abundance. State 3 represents a rebuilding phase where stock abundance levels have been negatively affected by previous high fishing mortality rates and are now being managed to allow the stock abundance to recover to sustainable population levels. Sufficient data are available to define the resource status relative to *F* and *B* target levels for 140 U.S. stocks and a majority of stocks are healthy (Figure 7). Of the 140 stocks, 101 are not experiencing overfishing and are not overfished, nine are not experiencing overfishing but are overfished (rebuilding), 12 are experiencing overfishing but are not overfished, and 18 are experiencing overfishing and are overfished.

PROTECTED RESOURCE STATUS

Marine Mammals

The Marine Mammal Protection Act of 1972 (Public Law 92-522, as amended in 1994 and 2007) requires the Secretary of Commerce and the Secretary of Interior to develop stock assessment reports (SAR's) for all marine mammal stocks found within U.S. waters. NMFS is responsible for assessing and managing stocks of whales, dolphins, porpoises, seals, sea lions, and fur seals, while the U.S. Fish and Wildlife Service (USFWS) has authority over stocks of Pacific walrus, Alaska polar bear, Alaska and Pacific Coast sea otter, and West Indian manatee.

Stock assessment reports must include, among other things, information on how a stock is defined, a minimum population estimate (N_{min}), the stock's current and maximum net productivity rate, current population trend, a calculation of potential biological removal (PBR), assessment of whether incidental fishery takes are "insignificant and approaching zero mortality and serious injury rate," and an assessment of whether the level of human-caused mortality and serious injury is likely to reduce the stock to below optimum sustainable population (OSP) or whether the stock should be classified as a strategic stock. Strategic stocks are stocks that are listed as endangered or threatened under the ESA or declining and likely to be listed in the foreseeable future, those designated as depleted under the MMPA (i.e. below OSP), and those for which human-caused mortality exceeds the PBR. SAR's are to be reviewed annually for strategic stocks and stocks that have new information available, and at least once every 3 years for all other stocks. Recent MMPA Amendments also require that take-reduction teams involving user groups and environmental groups be formed for each strategic stock, and charges them with developing plans to reduce takes below the PBR.

Harbor seals.

Stock assessment reports are produced by NMFS for 190 stocks of marine mammals across three regions—Alaska (36 stocks); the Pacific Ocean, including Hawaii (62 stocks); and the Atlantic Ocean, including the Gulf of Mexico (92 stocks; Table 6). Currently, 80 stocks under NMFS jurisdiction are classified as strategic, including 4 depleted stocks under the MMPA, 2 threatened and 25 endangered stocks under the ESA, 2 stocks for which the total annual mortality equals or exceeds the PBR, and 48 stocks for which the population status or fisheries-related mortality is uncertain.

Table 6
Status of marine mammals and sea turtles.

Unit number, area, and species	Number of stocks	Strategic	Endangered	Threatened	Depleted[1]
21. Alaska Region marine mammals	36	14	7	1	3
22. Pacific Region and Hawaii marine mammals	62	15	11	1	0
23. Atlantic Region and Gulf of Mexico marine mammals	92	51	7	0	1
Total	190	80	25	2	4
24. Sea turtles[2]	10		8	5	

[1]Stocks that are threatened or endangered under the ESA are also considered depleted under the MMPA, but not counted here.

[2]Some species of sea turtles include individual breeding populations with different ESA status.

There are sufficient long-term data to determine trends for 29 stocks (15%), with trends for the remaining stocks (85%) unknown (Table 7). Of the stocks with known trends, 6 are decreasing, 7 are stable, 2 are stable/increasing, and 14 are increasing. In the Alaska Region, 14 of 36 stocks have known trend status. The Pacific Region has made a significant improvement since the last *Our Living Oceans* (NMFS, 1999), when there were insufficient data to assign an abundance trend to any Pacific or Hawaiian marine mammal stock; now, 12 of 62 stocks have known abundance trends. In the Atlantic and Gulf of Mexico Region, only three stocks have known status, but all three stocks are increasing.

Table 7
Population trends of marine mammals.

Unit number, area, and species	Number of stocks	Decreasing	Stable	Stable/ Increasing	Increasing	Unknown
21. Alaska Region marine mammals	36	5	2	1	6	22
22. Pacific Region and Hawaii marine mammals	62	1	5	1	5	50
23. Atlantic Region and Gulf of Mexico marine mammals	92	0	0	0	3	89
Total	190	6	7	2	14	161

Sea Turtles

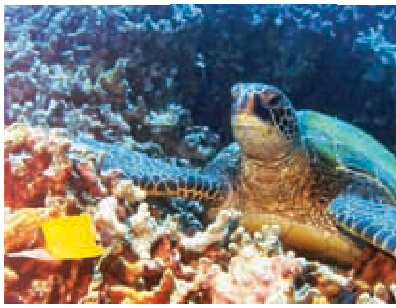
Six species of sea turtles regularly spend all or part of their lives off the U.S. Atlantic and Pacific coasts and in U.S. territorial waters of the Caribbean Sea and western Pacific Ocean. All six species are currently listed as either threatened or endangered under the ESA in both the Atlantic and Pacific Oceans (Table 6), and several species are endangered throughout their U.S. ranges. In the Atlantic Region, loggerhead turtle populations have been declining in recent years, while leatherbacks and green turtles appear to be increasing in the United States. Kemp's ridley turtles appear to be in the earliest stages of recovery under strict protection, including the requirement to use turtle excluder devices (TED's) in shrimp trawls in both the United States and Mexico and full protection of nesting turtles and their nests.

SEFSC Mississippi Laboratories

Captive turtle escaping from an experimental turtle excluder device (TED) during gear testing.

In the Pacific Region, loggerheads, leatherbacks, and green turtles have all shown dramatic declines at many locations, likely due to the harvest of eggs and adult turtles by humans in the case of leatherbacks and green turtles. Incidental mortality from fishing may also play a role in the decline of leatherbacks, and continues to threaten olive ridleys in the region as well. The status of hawksbill turtles in the Pacific Region is unknown, but the continued exploitation of hawksbills for their shells is an ongoing conservation concern.

Although much progress has been made toward reducing turtle injury and mortality in shrimp and bottomfish trawl gear through the use of TED's, the incidental capture of turtles in commercial fisheries remains the greatest concern. Capture in trawl, longline, and gillnet fisheries poses the greatest threats, although sea turtles are also taken and killed in poundnets and other types of fixed gear such as lobster and crab pots. Non-fishery interactions, such as propeller strikes and vessel collisions, also pose significant threats to sea turtles, especially in areas of high human population where recreational boat and commercial traffic is heavy and commercial ports are active. Additionally, a disease known as fibropapillomatosis that affects some species of sea turtles is emerging as a serious threat to the recovery of some populations.


Ursula Keuper-Bennett

Hawaiian green turtle.

REGIONAL ECOSYSTEM AND UNIT SUMMARIES

Northeast Shelf

Fisheries in the Northeast Shelf RE are grouped into demersal, pelagic, anadromous, and invertebrate resources. The combined MSY for the Northeast Shelf RE is 934,882 t; the U.S. share of this is 785,340 t (84%) due to sharing of transboundary resources with Canada (Table 8). The U.S. RAY (450,736 t) is about 57% of the U.S. MSY, primarily because a large number of stocks on the Northeast Shelf are below the biomass needed to produce MSY and fishing quotas have been reduced to help stocks rebuild to sustainable population abundances. The RAY for the Northeast Shelf excludes menhaden landed in the Northeast—these landings have been added to the data for Southeast menhaden (Unit 10) because they are an integral part of the South Atlantic menhaden stock.

The mixed-species groundfish fishery on the Northeast Shelf has traditionally been the most valuable fishery in this area, but profits have dropped while many northeast groundfishes recover from the effects of overfishing. Invertebrate fisheries are currently the most valuable fishery in the region; American lobster and sea scallop account for most of the value in these fisheries. Rec-

Table 8
Productivity in metric tons (t) of fisheries resources in the Northeast Shelf regional ecosystem.

	Total productivity (t) over the entire range of the stock			Prorated productivity (t) within the U.S. EEZ	
Unit number and fishery	Total recent average yield (RAY)[1]	Total current yield (CY)	Total sustainable yield (MSY)	U.S. RAY	U.S. MSY
1. Northeast demersal[2]	162,034	192,926	306,234	147,168	263,977
2. Northeast pelagic	229,633	550,461	406,065	160,335	336,766
3. Atlantic anadromous[2]	16,633	16,633	17,127	16,633	17,127
4. Northeast invertebrate[2]	155,316	169,407	205,456	126,600	167,470
Total	563,616	929,427	934,882	450,736	785,340

[1]2004–06 average.

[2]Total MSY is unknown due to unknown values for individual stocks; value shown is based on CY when available or on RAY.


OAR/NURP

American lobster in offshore Maine waters.

reational fisheries are also important to the region's economy, with species such as Atlantic cod, winter flounder, summer flounder, Atlantic mackerel, striped bass, bluefish, and bluefin tuna all being sought-after game fishes.

Demersal fishery resources on the Northeast Shelf (Unit 1) account for 33% of the total U.S. RAY and 34% of the U.S. MSY (Table 8). The U.S. RAY is presently 56% of the U.S. MSY for these stocks, primarily due to reductions in catch quotas while many stocks recover from overfishing. Many principal groundfish stocks were severely overfished previously, reaching record low levels of spawning stock biomass during the early 1990's. Although some stocks have since begun to rebuild, 23 demersal stocks remain below B_{MSY}, 22 are classified as overfished or rebuilding, and 10 are currently experiencing overfishing.

Measures currently in place to regulate demersal fisheries on the Northeast Shelf include effort control measures limiting allowable days at sea, coupled with closed areas, trip limits, and target levels for total allowable catch. In 2004, the New England FMC developed Amendment 13 to the Northeast Multispecies FMP to end overfishing and rebuild overfished stocks. The Amendment contained various effort-reduction measures, as well as measures to provide flexibility and business options for fishing permit holders. In 2006, Framework 42 adjusted rebuilding schedules for overfished stocks based on the results of stock assessments conducted in 2005. Amendment 16, currently under development by the New England FMC, will implement further rebuilding adjustments based on revised biological reference points and status of stocks through 2007.

Northeast pelagic fisheries resources (Unit 2) in general are somewhat underutilized; the U.S. RAY (160,335 t) is less than half of the U.S. MSY (Table 8). The combined MSY of the two most abundant pelagic species, Atlantic mackerel and herring, is more than 100,000 t higher than their combined RAY. Landings of these two species could likely be increased without jeopardizing stock productivity, though fishery expansion is limited by processing capacity, low export demand, and bycatch and ecosystem considerations. The other two pelagic species, bluefish and butterfish, are at low levels of abundance and below B_{MSY}; as a result, their respective RAY's are relatively low in comparison to MSY.


Jim Turek, NOAA Restoration Center

Alewife in the Nemasket River, Massachusetts.

Atlantic anadromous species (Unit 3) account for a very small proportion of Northeast Shelf fisheries, contributing only 4% of the U.S. RAY and 2% of the U.S. MSY (Table 8). The current RAY is higher than a decade ago but is still far below historic levels. All stocks with a known stock level are below B_{MSY}, and the harvest of Atlantic salmon and sturgeon is prohibited. Both species are considered Species of Concern[14] by NMFS, and the Gulf of Maine Distinct Population Segment of Atlantic salmon was listed as endangered under the ESA in 2000. The shortnose sturgeon is also listed as endangered and is managed under a recovery plan prepared under the ESA. As the landings of most anadromous species have notably declined in recent years, the aquaculture industry has grown greatly to fill the production void. Aquaculture production peaked in 2000 at 16,000 t, but has since declined due to changing aquaculture practices designed to reduce disease risks. Striped bass make up a majority of Northeast Shelf anadromous species landings and

[14]Species of Concern are species that NMFS has identified as having significant uncertainty regarding status and threats, and insufficient information is available to indicate a need to list the species under the ESA.

are a popular target of recreational fisheries. Following highly restrictive management actions in the 1980's, the stock was declared rebuilt in 1995 and has since been maintained at levels well above the threshold target biomass. Production of historically large year-classes in recent years should contribute to continued sustainable fisheries.

Northeast invertebrate fisheries resources (Unit 4) represent around a quarter of Northeast Shelf U.S. RAY and U.S. MSY. These fisheries are the Northeast's most valuable, contributing an average of $884 million ex-vessel annually in recent years. American lobster is the most important of the invertebrate fisheries resources, making up about 33% of the U.S. RAY and nearly half of the ex-vessel value. Sea scallops are also a significant fishery resource; landings and ex-vessel value are only slightly lower than for lobster. Most Northeast Shelf invertebrate stocks are considered to be healthy, with only a single stock (southern New England American lobster) classified as experiencing overfishing or overfished.

Southeast Shelf, Gulf of Mexico, and Caribbean Sea

The Southeast Shelf, Gulf of Mexico, and Caribbean Sea RE's share close proximity in the southeastern United States and a number of fishery stocks. Important fishery resources include Atlantic coastal sharks, coastal migratory pelagics, reef fishes, Sciaenids (drum and croaker), menhaden, and invertebrates. A conservative estimate of the total MSY for the three RE's combined is 1,171,131 t; the Southeast Shelf contributes 363,043 t to this total (Table 9), while the Gulf of Mexico makes up a majority of the rest (806,921 t; Table 10). The Caribbean Sea RE makes up a much smaller amount (1,167 t; Table 11). Values for Atlantic sharks have not been included in the totals listed here or throughout the National Overview because the RAY for these species is expressed in thousands of fish and cannot be converted to weights. The U.S. share of the MSY in the southeast is equal to the total MSY—although stock geographic areas do span international boundaries in this region, only the U.S. portion is reported here. The total RAY (also all U.S.) for the three RE's combined (862,690 t) makes up about 74% of the estimated MSY.

Matthew Gilligan

Additional data are needed on species such as nurse shark, seen above, before they can be assessed as a single species.

Table 9
Productivity in metric tons (t) of fisheries resources in the Southeast Shelf regional ecosystem.

	Total productivity (t) over the entire range of the stock			Prorated productivity (t) within the U.S. EEZ	
Unit number and fishery	Total recent average yield (RAY)[1]	Total current yield (CY)	Total sustainable yield (MSY)	U.S. RAY	U.S. MSY
6. Atlantic shark[2]					
7. Atlantic and Gulf of Mexico migratory pelagic[3]	10,179	10,696	10,328	10,179	10,328
8. Atlantic, Gulf of Mexico, and Caribbean reef fish[3]	6,142	6,240	7,691	6,142	7,691
9. Southeast drum and croaker[3]	31,046	31,046	65,822	31,046	65,822
10. Southeast menhaden	196,000	196,000	264,000	196,000	264,000
11. Southeast and Caribbean invertebrate	12,572	12,572	15,202	12,572	15,202
Total	255,939	256,554	363,043	255,939	363,043

[1]2004–06 average.
[2]Total RAY value for Atlantic sharks does not include prohibited shark species. RAY for Atlantic sharks is expressed in thousands of fish instead of metric tons and can not be converted to weights, so totals for this Unit have been excluded from this and other National Overview summary tables.
[3]Total MSY value is unknown due to unknown values for individual stocks; value shown is based on the CY when available, or the RAY.

Table 10

Productivity in metric tons (t) of fisheries resources in the Gulf of Mexico regional ecosystem.

Unit number and fishery	Total productivity (t) over the entire range of the stock: Total recent average yield (RAY)[1]	Total current yield (CY)	Total sustainable yield (MSY)	Prorated productivity (t) within the U.S. EEZ: U.S. RAY	U.S. MSY
6. Atlantic shark[2]					
7. Atlantic and Gulf of Mexico migratory pelagic[3]	7,303	8,263	8,145	7,303	8,145
8. Atlantic, Gulf of Mexico, and Caribbean reef fish[3]	17,177	16,242	28,520	17,177	28,520
9. Southeast drum and croaker[3]	9,948	9,948	11,979	9,948	11,979
10. Southeast menhaden	456,000	456,000	645,000	456,000	645,000
11. Southeast and Caribbean invertebrate	115,156	115,156	113,277	115,156	113,277
Total	605,584	605,609	806,921	605,584	806,921

[1]2004–06 average.

[2]RAY for Atlantic sharks is expressed in thousands of fish instead of metric tons and cannot be converted to weights, so totals for this Unit have been excluded from this and other National Overview summary tables.

[3]Total MSY value is unknown due to unknown values for individual stocks; value shown is based on CY when available, or on RAY.

Table 11

Productivity in metric tons (t) of fisheries resources in the Caribbean Sea regional ecosystem.

Unit number and fishery	Total productivity (t) over the entire range of the stock: Total recent average yield (RAY)[1]	Total current yield (CY)	Total sustainable yield (MSY)	Prorated productivity (t) within the U.S. EEZ: U.S. RAY	U.S. MSY
8. Atlantic, Gulf of Mexico, and Caribbean reef fish[2]	934	934	934	934	934
11. Southeast and Caribbean invertebrate	233	233	233	233	233
Total	1,167	1,167	1,167	1,167	1,167

[1]2004–06 average.

[2]Total MSY value is unknown due to unknown values for individual stocks; value shown is based on CY when available, or on RAY.

The RAY for Atlantic shark fisheries (Unit 6) is 1,271 thousands of fish (landings cannot be converted to weights) and represents a relatively small portion of landings in the Southeast Shelf and Gulf of Mexico RE's (pelagic shark species are discussed with the Highly Migratory Species). Although these species do not contribute heavily to landings in the southeast, they are important components of the ecosystem and are particularly vulnerable to the effects of overfishing due to their low reproductive capacity. Most sharks are assessed as part of several multispecies complexes, though improvements in data collection since *OLO '99* have allowed for some single species assessments to be conducted. Continued improvements in data collection will be required before additional stocks can be assessed on an individual basis; until then, aggregate management may result in excessive risk of overfishing on some species while other species may experience excessive regulation. A number of shark species have been declared prohibited species and can no longer be kept commercially or recreationally due to their rarity or susceptibility to exploitation. Three of these species, dusky, night, and sand tiger sharks, have been added to the NMFS Species of Concern list (see Appendix 7).

Coastal pelagic species (Unit 7) also account for only a small portion of southeast fisheries landings. However, coastal migratory species are popular components of recreational fisheries on the Southeast Shelf and in the Gulf of Mexico. These species are managed under a single FMP co-administered by the South Atlantic FMC and the Gulf of Mexico FMC. Several species (including dolphinfish and cobia) are primarily recreationally fished species, while both commercial fishermen and recreational anglers target other species. The division of total allowable catches (TAC's) between recreational and commercial fisheries remains an important issue for all of the coastal pelagic species. Improvements in the precision and accuracy of fishery-specific harvest levels and in the understanding of stock structure are needed to aid in future allocation decisions.

Reef fishes in the Southeast Shelf, Gulf of Mexico, and Caribbean Sea RE's (Unit 8) are a highly diverse group including more than 200 stocks of about 100 individual species. The RAY in the Gulf of Mexico (17,177 t; Table 10) is substantially larger than that in the South Atlantic (6,142 t; Table 9) or the Caribbean (934 t; Table 11). The status of many reef fish resources is unknown, and potential production estimates (CY and MSY) are not available for most species. In cases where CY and MSY estimates are available, they are likely higher than current RAY's would indicate, due to low stock abundances. Fishing pressure on reef fish resources continues to increase and is correlated with growing human populations, greater demand for fishery products, and technological improvements in fishing gear. This, combined with life history characteristics such as slow growth and late reproductive maturity, makes overfishing a continuing concern for reef fishes. Rebuilding plans are in place for all reef fishes classified as overfished, and some of these species (i.e. goliath grouper) are showing significant increases in population abundance. Collection of data necessary for adequate assessment and management in the reef fish fishery remains difficult due to the diversity of resource users, gears, and locations; data are often not available for individual species, fishery components, or areas. Additional or improved fishery-dependent and fishery-independent data would improve the accuracy of existing stock assessment models, and allow data-poor species to be assessed for the first time.


T. Potts, OAR/NURP/UNC

Gag grouper off the coastal Carolinas.

Fisheries for Sciaenid (drum and croaker; Unit 9) fishery resources in the southeastern United States have a long history dating back to the 1800's. These species are targeted in both recreational and commercial fisheries, with regulations on some stocks and in some areas heavily favoring recreational users. Much of the recreational fishing for drums and croakers occurs inshore of the 3-mile limit, in state waters, and management of these species is primarily by the coastal states. Allocation of resources between commercial and recreational fishing sectors remains an important issue in the management of drum and croaker fisheries. Sciaenids make up a majority of the finfish bycatch in southeast shrimp fisheries, and bycatch of these species is a major management issue in the Southeast Shelf and Gulf of Mexico RE's. Much of this bycatch is composed of juvenile fishes, and there is concern that mortality from shrimp bycatch may slow recovery of overfished stocks and reduce fishery yields.

Menhaden (Unit 10) comprise about 78% of the MSY for the three southeast RE's. The Gulf menhaden resource is approximately 2.5 times larger than Atlantic menhaden, and contributes a majority of the total RAY and MSY for southeast menhaden fisheries. Atlantic menhaden is at a healthy abundance level and above B_{MSY}, but the status of Gulf menhaden is currently unknown. Because menhaden stocks migrate long distances across state boundaries, management

William B. Folsom

Nets equipped with turtle excluder devices and bycatch reduction devices hang from a shrimp trawler tied to a dock in South Carolina.

requires coordination through interstate marine fisheries commissions (the Atlantic States Marine Fisheries Commission, ASMFC; and Gulf States Marine Fisheries Commission, GSMFC). The most significant issue in menhaden management is the importance of menhaden to ecosystem health—as key forage for many fishes, marine mammals, and sea birds, menhaden form an important trophic link in coastal ecosystems. Current research is focusing on the management of forage and predator fish species at a multispecies level.

Shrimp are the most important of the southeastern United States invertebrate fisheries resources (Unit 11). The fishery for shrimp in the Gulf of Mexico is much larger than that on the Southeast Shelf. Overall, shrimp are one of the most valuable U.S. fisheries and lead the region's fisheries in value although they make up only 14% of the RAY for the three southeast RE's. All of the commercial shrimp species are currently harvested at the maximum level and until very recently, the shrimp fishery was believed to be overcapitalized (i.e. there were more boats and fishing gear than economically needed to catch the available harvest, and yields were not closely tied to effort). Bycatch of commercially important finfish and protected species such as sea turtles in the small-mesh trawl nets used by shrimpers is a major issue currently facing managers in the Southeast Shelf and Gulf of Mexico RE's. Progress has been made to address these issues through gear modifications (turtle excluder and bycatch reduction devices) and other controls, and efforts continue to further reduce bycatch. Other invertebrate fisheries, such as those for spiny lobster and stone crab, contribute a much smaller amount to landings and ex-vessel values, but are important on local or regional scales. However, information on invertebrate species other than commercial shrimp stocks is incomplete, and abundance and production estimates are unknown for many species.

California Current

Fisheries of the California Current RE include Pacific salmon, coastal pelagic species, groundfish, and Pacific halibut. Highly migratory species (summarized in a separate section below) and state-managed invertebrate species are also important components. California Current fisheries resources have an estimated prorated U.S. MSY of 897,604 t (Table 12). This value is 79% of the total MSY for the California Current, due to sharing of transboundary resources with Canada (Pacific hake and Pacific halibut) and Mexico (some coastal pelagic species). The U.S. RAY is 486,773 t, or 54% of the MSY, due in part to underutilization of some coastal pelagic species and low abundance levels of some groundfish stocks. Many stocks are near or above B_{MSY}, although several groundfish stocks are below B_{MSY}.

Pacific salmon (Unit 12) stocks make up a small proportion of California Current fisheries, accounting for about 4% of the prorated U.S. RAY and U.S. MSY (Table 12). The RAY is 63% of the MSY; this depressed production is partly due to generally unfavorable ocean conditions resulting in poor survival of salmon off the Pacific Coast since the late 1970's. Recently, it briefly appeared that ocean conditions were improving for salmon species, but by 2005 most indicators of ocean productivity in the California Current had returned to unfavorable levels. Because salmon depend on freshwater habitat for spawning and rearing of juveniles, management of the Pacific salmon resource is complex, involving many stocks originating from various rivers and jurisdictions and requiring coordination with many entities not directly involved in the manage-

Unit number and fishery	Total productivity (t) over the entire range of the stock: Total recent average yield (RAY)[1]	Total current yield (CY)	Total sustainable yield (MSY)	Prorated productivity (t) within the U.S. EEZ: U.S. RAY	U.S. MSY
12. Pacific Coast salmon	21,110	33,312	33,312	21,110	33,312
14. Pacific Coast pelagic	238,424	255,177	408,180	175,989	331,685
15. Pacific Coast groundfish	388,403	458,660	682,238	288,604	531,607
19. Pacific halibut (Pacific Coast)	10,093	8,890	8,000	1,069	1,000
Total	658,030	756,039	1,131,730	486,773	897,604

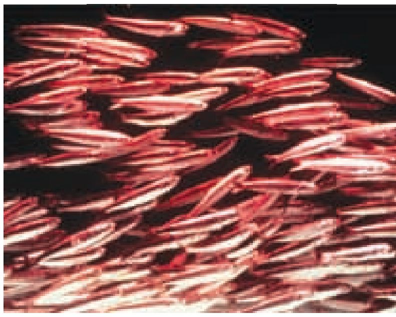
[1]2004–06 average.

Table 12

Productivity in metric tons (t) of fisheries resources in the California Current regional ecosystem.

ment of fisheries. Fisheries management is also complicated by the mixing of hatchery and wild stocks on fishing grounds—depleted wild stocks may be taken as bycatch in fisheries that target hatchery-produced stocks. Each of the coast-wide stocks of Pacific salmon is considered to be near B_{MSY}, although the status of individual runs may differ. Some runs are severely depleted and have triggered ESA designations to protect listed stocks and prevent further declines. The need to reduce impacts on listed stocks and to provide adequate spawning escapement for healthier stocks has constrained allowable harvest rates on healthy stocks in recent years, causing declines in landings to be more pronounced than declines in abundance. Sharp declines in the abundance of most southern salmon stocks over the past 5 years led to a closure of all ocean salmon fisheries off the coasts of Oregon and California in 2008 (with the exception of one small recreational coho fishery for hatchery fish in Oregon). Additionally, commercial fishermen face declining prices driven by market competition from steadily increasing aquaculture production of salmon and record landings of wild salmon in Alaska, Japan, and Russia. The use of hatcheries to enhance fisheries production and mitigate habitat loss on the Pacific Coast continues to be a contentious issue and raises concerns about the interactions between hatchery and wild salmon.

The abundance of coastal pelagic species (Unit 14) typically fluctuates widely from year to year, and consequently, landings of these species also tend to fluctuate. Coastal pelagic species currently make up 36% of the California Current U.S. RAY and 37% of the U.S. MSY (Table 12). Several coastal pelagic species (including jack mackerel and northern anchovy) are currently underutilized, primarily due to a lack of commercial markets, causing the RAY for the fishery to be only about half of the MSY. These species could potentially support increased harvest by U.S. fishermen, but increased data and biological information are necessary to ensure sustainable management of the stocks if landings increase. Coastal pelagic species form an important component of the California Current ecosystem as forage for fish, mammals, and birds. Thus, the continued well-being of ecologically related species is an important factor in the management of these species. The Coastal Pelagic Species FMP specifies a threshold for optimum yield that both prevents resource depletion and provides adequate forage for other species in the California Current ecosystem. Recently another forage species, krill, was added to this FMP to assure control of any potential future fishery. The transboundary nature of many of these species is also an important issue for fisheries managers; sardine, anchovy, and mackerels are exploited by both U.S. and Mexican fleets, but no bilateral management agreements have been reached to coordinate management of the stocks. Harvest levels are currently increasing in Mexican waters, further evidencing the need for a governing bilateral agreement. The problem is confounded by



OAR/NURP

School of northern anchovy.

ongoing uncertainty regarding stock structure, distribution, and environmental influences on the highly dynamic populations of coastal pelagic species.

The California Current groundfish fishery (Unit 15) harvests a wide variety of bottom-associated species along the coast from Washington to California. Many stocks have ranges that extend into Canadian or Mexican waters. The groundfish fishery has undergone a number of striking changes in recent years, and currently the RAY is just over half of the MSY (Table 12) due to a variety of factors. Foremost among these is the diversity of the fishing complex, with some species overfished and other species underutilized due to lack of markets or harvest restrictions in place to protect rebuilding stocks. Nine groundfish stocks were declared overfished between 1999 and 2002, and implementation of rebuilding plans for these stocks has limited fishing opportunities throughout nearly all sectors of the fishery. Two overfished stocks (Pacific hake and lingcod) have since been declared rebuilt, but rebuilding for other overfished stocks is expected to take decades due to low productivity of the species. To assist in this rebuilding, major portions of the Continental Shelf off the U.S. West Coast have been closed to fishing since September of 2003, further limiting fishing opportunities. These factors have combined to result in historically low allowable harvest levels. However, many strides have been made to improve management of the groundfish fishery, including implementation of a coastwide observer program to monitor bycatch, expansion of groundfish resource surveys, completion of several fleet capacity reduction programs, identification of Essential Fish Habitat (EFH) and Habitat Areas of Particular Concern (HAPC's), and implementation of coastwide conservation areas to protect overfished species and EFH.

V. O'Connell, ADFG, OAR/NURP

The Pacific Coast stock of lingcod was declared overfished in 1999, but has since been reclassified as rebuilt.

Alaska Ecosystem Complex

The Alaska Ecosystem Complex dominates all other U.S. RE's in fisheries landings (57% of the total U.S. RAY) and the tonnage that could be obtained in the long term (58% of the total U.S. MSY; Table 13). Major fisheries resources in Alaska include Pacific salmon, small pelagic species, Pacific halibut, groundfish, and shellfish. The combined MSY for all Alaska stocks is 4,399,299 t (all U.S. share). Current catch levels are substantially below the MSY levels because many resources, especially flatfishes, are underutilized, and long-standing optimum yield caps are in place to reduce risk and ensure ecosystem health.

Harvests of Alaska salmon (Unit 13) in recent years have remained favorable, with landings in 2005 reaching a new all-time harvest level of 222 million salmon. Catches in 2006 and 2007 were slightly lower, but still well above the long-term average. Although abundances of some individual salmon runs in Alaska are down, many runs continue to be successful, contributing to a RAY that was slightly above the MSY. An inverse production regime pattern associated with abundance levels of West Coast and Alaska salmon, along with some changes in environmental conditions, raised concerns that Alaska salmon catches would decline, but recent catch histories show no conclusive evidence of such a decline. However, the value of the Alaska salmon catch has declined significantly in recent years due to a number of worldwide factors. Foremost among these is a rising trend in world salmon production, mainly due to the rapid growth of salmon aquaculture, but also resulting from worldwide record catches of wild salmon (including fish produced from hatcheries and ocean ranching programs) in Alaska, Japan, and Russia.

David Csepp

The stern view of an Alaskan trawler.

	Total productivity (t) over the entire range of the stock			Prorated productivity (t) within the U.S. EEZ	
Unit number and fishery	Total recent average yield (RAY)[1]	Total current yield (CY)	Total sustainable yield (MSY)	U.S. RAY	U.S. MSY
13. Alaska salmon	377,449	317,900	317,900	377,449	317,900
14. Alaska pelagic	40,753	40,753	40,753	40,753	40,753
19. Alaska groundfish (total)	2,218,133	3,201,507	3,848,508	2,218,133	3,848,508
Bering Sea and Aleutian Islands	1,981,062	2,676,035	3,188,973	1,981,062	3,188,973
Gulf of Alaska	188,039	480,271	604,535	188,039	604,535
Pacific halibut (Alaska)	49,032	45,201	55,000	49,032	55,000
20. Alaska shellfish	26,101	30,853	192,138	26,101	192,138
Total	2,662,436	3,591,013	4,399,299	2,662,436	4,399,299

[1]2004–06 average.

Table 13

Productivity in metric tons (t) of fisheries resources in the Alaska Ecosystem Complex regional ecosystem.

Pacific herring (Unit 14) is the major pelagic species harvested in Alaska and produced a RAY of 40,753 t in the Gulf of Alaska and Bering Sea combined. The fishery occurs within state waters and is therefore managed by the Alaska Department of Fish and Game. Both stocks of Pacific herring in Alaska are thought to be near B_{MSY} and in a relatively stable condition, although estimates of their production potential are not available. As with many small pelagic species, herring abundance tends to fluctuate widely.

Pacific halibut (Unit 19) support an important traditional fishery for both the United States and Canada along the West Coast and in Alaska. Pacific halibut are thought to represent one large, interrelated stock and are managed throughout their entire range by a bilateral treaty between the United States and Canada and through research and regulation recommendations from the International Pacific Halibut Commission (IPHC). The center of abundance for Pacific halibut is the Gulf of Alaska; the two Alaskan management units account for a majority of halibut landings (RAY): 98% of the U.S. subtotal and 83% of the coastwide total. Recently, the Alaskan halibut fishery moved from an open-access fishery with a short derby-style fishing season to an Individual Fishing Quota (IFQ) fishery with a nearly 8-month-long season. Under the new fishing regulations, there has been an overall decline in the size of the halibut fleet, and most components of the fishery have been very successful in recent years. The halibut resource is considered healthy, with both Alaska management units above their respective B_{MSY} levels, and total catch near record levels.

Dan Rafla, IPHC

A Pacific halibut is hauled aboard the F/V *Bold Pursuit* in the eastern Gulf of Alaska.

One of the greatest successes of the 1976 Act has been the development of domestic groundfish fisheries off Alaska. Until its implementation in 1977, Alaska's groundfish fisheries were dominated by foreign vessels (with the exception of the U.S. fishery for Pacific halibut). However, under the new management regime the U.S. fleet has largely replaced foreign fishing fleets in U.S. EEZ waters off Alaska. The Alaska groundfish fishery is the largest fishery by volume in the U.S. EEZ.

Groundfish landings in the eastern Bering Sea and Aleutian Islands (BSAI) region (Unit 19) account for about 74% of the total Alaska RAY and 72% of the MSY (Table 13). Due to the high abundance (above B_{MSY}) of many stocks, the CY is nearly 1 million t higher than the RAY. However, the RAY of BSAI groundfish is currently only 62% of the MSY level because catch quotas

China rockfish.

have been capped at an optimal yield (OY) limit of 2 million t set in the BSAI Groundfish FMP to prevent harvesting of the full CY. Landings in the Alaska groundfish fisheries are dominated by walleye pollock; Pacific cod, flatfishes (especially yellowfin sole and rock sole), Atka mackerel, and rockfishes are also important. Walleye pollock in the BSAI region are highly productive, and yield the largest catch of any single species in the U.S. EEZ. Flatfish stocks in general are underutilized in the BSAI region, both because of the 2 million t OY cap and the need to prevent bycatch of prohibited species such as Pacific halibut, salmon, and king and Tanner crabs in flatfish trawl fisheries. Incidental take of prohibited species and allocation issues between user groups are important problems in the management of BSAI groundfish fisheries. Ecosystem considerations and marine mammal interactions with fish and fisheries are also important management issues in Alaska. Fisheries put marine mammals and sea birds at risk for incidental interactions with fishing gear and also compete for prey items that they depend on for food; the OY cap reduces these impacts on the ecosystem. The impact of fish removals has been implicated as a factor in the decline of Steller sea lion populations[15] in Alaskan waters. Because Steller sea lions feed on pollock, Atka mackerel, and Pacific cod, these groundfish fisheries are now carefully regulated to reduce adverse impacts near Steller sea lion rookeries.

Gulf of Alaska (GOA) groundfish (Unit 19) make up a much smaller proportion of the total Alaska RAY (7%) and MSY (14%; Table 13). The GOA RAY is currently only 39% of the CY, mainly due to underutilization of abundant flatfish species that are not fully harvested in order to prevent exceeding bycatch limits set for Pacific halibut. Important species in the GOA groundfish fishery include walleye pollock, Pacific cod, flatfishes, and rockfishes. Pollock in the GOA are currently estimated to be at their lowest known abundance levels. The pollock fishery is carefully managed due to concerns about the impact of fisheries on Steller sea lions in the area, and harvest rates have never exceeded 15%, so it is thought that variation in population abundance is related primarily to environmental forcing. Populations of Pacific cod, flatfishes, and rockfishes are all considered to be in good condition due to favorable conditions and precautionary management practices.

Crabs, including king, Tanner, and snow, dominate Alaska shellfish fisheries. A majority of shellfish production comes from the Bering Sea, which contributes a majority of king crab landings and all snow crab landings. Shellfish fisheries in Alaska are highly valued and generated an estimated $153 million in ex-vessel revenue in 2006. The RAY (26,101 t) is only slightly below the estimated CY, but well below the MSY value of 192,138 t (derived from historical data). This difference is largely due to depressed stock levels for several species and low harvest limits while stocks are rebuilding. The fishery for Tanner crab was closed in 1997 due to continued decreases in population abundance and landings, but abundance has increased, especially in the past two years, and abundance is now above the B_{MSY} level. King crab landings dropped steeply in the early 1980's and have remained low, while snow crab catches have decreased in recent years due to low stock abundance. However, some stocks of king and snow crabs are showing signs of increases. Shrimp resources, which make a minor contribution to Alaska shellfish fisheries, also remain depressed.

[15]The eastern Pacific population is classified as threatened, while the western U.S. Pacific population is endangered under the ESA. See Unit 21 for more information.

Pacific Islands Ecosystem Complex

The Pacific Islands Ecosystem Complex stretches across the central and western Pacific and includes the Main Hawaiian Islands (MHI), the Northwestern Hawaiian Islands (NWHI), and the U.S.-affiliated islands of American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands (CNMI; Figure 1). The area is made up of tropical and subtropical island waters with a high diversity of species, but relatively low sustainable yields due to limited ocean nutrients. Although catches are low compared to some mainland fisheries, Pacific Islands fisheries are highly valued and are important culturally and socially in Hawaii and the outer islands.

Fisheries resources of the Pacific Islands Ecosystem Complex include invertebrates, bottomfishes, and seamount groundfishes. The U.S. RAY for the region is 317 t (equal to the total RAY), which is 12% of the U.S. MSY level (Table 14). The MSY level is not well understood due to uncertainty in the estimates for lobsters and groundfishes. The considerable difference between RAY and MSY is due to the moratorium on fishing for seamount groundfishes, which make up an estimated 2,123 t of the total MSY.

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Scaly slipper lobster in the Northwestern Hawaiian Islands.

The most important invertebrate fisheries in the Pacific Islands Ecosystem Complex are for spiny and slipper lobsters (Unit 16). These species were fished primarily in the NWHI until 2000, when the NWHI fishery for lobsters was closed as a precautionary measure due to uncertainty about the status of the lobster stocks. In December 2000, President William J. Clinton established the NWHI Coral Reef Ecosystem Reserve, which established reserve preservation areas in which fishing activities were prohibited. President George W. Bush designated the area a National Monument in 2006, forever protecting this unique and remote ecosystem. Research since the 2000 fishery closure has indicated that spiny lobster populations in the NWHI constitute a metapopulation and that a variety of anthropogenic and biotic factors contributed to their decline. Additionally, it appears that as spiny lobsters were removed, slipper lobster populations expanded to fill habitats formerly occupied by spiny lobsters; this may affect the ability of spiny lobster stocks to rebound (although recent increases have been seen in certain locations). The fishery for precious coral was reinitiated in 1999 for the first time since the 1970's, and ended in 2001. The fishery remains open, though no harvesting is occurring due to the high cost of operations and the low price of coral. The biological information needed for the management of precious coral remains limited, and warrants further attention.

Table 14

Productivity in metric tons (t) of fisheries resources in the Pacific Islands Ecosystem Complex regional ecosystem.

	Total productivity (t) over the entire range of the stock			Prorated productivity (t) within the U.S. EEZ	
Unit number and fishery	Total recent average yield (RAY)[1]	Total current yield (CY)	Total sustainable yield (MSY)	U.S. RAY	U.S. MSY
16. Western Pacific invertebrate[2]	0	0	0	0	0
17. Western Pacific bottomfish and groundfish[3]	317	424	2,628	317	2,628
Total	317	424	2,628	317	2,628

[1]2004–06 average, unless otherwise noted.

[2]Total MSY is unknown due to unknown values for individual stocks; value shown is based on CY when available, or on RAY. Lobster fishery in the Northwestern Hawaiian Islands has been closed since 2000.

[3]RAY is 2002–04 average for Hawaii and 2003–05 for other island areas.

Bottomfishes (Unit 17) are harvested from a variety of rock and coral habitats around the Hawaiian Islands and western Pacific Islands. Across the region, the RAY for bottomfishes is 75% of the CY due to underutilization of some stocks and low abundance levels of others. Although no bottomfish stocks are classified as overfished, it is thought that overfishing is occurring in some areas of the Hawaiian Islands, and the Western Pacific Fishery Management Council has recommended that the State of Hawaii take action to prevent overfishing because the bottomfish fishery and bottomfish habitat are predominantly within state waters. The MHI stock of bottomfishes is currently below B_{MSY}, and assessments indicate that the biomass of some important species within this complex is at 5–30% of unfished levels due to excess harvest. The primary management concern for the Western Pacific bottomfish fishery is the adequacy of the biological and catch data collected—the reproductive biology of many of the important species in American Samoa, Guam, and CNMI is unknown and the spawning stock cannot be computed, leading to unreliable status determinations.

Hawaiian Undersea Research Laboratory

Onaga and boarfish at a depth of 200 m off Oahu in the Main Hawaiian Islands.

The fishery for seamount groundfishes (Unit 17) occurs on the summits and slopes of submerged seamounts along the southern Emperor–northern Hawaiian Ridge. The only area under U.S. jurisdiction is Hancock Seamount, which accounts for less than 5% of the total fishing grounds. Pelagic armorhead is the most important species of seamount groundfish, and fishing has been prohibited at Hancock Seamount since 1984 to allow the stock to recover after foreign catch rates declined to low levels. The current fishing moratorium extends at least through 2010, but the stock has yet to show any signs of recovery even after 20+ years of closures. It is likely that closure of only the small U.S. EEZ portion of the armorhead's demersal habitat is not sufficient to allow for population recovery; Hancock Seamount remains the only portion of the fishery currently under management. The primary issue for seamount groundfishes is how to implement some form of cooperative international management that will provide conditions conducive to stock rebuilding, but no progress has yet been made.

Highly Migratory Species

Highly migratory species include species that migrate great distances across the Atlantic or Pacific Oceans and are harvested widely by both U.S. and foreign fishermen. Fishing for highly migratory stocks occurs within the U.S. EEZ, on the high seas, and within the EEZ's of other nations. These transboundary fishery resources hold considerable interest internationally, with high collective importance and value to foreign nations and U.S. fleets fishing within and beyond the U.S. EEZ. Management of highly migratory stocks is complicated and requires a good deal of international coordination and cooperation. Regulations enforced by only one of the many nations that harvest these stocks will likely do little to manage the overall status of the stock and fishery as a whole.

Atlantic highly migratory pelagic species (Unit 5) include several species of tunas, swordfish, marlins, other billfishes, and other tuna relatives; also included in this discussion are the pelagic sharks (Unit 6). These species form important components of domestic fisheries along the U.S. Atlantic Coast. International management efforts for these stocks are coordinated by the International Commission for the Conservation of Atlantic Tunas (ICCAT). Landings by U.S. fishermen have been declining steadily since the late 1980's. Currently, the U.S. RAY accounts for

Unit number and fishery	Total productivity (t) over the entire range of the stock: Total recent average yield (RAY)[1]	Total current yield (CY)	Total sustainable yield (MSY)	Prorated productivity (t) within the U.S. EEZ: U.S. RAY	U.S. MSY
5. Atlantic highly migratory pelagic[2]	290,221	282,190	332,731	18,569	24,760
6. Pelagic sharks[3]					
18. Pacific highly migratory pelagic	2,926,372	2,960,401	4,422,354	145,596	258,628
Total	3,216,593	3,242,591	4,745,085	164,165	283,388

[1]2004–06 average.

[2]Total MSY is unknown due to unknown values for individual stocks; value shown is based on CY when available, or on RAY.

[3]RAY for Atlantic sharks is expressed in thousands of fish instead of metric tons and cannot be converted to weights, so totals for this Unit have been excluded from this and other National Overview summary tables.

Table 15

Productivity in metric tons (t) of highly migratory species fisheries resources utilized by the United States.

only 6% of the total RAY for migratory species over the range of their distribution (Table 15), indicating the significant role of foreign fisheries and the need for both national and international management measures. Many Atlantic migratory species are currently at low abundance levels and classified as both experiencing overfishing and overfished. The Consolidated Atlantic Highly Migratory Species FMP addresses rebuilding and overfishing for depleted stocks, but only has jurisdiction over the U.S. portion of the fisheries.

Pacific highly migratory stocks (Unit 18) such as tunas, billfishes, and sharks range the high seas and often migrate across multiple management jurisdictions in the Pacific Ocean. These stocks support some of the most valuable fisheries in the world. Tunas make up the major catch component of highly migratory fisheries. The combined MSY of these stocks throughout their migratory range is 4,422,354 t, but the U.S. prorated share of the MSY is only 6% of that (258,628 t; Table 15). The status of most tuna stocks is relatively well known, with only one stock (Eastern Pacific bigeye tuna) below B_{MSY}; however, three tuna stocks (Eastern Pacific skipjack tuna, South Pacific albacore, and Pacific bluefin tuna) continue to have an unknown status relative to the biomass that would support the MSY. Less is known about the status of other species, although stocks that do have sufficient information appear to be healthy. International coordination for the management of Pacific tuna fisheries is carried out by the Inter-American Tropical Tuna Commission (IATTC), in which the United States is a member country. In addition to the problem of unknown population status for some highly migratory stocks, a management issue of increasing concern is the growth of total fleet fishing capacity in the Pacific. Many stocks are believed to already be harvested at or above sustainable levels, and the economic effects of overcapacity are becoming more evident. Closely related to overcapacity is the problem of illegal, unreported, and unregulated (IUU) fishing by vessels operating outside the control of regional management regimes.

NOAA

Juvenile albacore being brought aboard in the U.S. troll fishery.

RECENT TRENDS FOR FISHERIES

Successive editions of *Our Living Oceans* have sought to maintain consistency in the way stocks are classified and in the way data are reported, in order to provide a basis for examining overall trends in the health of fishery resources. However, some changes have been introduced into this new edition of *Our Living Oceans* to reflect the way that data are currently being collected for stocks and to more closely align with how stocks are tracked and reported in the annual *Status of U.S. Fisheries* as mandated by the MSA. Changes in the stock status tables include: stocks have been broken out by geographic area where information is available; Current Yield replaces Current Potential Yield (CPY) in *OLO '99*; Sustainable Yield replaces Long Term Potential Yield (LTPY) in *OLO '99*; Stock Level Relative to B_{MSY} replaces Stock Level Relative to LTPY in *OLO '99*; and Harvest Rate and Stock Status (equivalent to overfishing and overfished determinations in the *Status of U.S. Fisheries*) replace Fishery Utilization Level in *OLO '99*.

Allen Shimada, NMFS

Yellowfin tuna awaiting sale at the Honolulu fish auction.

An examination of recent trends is presented here by comparing equivalent data reported in *OLO '99* and *OLO 6th Edition*. These editions pertain to stock status averaged over 1995–97 and 2004–06, respectively. Comparisons provide an idea of trends over a 9- to 11-year timeframe. Readers wishing to obtain a more detailed accounting of interannual changes for stocks of interest should refer to the references listed at the end of each species unit or consult stock assessment reports, which may be obtained electronically from Fishery Management Council websites listed in Appendix 2.

Stock Level

Stock level relative to B_{MSY} is a measure of how current fish stock abundance compares to the stock size that, on average, would support the MSY. Generally, management actions seek to prevent stock abundance from falling below B_{MSY}, and to rebuild stocks that have fallen below this level. Between *OLO '99* and *OLO 6th Edition*, the status of 20 stocks had improved: 14 moved from Below B_{MSY} to Near B_{MSY} and 6 moved from Below B_{MSY} to Above B_{MSY} (Table 16). Although 8 stocks moved from Near or Above to Below B_{MSY}, in aggregate these changes are positive, and resulted in a net reduction of stocks Below B_{MSY}. Although rebuilding of overfished stocks can sometimes take many years depending on the stock's intrinsic natural capacity to grow, its initial level of depletion, the specific management measures in place, and other factors, it would appear that the process of rebuilding overfished stocks is underway. Less positive news is that the number of stocks with unknown stock level status has increased, with 2 stocks becoming known and 41 stocks being reclassified as unknown. The reasons for a stock being reclassified as unknown vary

Table 16

Changes in stock level relative to B_{MSY} between *OLO '99* and *OLO 6th Edition* (Units 1–20).[1]

Total number of stocks by stock level status relative to B_{MSY} in *OLO '99*		Number of stocks by stock level status relative to B_{MSY} in *OLO 6th Edition*			
Stock level status (1999)	Total	Below (and change)	Near (and change)	Above (and change)	Unknown (and change)
Below	72	35 (–37)	14 (+14)	6 (+6)	17 (+17)
Near	60	5 (+5)	20 (–40)	16 (+16)	19 (+19)
Above	24	3 (+3)	2 (+2)	12 (–12)	7 (+7)
Unknown	41	0 (0)	0 (0)	2 (+2)	39 (–2)
Total	197	43 (–29)	36 (–24)	36 (+12)	82 (+41)

[1]This table shows the number of stocks in each *OLO '99* category (Below, Near, Above, and Unknown) that have stayed in the same category or shifted to a different category in *OLO 6th Edition*. These comparisons can be interpreted as changes between the mid 1990's and the mid 2000's. Only stocks appearing in both *OLO '99* and *OLO 6th Edition* are included in this summary. Entries of Variable and Unidentified have been counted as Unknown.

and may include a number of factors, including 1) improved stock assessment review processes that have increased expectations about the data that are needed to gain sufficient knowledge of a stock's status and ensure the best science available is used to manage it; 2) better recognition of the uncertainty associated with determining target abundance levels due to environmental variables and other ecosystem factors; and 3) the challenges associated with maintaining adequate data streams for all stocks.

Recent Yields

Overall, the U.S. share of the fishery resources reported in Units 1–20 has held fairly steady in recent years, decreasing just 1% between the time periods considered by *OLO '99* and *OLO 6th Edition*. This corresponds to a decrease of 39,702 t in the U.S. RAY (Table 17). This corresponds to an overall increase in the total RAY (10%), but a decrease in the U.S. share, mainly of Pacific highly migratory pelagic fisheries. Although the overall level has been relatively steady, some individual fisheries have experienced increases or decreases. The largest increases in terms of tonnage occurred for Alaska groundfish fisheries (156,930 t) and Pacific Coast and Alaska pelagic fisheries (52,784 t). In terms of percentage, Atlantic anadromous fisheries also had a large increase (77%). Large tonnage declines occurred for Southeast menhaden fisheries (–208,000 t) and Pacific highly migratory pelagic fisheries (–108,158 t). Large percentage decreases were experienced by Western Pacific invertebrates (–100% due to fishery closure) and Alaska shellfish (–50%).

Unit number and fishery	U.S. RAY *OLO '99*	U.S. RAY *OLO 6th Edition*	Change (t)	Change (%)
1. Northeast demersal[1]	142,215	146,324	4,109	3%
2. Northeast pelagic	121,300	160,335	39,035	32%
3. Atlantic anadromous	9,408	16,633	7,225	77%
4. Northeast invertebrate	127,200	126,600	–600	0%
5. Atlantic highly migratory pelagic	18,300	18,569	269	1%
6. Atlantic shark[2]				
7. Atlantic and Gulf of Mexico migratory pelagic[1]	15,432	17,482	2,050	13%
8. Atlantic, Gulf of Mexico, and Caribbean reef fish	24,739	24,253	–486	–2%
9. Southeast drum and croaker	33,623	40,994	7,371	22%
10. Southeast menhaden	860,000	652,000	–208,000	–24%
11. Southeast and Caribbean invertebrate[1]	119,376	127,784	8,408	7%
12. Pacific Coast salmon	17,304	21,110	3,806	22%
13. Alaska salmon	376,100	377,449	1,349	0%
14. Pacific Coast and Alaska pelagic[1]	112,500	165,284	52,784	47%
15. Pacific Coast groundfish	268,085	288,605	20,520	8%
16. Western Pacific invertebrate	109	0	–109	–100%
17. Western Pacific bottomfish and armorhead	492	317	–175	–36%
18. Pacific highly migratory pelagic[1]	253,606	145,448	–108,158	–43%
19. Alaska groundfish	2,026,272	2,219,202	156,930	8%
20. Alaska shellfish	52,131	26,101	–26,030	–50%
Total	4,614,192	4,574,490	–39,702	–1%

[1]Some stocks were not listed in both reports. For comparability, these RAY totals exclude the following: hagfish, Unit 1, *OLO 6th Edition*; cero mackerel, Unit 7, *OLO '99*; Gulf of Mexico grunts, Unit 8, *OLO 6th Edition*; golden crab, Unit 11, *OLO 6th Edition*; market squid, Unit 14, *OLO 6th Edition*; and bluefin tuna, Unit 18, *OLO 6th Edition*.

[2]RAY for Atlantic sharks is expressed in thousands of fish instead of metric tons and cannot be converted to weights, so totals for this Unit have been excluded from this and other National Overview summary tables.

Table 17

Comparison of U.S. recent average yield (RAY) in metric tons (t) reported by *OLO '99* and *OLO 6th Edition*.

Stock	Regional Ecosystem	*OLO* Unit	U.S. RAY *OLO '99*	U.S. RAY *OLO 6th Edition*	Change (t)	Change (%)	Stock level relative to B_{MSY}
American plaice	Northeast Shelf	1	4,300	1,627	–2,673	–62%	Below
Cusk	Northeast Shelf	1	600	78	–522	–87%	Unknown
Red hake	Northeast Shelf	1	1,400	519	–881	–63%	Unknown
Silver hake	Northeast Shelf	1	15,500	6,941	–8,559	–55%	Below
Spiny dogfish	Northeast Shelf	1	23,900	6,451	–17,449	–73%	Undefined
Weakfish	Northeast Shelf	1	4,200	1,013	–3,187	–76%	Unknown
Wolffishes	Northeast Shelf	1	400	106	–294	–74%	Unknown
Northern shrimp	Northeast Shelf	4	7,600	2,199	–5,401	–71%	Unknown
Amberjacks—South Atlantic	Southeast Shelf	8	1,078	382	–696	–65%	Unknown
Red porgy—South Atlantic	Southeast Shelf	8	236	47	–189	–80%	Below
Wreckfish—South Atlantic	Southeast Shelf	8	349	71	–278	–80%	Unknown
Rock shrimp	Gulf of Mexico	11	6,240	2,189	–4,051	–65%	Unknown
Seabob shrimp	Gulf of Mexico	11	3,947	1,149	–2,798	–71%	Unknown
Stone crab	Gulf of Mexico	11	2,961	1,177	–1,784	–60%	Near
Pink salmon	California Current	12	3,931	1,846	–2,085	–53%	Near
Chub mackerel	California Current	14	20,000	6,433	–13,567	–68%	Above
Jack mackerel	California Current	14	2,000	705	–1,295	–65%	Unknown
Pacific herring—Pacific Coast	California Current	14	6,000	85	–5,915	–99%	Unknown
Bocaccio	California Current	15	863	81	–782	–91%	Below
Canary rockfish	California Current	15	1,054	55	–999	–95%	Near
Chilipepper	California Current	15	1,846	125	–1,721	–93%	Above
Lingcod	California Current	15	1,966	821	–1,145	–58%	Above
Other rockfishes	California Current	15	7,766	3,113	–4,653	–60%	Unknown
Pacific ocean perch	California Current	15	800	104	–696	–87%	Below
Shortbelly rockfish	California Current	15	38	11	–27	–71%	Above
Thornyhead rockfishes	California Current	15	6,514	1,605	–4,909	–75%	Above
Widow rockfish	California Current	15	6,426	196	–6,230	–97%	Near
Yellowtail rockfish	California Current	15	4,073	840	–3,233	–79%	Above
Bottomfishes—CNMI	Pacific Islands	16	17	6	–11	–65%	Above
Greenland halibut—BSAI	Alaska	19	7,400	2,247	–5,153	–70%	Above
Sea snails	Alaska	20	1,414	0	–1,414	–100%	Unknown
Snow crab	Alaska	20	39,053	12,976	–26,077	–67%	Below
White marlin—Atlantic	Highly Migratory	6	1,600	400	–1,200	–75%	Below

Table 18

Comparison of recent average yield (RAY; U.S. share only except for highly migratory stocks from Units 5 and 18, which have a very high percentage of non-U.S. landings) between *OLO '99* and *OLO 6th Edition*. Only stocks with RAY changes greater than –50% are listed. RAY is in metric tons (t). Not included here are those stocks which have been closed to fishing: Atlantic salmon, Atlantic sturgeon, goliath and Nassau groupers throughout their range, and spiny and slipper lobsters in the NWHI. Atlantic sharks (Unit 6) are also excluded because RAY for these stocks is expressed in thousands of fish instead of metric tons and cannot be converted to weights. CNMI = Commonwealth of the Northern Mariana Islands; BSAI = Bering Sea and Aleutian Islands.

Table 18 lists individual stocks for which RAY decreased by 50% or more between *OLO '99* and *OLO 6th Edition*. These stocks are distributed around the country and are found in every RE except the Caribbean Sea, although more stocks from the Northeast Shelf and California Current had substantial decreases. In terms of tonnage, the largest decrease in RAY was for snow crab (–26,077 t). Snow crab and several other Alaska crab stocks are currently at low abundance levels, so lower harvest allowances have been set to allow the stocks to rebuild to healthy levels. Other stocks that experienced large decreases in tonnage included spiny dogfish (–17,449 t), as a result of recent restrictions on dogfish landings, and Pacific chub mackerel (–13,567 t), due mainly to a lack of commercial markets. Many stocks have experienced large percentage declines

Stock	Regional Ecosystem	*OLO* Unit	U.S. RAY *OLO '99*	U.S. RAY *OLO 6th Edition*	Change (t)	Change (%)	Stock level relative to B_{MSY}
Haddock	Northeast Shelf	1	900	8,836	7,936	882%	Below
Ocean pout	Northeast Shelf	1	60	294	234	390%	Below
Pollock	Northeast Shelf	1	3,800	6,190	2,390	63%	Below
Scup	Northeast Shelf	1	3,300	6,955	3,655	111%	Below
Skates	Northeast Shelf	1	10,700	41,575	30,875	289%	Undefined
Yellowtail flounder	Northeast Shelf	1	2,400	5,250	2,850	119%	Below
Atlantic mackerel	Northeast Shelf	2	14,600	52,455	37,855	259%	Above
Striped bass	Northeast Shelf	3	8,300	15,933	7,633	92%	Below
Red deepsea crab	Northeast Shelf	4	1,000	1,923	923	92%	Unknown
Sea scallop	Northeast Shelf	4	7,100	28,716	21,616	304%	Above
Other porgies—South Atlantic	Southeast Shelf	8	67	989	922	1,376%	Unknown
Atlantic croaker	Southeast Shelf	9	7,657	15,224	7,567	99%	Below
White shrimp—Gulf of Mexico	Gulf of Mexico	11	28,942	51,995	23,053	80%	Near
Chum salmon	California Current	12	2,768	6,170	3,402	123%	Near
Coho salmon	California Current	12	1,421	3,127	1,706	120%	Near
Northern anchovy	California Current	14	4,000	11,641	7,641	191%	Unknown
Pacific sardine	California Current	14	35,000	105,667	70,667	202%	Above
Arrowtooth flounder	California Current	15	2,257	4,160	1,903	84%	Above
Other groundfishes	California Current	15	1,693	5,115	3,422	202%	Unknown
Pacific cod	California Current	15	515	898	383	74%	Unknown
Pacific halibut—U.S. Pacific Coast	California Current	19	570	1,069	499	88%	Near
Pacific herring—Gulf of Alaska	Alaska	19	11,500	17,212	5,712	50%	Near
Bigeye tuna	Highly migratory	18	132,615	240,823	117,208	95%	Unknown
Skipjack tuna—Central Western Pacific	Highly migratory	18	950,527	1,494,421	543,894	57%	Above
Skipjack tuna—Eastern Pacific	Highly migratory	18	135,967	274,974	139,007	102%	Unknown
Wahoo	Highly migratory	18	160	831	671	419%	Unknown

Table 19

Comparison of recent average yield (RAY; U.S. share only except for highly migratory stocks from Units 5 and 18, which have a very high percentage of non-U.S. landings) between *OLO '99* and *OLO 6th Edition*. Only stocks with RAY changes greater than +50% are listed. RAY is in metric tons (t). Atlantic sharks (Unit 6) were not considered for this analysis because RAY for these stocks is expressed in thousands of fish instead of metric tons and cannot be converted to weights.

in RAY, although the absolute magnitude of the landings is small. Stocks on the Northeast Shelf have seen decreased landings in recent years due to harvest restrictions designed to allow stocks to rebuild. In the California Current, some of the stocks have decreased RAY's due to stock re-building, while others could support higher catch levels but are restricted due to co-occurrence with overfished stocks. Overall, 33 stocks (excluding those stocks for which fisheries have been entirely closed) experienced a decrease in RAY greater than 50%, accounting for a decrease of 129,874 t since *OLO '99*.

Table 19 lists stock groups that experienced a RAY increase of 50% or greater between the publication of *OLO '99* and *OLO 6th Edition*. Many of the stocks showing increases are from the Northeast Shelf or California Current; the others are spread around the other RE's, although there are none found in the Caribbean Sea or Pacific Islands Ecosystem Complex. In terms of tonnage, the largest increases in RAY were seen for several Pacific highly migratory species: skipjack tuna (543,894 t for the Central Western Pacific stock; 139,007 t for the Eastern Pacific stock) and bigeye tuna (108,208 t for both Pacific stocks combined). Skipjack tuna are currently the volume leader in Pacific fisheries for highly migratory species, and the stocks are believed to be underutilized, although MSY and the biomass relative to B_{MSY} are unknown for the Eastern Pacific stock (the Central Western Pacific stock is above B_{MSY}). Bigeye tuna are a highly migratory stock fished by several nations; the stock is experiencing overfishing and the eastern Pacific population is below B_{MSY}. Other tonnage increases were less substantial, but some stocks experienced large percentage increases in RAY. Some of these increases are due to improved management measures and reduced harvest restrictions on stocks as they rebuild to sustainable population levels. In total, 26 stocks showed an increase in RAY greater than 50%, accounting for a 1,034,624 t increase between *OLO '99* and *OLO 6th Edition*.

Many of the stocks (37%) with known status listed in Table 18 that experienced declines in landings are below the biomass level that would support the MSY. This indicates that landings for a significant portion of the stocks listed on the table decreased because their population sizes can no longer support historical catch levels. However, the rest of the known-status stocks experiencing RAY decreases are at healthy population levels. Declines in RAY for these stocks may be a result of a lack of commercial markets, shifts in fishing effort, or management restrictions to prevent bycatch of overfished co-occurring stocks that are overfished and rebuilding. Decreases in RAY may also be seen in healthy stocks as population abundance moves from above B_{MSY} to B_{MSY}. Unfortunately, a large number of stocks (42%) experiencing a large decrease in RAY had an unknown or undefined stock level, indicating the need for improved data collection and additional stock assessment efforts. About half of the stocks with known stock levels that experienced an increase in RAY had healthy population abundance levels; some of the increases seen for stocks classified as below B_{MSY} are due to easing of catch restrictions as the populations rebuild toward sustainable levels (the case for several stocks of Northeast groundfish). About 35% of the stocks with substantial RAY increases have unknown stock levels, indicating the need for cautious management of these stocks as fisheries for them increase.

RECENT TRENDS FOR PROTECTED RESOURCES

Since the last *OLO* report in 1999, the quality of stock assessments for protected resources such as marine mammals and sea turtles has continued to improve. *OLO '99* reported on 145 stocks of marine mammals and assigned trends to 12% of the stocks. *OLO 6th Edition* reports on a total of 190 marine mammal stocks, and assigns trends to 15% of the stocks (a gain of 11 stocks with assigned trends, relative to *OLO '99*). The largest improvements have been in the Pacific Ocean, where in 1999 authors were not able to assign population trends to any stocks (except for sea turtles), and now a total of 12 marine mammal stocks have known trends.


Louis M. Herman

Humpback whales, Hawaiian Islands Humpback Whale National Marine Sanctuary.

Marine Mammals

Recent stock assessments in Alaska show continued increases for bowhead whales, gray whales, and central North Pacific humpback whales. The Eastern Pacific stock of Steller sea lion also continues to increase, and the Western U.S. Pacific stock of Steller sea lion has showed increases in annual census counts since 2000—the first region-wide increase for that stock since standardized surveys began in the 1970's. These increases suggest a change in trend for the endangered stock, which is now considered to be stable. Other improvements in the Alaska Region include improved population trends for Bristol Bay beluga; trends for Cook Inlet beluga, fin whale, and eastern North Pacific Northern Resident killer whale going from unknown to known; stocks of killer whales increasing from two to five stocks; and the addition of known values for population or mortality estimates for several stocks. Additionally, the North Pacific right whale was recognized as a separate species from the North Atlantic right whale in 2000 and classified as endangered under the ESA. Between *OLO '99* and *OLO 6th Edition*, three stocks (Beaufort Sea beluga, southeast Alaska harbor seal, and spotted seal) went from known status to unknown, northern fur seal went from stable to decreasing, Cook Inlet beluga was classified as depleted, and three stocks were reclassified as strategic (as well as the addition of a new strategic stock, AT1 Transient killer whales).

Brent Stewart

The status of spotted seal and two other stocks in Alaska went from known to unknown between *OLO '99* and *OLO 6th Edition.*

In the Pacific region and Hawaii, a good amount of progress has been made since the last *OLO*. In *OLO '99*, no population trends were available for marine mammal stocks, but now 12 stocks have known trends. Five new stocks have been added to the Hawaii area of the Pacific, and the stock structure for harbor porpoises has been refined and now contains six stocks instead of four. New estimates have been made for a number of stocks that previously had unknown population or mortality values, and one stock (CA/OR/WA short-finned pilot whale) is no longer considered a strategic stock. Unfortunately, the Eastern North Pacific Southern Resident killer whale (found principally in Puget Sound) is now considered strategic and was also recently classified as endangered under the ESA.

In the Atlantic region and Gulf of Mexico, three new stocks have been added in the western North Atlantic, and the stock structure of bottlenose dolphin in the Gulf of Mexico has been refined. Since *OLO '99*, nine stocks have moved from strategic to not strategic status, while four moved from not strategic to strategic—a net gain of five fewer non-strategic stocks. In the Atlantic region, less progress has been seen in terms of defining abundance trends for marine mammal stocks. No new trends have been added, and two stocks with previously known trends are now unknown. Of the greatest concern in the Atlantic region is the North Atlantic right whale, which continues to show no sustained population growth despite six decades of protection.

Sea Turtles

Of the seven species of sea turtles found worldwide, six species are found in U.S. waters and all are currently listed as either threatened or endangered under the ESA. Authority to conserve and protect sea turtles is shared by NMFS (responsible for turtles while in the marine environment) and USFWS (jurisdiction over nesting beaches and turtles on land). A lack of historical abundance data makes it difficult to fully understand current population dynamics, but standardized surveys of selected nesting beaches that began in the 1980's (1973 for Hawaiian green turtles) provide an indication of whether turtle relative abundances are declining, stable, or increasing.

In the Atlantic Ocean, southeast U.S. nesting populations of green turtles seem to be increasing, but are not genetically distinct from other nesting populations. The Kemp's ridley turtle, after dramatic earlier declines, appears to be in the earliest stages of recovery under strict protection (including full protection of nesting females and required use of turtle excluder devices).

FKNMS

Hawksbill turtle off the coast of Florida.

Other species in the Atlantic are not faring as well as the green and Kemp's ridley. Leatherback turtle nesting populations in the United States are stable but small in number, but the status and trends of larger populations in the Guianas and Trinidad are unclear. The Florida subpopulation of loggerhead turtle is in decline.

Sea turtles in the Pacific Ocean face continued threats, and some species are currently experiencing serious population declines. Although the olive ridley does not nest on any U.S. beaches, it faces continued threats in U.S. and other waters from incidental capture in trawl and longline fisheries. The loggerhead has two primary nesting locations in the Pacific Ocean—Japan and eastern Australia; current nesting and foraging data from eastern Australia indicate a severe decline for the species. Serious declines are also occurring for leatherback turtles at all major nesting beaches throughout the Pacific, primarily due to the overharvest of eggs, direct harvest of adult turtles, and incidental mortality from fishing. The exploitation of hawksbill turtles for their shells remains an ongoing concern for the conservation of the species; a recent decision by Japan to end the import of hawksbill shells was an important conservation achievement. The degradation and destruction of coral reefs important to hawksbills for food and habitat is also a major threat to their recovery. Green turtles have shown continued population increases in the Northwestern Hawaiian Islands due to reduced human-caused mortality under ESA protection, but populations in many other Pacific Island areas continue to decrease as a result of the harvest of eggs and adults by humans.

ISSUES OF NATIONAL CONCERN

The management of living marine resources is complex and involves many considerations, including biology, economics, sociology, and politics. Changing conditions require resource managers to continually make adjustments to management schemes, even in regions and fisheries that are currently at healthy abundance levels with catches near their sustainable yield levels. In order to increase the long-term benefits from those stocks that are currently overfished, the difficult issues and practices that have led to the overfished status must be confronted. In each of the 24 units in this report, the major issues affecting the resources and their management are raised. Although each unit has its own unique issues affecting the management of its resources, some issues are common across many LMR's or important at the National level and are discussed below.

OAR/NURP

Fishing is prohibited on all three stocks of Nassau grouper (South Atlantic, Gulf of Mexico, and Caribbean) to allow the stocks to rebuild.

Stock Rebuilding and Recovery

The goal of fisheries management is conservation of living marine resources for maximum societal benefits. A stock that is depleted (i.e. below B_{MSY}) or overfished cannot be fully utilized until it has been rebuilt, and management restrictions must remain in place while rebuilding is occurring. The list of stocks that are overfished or below B_{MSY} includes some of our Nation's most valuable fishery resources, including New England groundfishes, several pelagic highly migratory fish stocks (including Atlantic albacore, bluefin tuna, bigeye tuna, several billfishes, and eastern Pacific bigeye tuna), several Southeast reef fishes, some Pacific Coast groundfish stocks, and crabs and groundfishes in Alaska (Table 20). The Northeast Region presents the largest number of depleted stocks (see Tables 4 and 5), although examples of resource depletion can be found in

Stock	Regional ecosystem	*OLO* unit	Recent average yield (RAY)	Sustainable yield (MSY)	Change (t)	Change (%)
Acadian redfish	Northeast Shelf	1	487	8,200	7,713	1,584%
American plaice	Northeast Shelf	1	1,627	4,900	3,273	201%
Atlantic cod—coastwide	Northeast Shelf	1	8,852	41,226	32,374	366%
Atlantic halibut	Northeast Shelf	1	14	175	161	1,150%
Haddock—coastwide	Northeast Shelf	1	8,836	26,593	17,757	201%
Ocean pout	Northeast Shelf	1	294	1,500	1,206	410%
Pollock	Northeast Shelf	1	6,190	13,861	7,671	124%
Red hake—Gulf of Maine/N. Georges Bank	Northeast Shelf	1	165	2,000	1,835	1,112%
Silver hake—Gulf of Maine/N. Georges Bank	Northeast Shelf	1	466	Unknown	Unknown	Unknown
Silver hake—S. Georges Bank/Mid-Atlantic	Northeast Shelf	1	6,475	Unknown	Unknown	Unknown
White hake	Northeast Shelf	1	2,543	4,069	1,526	60%
Windowpane—S. New England/Mid-Atlantic	Northeast Shelf	1	385	900	515	134%
Winter flounder—coastwide	Northeast Shelf	1	5,407	14,942	9,535	176%
Yellowtail flounder—coastwide	Northeast Shelf	1	5,250	25,401	20,151	384%
Spiny dogfish	Northeast Shelf	1	6,451	Unknown	Unknown	Unknown
Black sea bass	Northeast Shelf	1	2,200	Unknown	Unknown	Unknown
Goosefish—northern stock	Northeast Shelf	1	10,800	Unknown	Unknown	Unknown
Goosefish—southern stock	Northeast Shelf	1	10,500	Unknown	Unknown	Unknown
Scup	Northeast Shelf	1	6,955	Unknown	Unknown	Unknown
Summer flounder	Northeast Shelf	1	13,484	21,444	7,960	59%
Tilefish	Northeast Shelf	1	918	2,000	1,082	118%
Bluefish	Northeast Shelf	2	9,706	51,890	42,184	435%
Butterfish	Northeast Shelf	2	1,468	12,175	10,707	729%
American shad	Northeast Shelf	3	367	Unknown	Unknown	Unknown
Atlantic salmon	Northeast Shelf	3	0	Unknown	Unknown	Unknown
Atlantic sturgeon	Northeast Shelf	3	0	Unknown	Unknown	Unknown
Striped bass	Northeast Shelf	3	15,933	16,427	494	3%
Black sea bass	Southeast Shelf	8	770	1,730	960	125%
Goliath grouper	Southeast Shelf	8	0	Unknown	Unknown	Unknown
Nassau grouper	Southeast Shelf	8	0	Unknown	Unknown	Unknown
Red porgy	Southeast Shelf	8	47	450	403	857%
Snowy grouper	Southeast Shelf	8	130	142	12	9%
Other groupers	Southeast Shelf	8	489	Unknown	Unknown	Unknown
Atlantic croaker	Southeast Shelf	9	15,224	50,000	34,776	228%
Red drum	Southeast Shelf	9	709	Unknown	Unknown	Unknown
Pink shrimp	Southeast Shelf	11	551	786	235	43%

Table 20

Potential gains in yield in metric tons (t) from rebuilding stocks currently classified as either overfished/rebuilding or below B_{MSY}. Values are the U.S. share only, except for Highly Migratory Species. When a range of values is available for the MSY estimate, the lower end of the range is used to calculate totals. Atlantic sharks (Unit 6) were not considered for this analysis because RAY for these stocks is expressed in thousands of fish instead of metric tons and cannot be converted to weights. (Table continued on next page.)

all other Regions. Table 20 indicates that if stocks currently classified as overfished, rebuilding, or below B_{MSY} were rebuilt to healthy population levels (i.e. B_{MSY}), U.S. fishery yields could potentially increase up to 23% over recent yields. This is a conservative estimate, using the lower end of ranges and the RAY when MSY is unknown, but it illustrates the consequences to fishery yield of depleted fishery stocks.

Stock	Regional Ecosystem	*OLO* unit	Recent average yield (RAY)	Sustainable yield (MSY)	Change (t)	Change (%)
King mackerel—Gulf group	Gulf of Mexico	7	4,434	5,183	749	17%
Red snapper—Gulf of Mexico	Gulf of Mexico	8	3,657	15,000	11,343	310%
Red drum—Gulf of Mexico	Gulf of Mexico	9	5,869	7,900	2,031	35%
Nassau grouper—Caribbean	Caribbean	8	0	Unknown	Unknown	Unknown
Queen conch	Caribbean	11	110	Unknown	Unknown	Unknown
Chinook salmon	California Current	12	5,106	5,200	94	2%
Coho salmon	California Current	12	15,642	17,600	1,958	13%
Bocaccio	California Current	15	81	1,974	1,893	2,337%
Canary rockfish	California Current	15	55	1,574	1,519	2,762%
Cowcod	California Current	15	2	61	59	2,950%
Darkblotched rockfish	California Current	15	186	621	435	234%
Pacific ocean perch	California Current	15	104	1,411	1,307	1,257%
Widow rockfish	California Current	15	196	2,000	1,804	920%
Yelloweye rockfish	California Current	15	15	44	29	193%
Pacific cod—Bering Sea and Aleutian Islands	Alaska Ecosystem	19	208,717	207,000	–1,717	–1%
Walleye pollock—Eastern Bering Sea	Alaska Ecosystem	19	1,483,411	1,640,000	156,589	11%
Walleye pollock—Gulf of Alaska	Alaska Ecosystem	19	72,262	95,429	23,167	32%
Blue king crab—Pribilof Islands	Alaska Ecosystem	20	0	1,179	1,179	NA
Blue king crab—Saint Matthews Island	Alaska Ecosystem	20	0	1,995	1,995	NA
Snow crab	Alaska Ecosystem	20	12,976	125,397	112,421	866%
Shrimp	Alaska Ecosystem	20	853	14,722	13,869	1,626%
Bottomfishes—Hawaiian Islands	Pacific Islands Ecosystem	17	274	368	94	34%
Seamount Groundfishes	Pacific Islands Ecosystem	17	0	2,123	2,123	NA
Albacore—North Atlantic	Highly Migratory Species	5	32,400	26,800–34,100	–5,600	–17%
Bigeye tuna—Atlantic	Highly Migratory Species	5	74,500	68,000–99,000	–6,500	–9%
Blue marlin—Atlantic	Highly Migratory Species	5	2,500	Unknown	Unknown	Unknown
Bluefin tuna—Western Atlantic	Highly Migratory Species	5	1,900	3,000–3,400	1,100	58%
Sailfish—Western Atlantic	Highly Migratory Species	5	900	Unknown	Unknown	Unknown
Swordfish—North Atlantic	Highly Migratory Species	5	12,000	12,800–14,790	800	7%
White marlin—Atlantic	Highly Migratory Species	5	400	Unknown	Unknown	Unknown
Bigeye tuna—Eastern Pacific	Highly Migratory Species	18	109,987	81,350	–28,637	–26%
Subtotal for "known" MSY			2,142,908	2,639,542	496,634	23%
Subtotal for "known" MSY excluding HMS			1,912,121	2,447,592	535,471	28%
Total			2,192,230	2,688,864	496,634	23%

Table 20

Continued from previous page.

In many fisheries with overfished stocks, rebuilding of stocks is the most pressing issue. The MSRA requires that FMC's (or the Secretary of Commerce, when necessary) develop rebuilding plans for overfished stocks to rebuild the stocks as quickly as possible. For some stocks, rebuilding may occur over a few years, but for others rebuilding may take decades. The amount of time required to rebuild a stock depends on the species' longevity and growth potential, environmental conditions, and on the management controls put into place (which may be affected to a limited extent by economic and social considerations).

Implementation of rebuilding plans can sharply curtail fishing opportunities not only for overfished species, but also for co-occurring species, affecting multiple sectors of a fishery. In the short term, fishermen may see allowable harvests and landings in some fisheries drop to near-historic lows during rebuilding, as catch quotas are reduced to allow overfished species to rebuild to sustainable stock levels. However, there are many benefits that can be gained from rebuilding overfished stocks. The economic benefits from restoring depleted stocks to healthy levels are apparent to the commercial and recreational fishing industries and to fishing communities. The benefits to the Nation of restoring important components of ecosystems and the functions associated with healthy ecosystems are more difficult to quantify.

Stock recovery and conservation is also a vital issue for protected species. Of the 190 marine mammal stocks found in U.S. waters, 27 are listed as threatened or endangered under the ESA and an additional 4 stocks are classified as depleted under the MMPA. All sea turtle stocks are listed under the ESA, as well as a number of other stocks, including several Pacific salmon stocks, other anadromous and marine fish stocks, several invertebrate stocks, and one marine plant (Johnson's sea grass). As one means of recovering protected species, the ESA requires development of recovery plans for all species listed as threatened or endangered; these plans help to organize and guide the recovery process. A wide variety of methods are in use to recover protected species around the country. These include measures to reduce interaction with, and bycatch in, commercial and recreational fisheries, such as time and area closures and gear restrictions or modifications; measures to reduce mortality and serious injury associated with other human activities (ship collisions, etc.); research to increase available information on protected species biology, ecology, habitat requirements, and threats; and measures to protect, conserve, and rehabilitate critical habitat used by protected species. Recovery of protected species not only restores vital ecosystem functions and the intrinsic value associated with these species, but also can lead to delisting of species and a reduction in the management restrictions in place to recover the stock.

Recreational Fishing

Marine recreational fishing supports nearly 350,000 jobs and generates $30.5 billion annually in the United States. It is the top outdoor recreational sport, attracting 17 million saltwater anglers in the U.S. EEZ. In every region of the United States, sport fishing is a popular pursuit, attracting an ever-increasing number of users and contributing millions of dollars to local economies. Because recreational fishing is so popular in the United States, keeping track of recreational fishermen and their catches is an important part of managing our Nation's fisheries. High quality marine recreational fisheries statistics are required by law and are necessary for effective, fair, and responsible management of fishery resources. Improving marine recreational fisheries statistics will also increase recreational fishing opportunities for Americans, enhance and protect stocks, improve the economy, and promote the best use of the resources of the Nation.

Mary Hollinger, NOAA/NODC

Two young anglers with their striped bass catch in Chesapeake Bay, Maryland.

NMFS has a Recreational Fisheries Statistics Program whose mission is to provide accurate, precise, and timely fisheries-dependent information for U.S. marine waters through the coordination and administration of recreational fishing surveys nationwide. The Program has historically collected information on participation, effort, and catch through its Marine Recreational Fisheries Statistics Survey (MRFSS). Economic questions were also added to the MRFSS to allow NMFS to estimate the economic impacts of marine recreational fishing in addition to the other data currently collected.

In April 2006 the National Research Council (NRC) completed a review of recreational data collection programs at the request of NMFS and found that improvements could be made to MRFSS to increase the quality and accuracy of its information (NRC, 2006). The report iden-

Charles Gardner, NMFS

Measuring a pair of banded rudderfish during a NMFS Marine Recreational Fisheries Statistics Survey.

tified a number of potential problems with the sampling and estimation designs employed in the current surveys and questioned the adequacy of the existing surveys to provide the statistics needed to support accurate stock assessments and appropriate fishery management decisions. In the report, the NRC recommended that current surveys be redesigned to improve their effectiveness, the appropriateness of their sampling procedures, their applicability to various kinds of management decisions, and their usefulness for social and economic analyses.

NMFS has taken the recommendations of the NRC report very seriously and, working together with the interstate marine fisheries commissions, state agencies, regional fishery management councils, and constituents, has already begun the process of responding to the recommendations and making the changes necessary to develop a credible and usable data collection program. The existing MRFSS program will be phased out over the next several years and a new program, the Marine Recreational Information Program (MRIP), will replace it. The MRIP is designed to improve the collection and analysis of marine recreational fishing data. Its surveys will better answer fundamental questions important to resource management, such as who is fishing and what is being caught. The MRIP will ultimately help policymakers gain a more complete understanding of the role of recreational fishing in the conservation of living marine resources and marine ecosystems. In January 2009, NMFS will deliver a comprehensive report to Congress on the MRIP and its status.

The recently passed MSRA requires additional improvements to the collection of marine recreational fisheries data. The MSRA requires the Secretary of Commerce to establish and implement a regionally based saltwater angler registry program to track recreational fishermen in each of the eight fishery management regions. A proposed rule for the new Saltwater Angler Registration Program was released in June 2008. Such a registry program is deemed necessary because 1) accurately counting the United States' marine anglers is widely acknowledged as being a necessary step towards improving Federal fisheries management; and 2) the existing state-based system of fishing licenses is incomplete, which hampers enumeration of this important user group and subsequent collection of angler information for fisheries management. The Federal program will provide for registration (including identification and contact information) of individuals engaging in recreational fishing in the U.S. EEZ for anadromous species, or for Continental Shelf fishery resources beyond the EEZ; and if appropriate, will provide for the registration (including ownership, operator, and identification) of vessels used in these fishing activities. The resulting regionally based registry programs will be used to support more efficient statistical surveys of recreational fishing.

Paula Whitfield, NOAA

Marine protected areas protect species and the habitats they depend on, such as this seagrass bed.

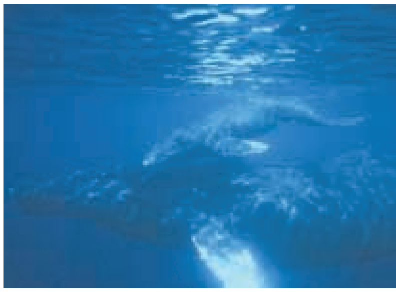
Place-based Management

Place-based management is a broad term that refers to a range of management tools, including fishery management zones, marine reserves, and marine protected areas (MPA's). Sometimes the terms "marine reserve" and "MPA" are confused or used interchangeably, but these are actually different kinds of management zones. Marine reserves are relatively rare "no-take" areas that prohibit all extractive uses and are designed to protect spawning or nursery grounds or to protect ecologically important habitats. MPA is an umbrella term that encompasses a wide variety of place-based approaches to marine management and includes multiple-use conservation areas that may permit both consumptive and non-consumptive uses such as fishing, diving, boating, and swimming. Multiple-use MPA's allow managers to protect ecosystems and, at times, support sustainable fisheries while allowing other user groups to enjoy the resource. Gear restrictions or zoning schemes are sometimes used in MPA's to manage potentially harmful activities like fishing, or to restrict them to appropriate habitats and/or seasons. Fishery management zones include area closures that may be gear- or species-specific and may be temporary, seasonal, or permanent.

The term "MPA" may be relatively new, but the use of place-based management is not. Resource managers have used place-based management tools for decades to manage living marine resources in the United States. Examples include the Nation's 13 National Marine Sanctuaries, the recently designated Papahānaumokuākea Marine National Monument in the Northwestern Hawaiian Islands, dozens of fishery management zones administered by NMFS, and many smaller MPA's and marine reserves around the United States. The first National Marine Sanctuary was established in 1975, and the use of fishery management zones as a management tool by fishery managers has a long history in the United States.

Although place-based management is not new, the use of these management tools, especially MPA's, is gaining a new emphasis. Traditional management measures have failed to prevent stock depletion in some fisheries, and managers are increasingly being tasked with protecting habitat, particularly from the effects of certain types of fishing gear. Place-based management tools can be used to enhance rebuilding of overfished stocks and protect habitat, and may be combined with other management tools such as effort controls and gear restrictions to achieve conservation and management goals. Place-based management can also contribute to the conservation and recovery of protected species, and is useful for protecting the critical habitat of endangered and threatened species. Because ecosystem-wide processes can be managed in an MPA, these areas are ideal for contributing to an EAFM. Many existing examples of EAFM include MPA's as important tools for the conservation and management of living marine resources and their ecosystems. In May of 2000, Executive Order 13158 on Marine Protected Areas was issued, emphasizing the emerging importance of MPA's as a tool for the conservation and management of living marine resources in the United States. The Executive Order (EO) directs Federal agencies to work with government and non-governmental partners to increase protection and sustainable use of ocean resources by strengthening and expanding a national system of MPA's.

Dave Glickman



Marine protected areas can be created to protect a variety of fishery stocks, protected species, habitats, or life history stages. The Hawaiian Islands Humpback Whale National Marine Sanctuary protects breeding humpback whales and their young in important tropical wintering habitats around Hawaii.

Place-based management is used to complement traditional management measures in many areas to conserve and protect living marine resources. Management actions implemented by NMFS to protect endangered Steller sea lions in Alaska include setting no-entry buffer zones around rookeries to prevent human disturbance of sea lions and a prohibition on groundfish trawling within 10–20 n.mi. of certain rookeries to minimize competition for fish between commercial fisheries and sea lions. The Hawaiian Islands Humpback Whale National Marine Sanctuary was created to protect endangered humpback whales and their breeding grounds in Hawaii. The North Pacific and South Atlantic FMC's use a variety of spatial management zones in addition to traditional management measures to manage their fisheries resources; the South Atlantic FMC is also currently considering MPA's as a management tool to conserve deepwater snapper-grouper species. Similarly, the Gulf Reeffish FMP developed by the Gulf of Mexico FMC includes several MPA's in its regulations. In the Northeast, three large areas have been closed since the mid 1990's to protect and help rebuild depleted groundfishes; these closed areas have been used in combination with traditional management restrictions to manage the stocks. The closed areas in the Northeast also benefited the Atlantic sea scallop stock and fishery, increasing stock biomass and leading to large increases in scallop landings and revenues when the areas were reopened to scallop harvest. Because of the benefits to the scallop fishery, the Sea Scallop FMP has been amended to include rotational area management to close some fishing areas to allow young scallops to grow, and to shift effort toward larger scallops with the highest meat yields.


John Butler, SWFSC

A variety of marine reserves and marine protected areas have been created on the West Coast to protect species such as these whitespeckled and starry rockfishes.

The West Coast is currently at the forefront of place-based management activity in the United States, and has a growing network of multiple-use conservation areas and reserves supported by strong science and stakeholder input. Major portions of the Continental Shelf off the U.S. West Coast have been closed to fishing since 2003, in addition to several rockfish conservation areas implemented the same year to protect overfished species. Additionally, in 2006, Federal regulations introduced a network of 51 MPA's to protect West Coast groundfish EFH from fishing gear impacts. This network will serve as a pilot project for the national MPA system described in EO 13158; its goals are to facilitate the effective use of MPA's as an ecosystem management tool to conserve and protect living marine resources and their habitats, and to inform the development of a regionally-based national system of MPA's. The coastal states (California, Oregon, and Washington) are also adopting networks of marine managed areas to conserve and protect habitat and marine populations inshore of the Federal EEZ. California is leading the way with its Marine Life Protection Act Initiative, which divides the coast of California into five study regions and is implementing MPA networks in each region; so far, the State has adopted 29 new management areas in the central coast study region, and the planning process for the north central coast is nearly complete.

Limited Access Privilege Programs

After the initial passage of the 1976 Act, domestic fisheries rapidly expanded in U.S. waters to replace the excluded foreign fleets. This combined with advances in technology over the past 30 years that have allowed fishing vessels to harvest more quickly and efficiently has caused fleets in some fisheries to expand beyond sustainable levels. When there are too many vessels present in a fishery than are necessary to harvest the resource, this is termed overcapacity. Many fisheries throughout the Nation are currently experiencing overcapacity. Overcapacity leads to a number of problems, including exacerbating overfishing, increasing safety concerns, gear conflicts and allocation issues, and reducing the economic viability of fisheries and creating market gluts. Overcapacity often can lead to greater fishing restrictions.

One solution to the overcapacity problem is the implementation of limited access privilege programs (LAPP's; also called dedicated access privilege) such as individual transferable quota (ITQ) and individual fishing quota (IFQ) programs. LAPP's typically work by allocating a percentage of the total allowable catch for the fishery to each qualifying individual or business entity. Allocation can be accomplished in several different ways, but is usually based on the historical landings associated with a permit or vessel; other considerations may include allocating a portion of the quota equally among qualifying fishermen. In many cases, it is prohibitively expensive for new participants not originally allocated quotas to enter the fishery once allocation has taken place, effectively solving the overcapacity issue. However, LAPP's often have a small amount of quota set aside for distribution to or purchase by new entrants and/or non-qualifying small-scale fishermen.

The MSRA contains language supporting the development of LAPP's in U.S. fisheries and provides specific guidelines and requirements for the implementation of such programs. LAPP's should promote conservation and management goals, and the MSRA specifies that such programs must assist in the rebuilding of a stock if established in a fishery that is overfished or subject to a rebuilding plan, or contribute to reducing capacity if established in a fishery that is determined to have overcapacity. LAPP's also must promote fishing safety and social and economic benefits in addition to their fishery conservation and management goals.

There are many benefits of LAPP's. Foremost among these are achieving conservation goals such as reducing fishing mortality and increasing stock size to sustainable levels. However, there are many direct benefits to fishermen as well. By reducing overcapacity, LAPP's result in more efficient and more sustainable fisheries. LAPP's also increase safety for fishermen, especially in fisheries where derby fishing[16] existed prior to implementation of the LAPP. The increased flexibility for fishermen to fish during a longer fishing season prevents market gluts, which combines with greater control over product quality to increase profitability of fisheries. Additionally, LAPP's increase the level of individual accountability, and encourage greater levels of responsibility and stewardship.


Aleksey Zuyev, Murmansk Marine Biological Institute

King and Tanner crab fisheries in the Bering Sea have recently entered the Crab Rationalization Program, which allocated crab resources among harvesters, processors, and coastal communities. The Program is a limited access system that addresses conservation and management issues associated with the previous derby fishery, reduces bycatch and associated discard mortality, and increases the safety of crab fishermen by ending the "race for fish."

Limited access privilege programs may also have some drawbacks as well. Market transfers can redistribute fishery infrastructure, impacting local economies and coastal communities dependent on fisheries. Similarly, concentration of quota ownership can concentrate fishery resource usage. Creation of LAPP's may also create a situation where new entrants or those who did not receive an allocation have difficulty entering the fishery due to the cost of quota shares. Additional rules or special programs built into the LAPP either at implementation or after implementation can often mitigate any potential negative impacts.

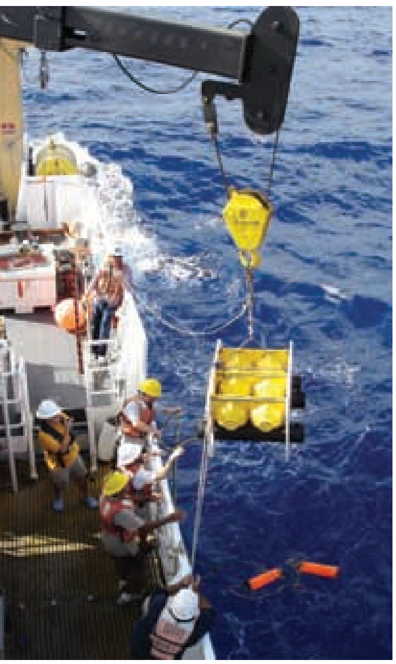
Limited access privilege programs have already been implemented in a total of 12 U.S. fisheries. Alaska leads the way with six current LAPP's; other programs exist in the Northeast Shelf, Gulf of Mexico, and California Current RE's. Five additional LAPP's are currently planned for the tilefish, Atlantic sea scallop, Gulf of Mexico grouper, South Atlantic snapper-grouper, and the West Coast groundfish trawl fisheries. The Atlantic surfclam and ocean quahog fishery in the Mid-Atlantic is one of the oldest LAPP's in the United States, operating under an ITQ system enacted in 1990; the ITQ system has successfully rationalized harvesting capacity, promoted higher profitability, and helped to reduce fishing mortality. In Alaska, the halibut fishery moved from an open access fishery with a short fishing season to a nearly 8-month-long season under an IFQ program; under IFQ, the resource has been healthy while the total catch has been near record levels, and most components of the fishery have been very successful in recent years. The crab fisheries in Alaska just recently underwent the Crab Rationalization Program, in which crab resources were allocated among harvesters (as IFQ's), processors (as individual processing quotas,

[16]A fishery of brief duration during which fishermen race to take as much catch as they can before the fishery closes.

or IPQ's), and local communities (as community development quotas, or CDQ's). The Crab Rationalization Program addresses conservation and management issues associated with the previous derby fishery, reduces bycatch and associated discard mortality, and increases the safety of crab fishermen by ending the "race for fish." An ITQ program in the South Atlantic wreckfish fishery, established under the South Atlantic Reeffish FMP, has stabilized management of that resource while assuring fishermen a stable, reasonable price.

Scientific Advice and Adequacy of Assessments

Timely, precise, and comprehensive scientific advice serves as the basis for preventing overfishing and rebuilding overfished stocks, guiding and tracking recovery of protected resources, and enveloping fisheries management in a more holistic approach for an EAFM. NMFS is mandated by legislation and guided by executive order to provide the best scientific information available[17] for stewardship of the Nation's living marine resources. The MMPA established three independent regional scientific review groups to advise and report on the status of marine mammals in Alaskan waters, along the Pacific Coast (including Hawaii), and along the Atlantic Coast (including the Gulf of Mexico) and requires evaluation of the interactions between marine mammals and commercial fisheries. The ESA requires the designation of critical habitat for endangered and threatened species, the development of recovery plans and long-term conservation plans, and authorizes research to learn more about protected species. The recently passed MSRA increases NMFS' responsibilities for marine fisheries stocks by requiring greater use of science in the fishery management process and authorizing the establishment of a peer review process to strengthen the scientific information used to advise the FMC's about the conservation and management of fisheries.



Allen Shimada, NMFS

Advanced scientific technologies such as this acoustic buoy being deployed from the NOAA ship *Oscar Elton Sette* help to collect environmental data used in stock assessments.

The National Marine Fisheries Service's living marine resource and essential habitat assessments provide the basis for scientific advice to management. The provision of the best scientific information for the management of fisheries involves collecting and evaluating relevant data; analyzing those data by using an assessment model of the stock and its fishery; subjecting the data, methods, and assessment results to a peer-review process; and delivering the results of the assessment to the FMC and other clients. A fully adequate fish stock assessment provides estimates of historical, current, and future abundance of the stock and mortality caused by fishing; in other terms, it provides the necessary information to determine if overfishing is occurring and if the stock has become depleted. Data sources for stock assessments include fishery-dependent data collected from fishermen, processors and observers, and fishery-independent data collected through at-sea resource surveys conducted by NOAA Fisheries Survey Vessels (FSV's) and program-chartered fishing vessels. A National Research Council review in 1998 determined that fishery-independent surveys are the most reliable source of information on trends in fish abundance (NRC, 1998). NOAA's multiyear initiative to modernize and replace its aging fleet of FSV's is a key component to improving NMFS' fishery-independent data collection and providing multidisciplinary capabilities to simultaneously collect biological, environmental, and ecosystem-level data. Such

[17]In the United States, use of the term "best scientific information available" and related terms originated in MMPA legislation, in later amendments to the ESA, and in establishing management standards for marine fisheries in the original 1976 Act, carried through in the reauthorized MSA and refined in the MSRA.

Wayne Hoggard, NMFS

The launch of the NOAA Ship *Bell M. Shimada*, the fourth in a series of new state-of-the-art fishery survey vessels for the NOAA fleet. The ship, designed to conduct both fisheries and oceanographic research, is one of the most technologically advanced survey vessels in the world. Once operational, the *Shimada* will support NMFS' living marine stewardship and ecosystem management requirements in the California Current and adjacent international waters of the eastern tropical Pacific Ocean.

multidisciplinary approaches are necessary to support ecosystem-based management, which requires additional information beyond target species abundance trends.

Stock assessments also provide information on the health of marine mammals and other protected resources. The MMPA requires that Stock Assessment Reports be prepared at least every 3 years for all cetacean and pinniped stocks in U.S. waters. The data used to assess protected species includes fishery-dependent data on fishery interactions with protected species, biological research conducted by NMFS scientists, and surveys performed aboard NOAA FSV's. The information in protected resource assessments is necessary to design effective and efficient conservation and recovery programs.

Many stocks still lack adequate assessment advice about their current status, which diminishes NMFS's ability to sufficiently manage these stocks (i.e. select appropriate thresholds or limits and determine status). Of the stocks reported in Units 1–20, 18% have unknown harvest rates (Table 3) and 17% have unknown stock statuses (Table 4). A number of stocks are still classified as having undefined harvest rates or stock status, meaning that no thresholds have been set in the FMP to measure current fishing mortality or biomass levels against. Although these stocks account for only a small proportion of the total RAY, they include stocks that support important local fisheries and important ecosystem components such as sharks and several pelagic species. Of the marine mammal stocks listed in Units 21–23, 35% have no minimum population estimate (N_{min}) available, 44% have unknown values for potential biological removal (PBR) or total annual human-caused mortality, and 85% do not have population trends available. In most cases, data availability is much more limiting at this point than assessment theory, models, or computation capacity. To improve scientific advice to management, more comprehensive data

Fishery scientists process the catch aboard a chartered fishing vessel in a survey of Gulf of Alaska groundfish stocks.

collection, better species identification and stock delineation, and additional biological research is needed to enable the assessment of additional stocks.

The practical consequence of NMFS' mandate to provide the best science information available is that NMFS has the responsibility to improve scientific information for better decision making. Improved data collection for many stocks will be necessary before there is sufficient information available to assess these stocks. For some fisheries stocks, such as many shark and reef fish species in the Atlantic and Pacific, species-specific catch data are needed to move from multispecies complex assessments to adequate assessments completed on an individual stock basis. Other stocks will need additional fishery-independent surveys to provide data for assessments; an example is some of the nearshore rockfish species on the U.S. West Coast that cannot be adequately sampled with traditional techniques because of their rocky habitats. Additionally, the requirements for the next generation of fish and protected resource stock assessments will necessitate continued improvements to data and refinements to models to allow managers to emphasize ecosystem considerations such as multispecies interactions, trophic structure, environmental effects, fisheries oceanography, socioeconomic use data, and spatial and seasonal analyses.

Although there is still a need for improved data collection to support stock assessments and advice to management, substantial advances have been made toward improving the adequacy of assessments. Improving data collection is a top priority in order to improve the quality of scientific advice to management. Data collection improvements are being achieved through a number of programs, including increased cooperative research programs with university and fishing industry partners; increased observer coverage; improved recreational fishing surveys; higher quality fishery-independent surveys being conducted on the new state-of-the-art NOAA Fishery Survey Vessels (FSV's); and outreach efforts to improve species identification and reporting from commercial fishermen. Such improvements in data collection have led to new insights into the biology of some species that have allowed for more precise stock assessments. Additionally, improvements in data collection for some stock complexes have allowed for some stocks to be assessed as single species independent of the rest of the complex. New technologies are also playing an important role in enhancing NMFS' capacity to provide more efficient and accurate population surveys (see Feature Article "Improving Fisheries with Advanced Sampling Technologies" for more information).

OUTLOOK

The recent reauthorization of the MSA highlights the main issues facing living marine resource management in the United States in the 21st century. The movement towards ecosystem approaches to management, ending overfishing, rebuilding overfished stocks to healthy and sustainable levels, improving data collection and the quality of scientific advice for management, and developing new approaches to meet these goals are currently some of the most important issues of national concern.

Substantial advances have been made since the first *Our Living Oceans* was published in 1991. However, because each stock and each fishery is unique, the progress made towards resolving the problems facing them as a whole may seem slow. Additionally, our oceans and living marine resources face ever-increasing pressures from intensifying fishing effort and technological advances allowing for more efficient harvests, increasing demand for seafood products and recreational fishing experiences, habitat pressures from urbanization of coastal zones and population growth, and the long-term effects of climate change. These increasing pressures act to balance out some of the forward progress that has been made and create additional challenges for scientists and managers working to conserve and protect the Nation's LMR's.


John Butler, SWFSC

A school of pygmy rockfish.

The outlook for the Nation's living marine resources depends in good part on the management actions that are being taken at present. The MSRA gives NMFS and the FMC's powerful new tools to end overfishing, reduce overcapacity, and accelerate the rebuilding of depleted stocks. Additionally it encourages movement toward ecosystem-based management, which will allow for a more holistic approach to managing fisheries and the marine ecosystems they are an integral part of. Substantial progress toward implementation of the MSRA management measures has already been made, but the success of these new management tools depends on continued progress and effective implementation in the foreseeable future. Losses in yield may occur as an immediate cost of rebuilding some overfished stocks, but these are expected to last only in the short-term. Judging from the remarkable ability of many stocks to recover from overfishing, the outlook is very positive over the long term regarding the potential for higher sustainable yields from healthy stocks.

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Part 2
Feature Articles

Photo on previous page: Conch beds move en masse when food is scarce. Photo courtesy of G. Wenz, NURP/ Caribbean Marine Research Center.

Prelude to Sustainability: Ending Overfishing in U.S. Fisheries

Feature Article 1

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OVERFISHING: *"a rate or level of fishing mortality that jeopardizes the capacity of a fishery to produce the maximum sustainable yield on a continuing basis."*
—Magnuson-Stevens Fishery Conservation and Management Act

INTRODUCTION

Sustainable management of fisheries is a core mission for the National Marine Fisheries Service (NMFS). Sustainable fishing has been defined as "fishing activities that do not cause or lead to undesirable changes in the biological and economic productivity, biological diversity, or ecosystem structure and functioning from one human generation to the next" (NRC, 1999). It is necessary to end overfishing in order to achieve the goal of sustainable fisheries. Ending overfishing is a priority of both the Administration and Congress. In 2006, Congress amended the Magnuson-Stevens Fishery Conservation and Management Act (MSA) with the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006 (MSRA) to include requirements to end overfishing by 2010.

This article describes the problem of overfishing in U.S. marine fisheries, efforts to address it, and the outlook for the future. The outlook is optimistic because management measures have been implemented or are under development to end overfishing for most stocks, and because the MSRA requires strict annual catch limits starting in 2010 to ensure that overfishing does not occur.

A BRIEF HISTORY OF OVERFISHING SINCE THE MAGNUSON-STEVENS ACT OF 1976

Congress passed the Magnuson Fishery Conservation and Management Act in 1976 (1976 Act), establishing jurisdiction over fisheries out to 200 nautical miles (n.mi.), largely because foreign fleets were thought to be overfishing domestic fish stocks. The 1976 Act's stated purpose was "to take immediate action to conserve and manage the fishery resources found off the coasts of the United States." The 1976 Act established eight Regional Fishery Management Councils (FMC's) to develop fishery management plans (FMP's) for fisheries within their jurisdiction. It also established a process for phasing out foreign fishing in favor of domestic fisheries. The 1976 Act also established seven national standards for fishery management and conservation. National Standard 1 (NS1) states that "conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry."

The National Marine Fisheries Service first developed guidelines for NS1 in 1989. These guidelines directed the FMC's to amend all FMP's to include measurable definitions of overfishing for each stock or stock complex. In most FMPs', this requirement was met by defining recruitment overfishing,[1] which was generally specified in terms of a limit on fishing mortality rate. The most common definition of recruitment overfishing referred to fishing mortality rate that would reduce spawning biomass per recruit to 20 or 30% of the unfished level (Rosenberg et al., 1994). Although FMP amendments intended to end overfishing were implemented, management measures proved insufficient for many stocks, and some stocks continued to show declines in biomass.

The 1976 Act was reauthorized and amended by the Sustainable Fisheries Act of 1996 to form the Magnuson-Stevens Fishery Conservation and Management Act (MSA). The MSA introduced new requirements for specifying objective and measurable criteria for determining overfishing and for rebuilding overfished stocks. Revised NS1 guidelines to implement the new provisions were published in 1998.[2] These guidelines addressed an ambiguity in the statutory language by distinguishing between the condition of overfishing (fishing mortality rate too high) and the state of being overfished (stock biomass too low), and they required new FMP amendments to specify status determination criteria for determining overfishing and overfished status. The MSA also required NMFS to submit an annual report to Congress on the status of U.S. fisheries.

In spite of the strengthened provisions of the MSA, overfishing continued for some stocks in the 200-mile Exclusive Economic Zone (EEZ) for the entire 11-year period from 1997 through 2007. This was one of the major issues that Congress addressed in the 2006 reauthorization of the MSA. The MSRA requires establishment of annual catch limits (ACL) and accountability measures in all fisheries to ensure that overfishing does not occur. Fisheries subject to overfishing must have ACL's beginning in the 2010 fishing year, and all other fisheries must have ACL's beginning in the 2011 fishing year. The only exceptions to the ACL requirement are for some stocks managed under international agreements, or species such as shrimp that have a life cycle of approximately 1 year and are not subject to overfishing (MSA section 303).

In addition, the new law specifically requires that overfishing must be ended immediately when rebuilding plans are implemented (MSA section 304(e)(3)(A)). Previously, Councils were allowed 1 year to prepare a rebuilding plan after they were notified by NMFS that a stock was overfished. The rebuilding plan could allow overfishing to continue during some years, provided the biomass rebuilding goal was met in the required time. In contrast, the MSRA now gives Councils 2 years to prepare and implement rebuilding plans that, when implemented, must immediately end overfishing.

EFFECTS OF OVERFISHING

The primary impact of overfishing is its effect on stock biomass. The biomass level that supports the maximum sustainable yield (MSY) is the target biomass mandated by the MSA. High levels of overfishing can cause biomass to decline enough that a stock is considered to be overfished, and can prevent overfished stocks from rebuilding. Relatively small levels of overfishing lead to smaller declines in biomass, but any degree of overfishing, particularly over a period of years, may prevent stock biomass from reaching the MSY level mandated by the MSA.

In addition to the effect on the specific stock subject to overfishing, overfishing can also adversely affect marine ecosystems in several ways. Overfishing can contribute to increased levels of bycatch, which can have serious ecosystem impacts (Kelleher, 2005). Overfishing may also affect predator–prey systems (Pauly et al., 1998), contribute to the collapse of coastal ecosystems (Jackson et al., 2001), and lessen the productivity of target or nontarget species by affecting their habitat (Kaiser et al., 2004).

Additionally, overfishing has long-term negative impacts on the economy. Depleted fish stocks result in a loss of economic benefits as well as a reduction in the Nation's supply of wild-caught seafood. In the short term (before a stock becomes depleted), overfishing may increase harvests and revenue from the fishery; however, these increases are not sustainable, and in the long term they will have adverse economic impacts on fishing commu-

[1]Recruitment overfishing is generally defined as a reduction in spawning stock biomass to the point where recruitment is significantly reduced.

[2]Federal Register, 63 FR 24212, 5 May 1998.

nities. According to the Pew Oceans Commission (2003), "Increasing annual catches to long-term sustainable levels could add at least $1.3 billion to the U.S. economy." Ending overfishing has the potential to increase net economic benefits from currently overfished stocks (Sumaila and Suatoni, 2006).

WHY OVERFISHING PERSISTS

A number of factors have contributed to continued overfishing on U.S. stocks. They include the need by fishery managers to achieve multiple objectives, imperfect scientific knowledge about the population dynamics of stocks, the length of time needed to develop and implement new management measures, bycatch, overcapacity, and international fishing effort.

Fishery managers must weigh impacts on the fishing community against the need to quickly end overfishing. Ending overfishing necessitates reductions in catch until stocks can rebuild, and this reduces fishing income in the short term. Fisheries management stakeholders often express concerns that new regulations may affect certain sectors of the fishery disproportionately, change the character of the local processing infrastructure, or cause U.S. fishermen to lose market share to seafood imports.

Often, management decisions are based on considerations of acceptable risk. Sometimes confidence in the available scientific information is lacking, and managers may be unwilling to make major decisions based on incomplete data. More conservative or risk-averse approaches to end overfishing usually have greater short-term economic impacts on fishermen, whereas riskier approaches have fewer impacts on fishing communities in the short term but could result in even greater stock declines—and more drastic regulatory action—in the future.

In some instances, managers determine that particular management measures are adequate to end overfishing or achieve stock rebuilding, but new data or stock assessment approaches reveal that a stock is worse off than previously thought or that rebuilding plans are insufficient to meet targets. For example, the final environmental impact statement for Amendment 2 to the Consolidated Atlantic Highly Migratory Species FMP (NMFS, 2007a) cut the sandbar shark quota by 85% of 2003–05 levels. This dramatic cut was partly due to revisions in life history parameters between stock assessments of large coastal sharks conducted in 2002 and 2006. The new data from the 2006 assessment revealed that the existing quota was too high to allow the sandbar shark to meet its rebuilding target.

A great deal of time is needed to develop and implement management measures through an FMP amendment process, often several years. Only rarely can amendments be developed and implemented in less than 2 years, and management measures do not always successfully end overfishing. For example, the process of determining stock status and addressing overfishing may consist of the following steps:

- Data for a fishing year are collected and finalized; the stock assessment is completed; the overfishing determination is made; and the Council is notified (may take 1 year).
- FMP amendment is developed and approved (may take another 2 years).
- Management measures take effect in the fishery.
- After a few years of fishing under the new measures, another stock assessment needs to be conducted to determine the overfishing status (similar to the first step, this takes about 1 year).
  - If the stock assessment determines that overfishing is not occurring, then the status determination is changed (i.e. the stock is no longer listed as subject to overfishing).
  - If the stock assessment determines that overfishing is still occurring, it may be another 2 years before improved measures can be developed and implemented.

This outline of events illustrates why overfishing can persist for a number of years, even when management takes steps to end it. Because of limitations in the availability of data and the capacity to conduct stock assessments, several years may pass between stock assessments. For example, in 1994, Amendment 6 to the FMP for the Snapper–Grouper Fishery of the South Atlantic established a one-fish-per-trip limit (commercial and recreational) for Warsaw grouper and speckled hind, and also prohibited sale of the fish. However, assessments will not take place for Warsaw grouper and speckled hind until 2012, so the effectiveness of these 1994 measures to end overfishing will not be determined for a few more years.

The annual catch limit provisions required by the MSRA, when implemented beginning in 2010, will largely solve this problem. They require that FMP's contain ACL's and accountability measures to control fishing mortality on an annual basis and to make adjustments quickly (in the next year, if possible) to limit mortality and prevent overfishing. This is similar to the system used for some stocks on the West Coast, where overfishing is determined by comparing annual catch levels with a specified limit, called the overfishing level. For these stocks, annual changes in the status of the stock can be readily detected and reported.

Bycatch can contribute to overfishing problems. Bycatch is "the discarded catch of any living marine resource plus unobserved mortality due to a direct encounter with fishing gear" (NMFS, 2004a). Large amounts of discards of juvenile and adult fish belonging to a stock that is subject to overfishing can significantly delay the ending of overfishing. For example, it will not be possible to end overfishing of red snapper without addressing the significant levels of juvenile bycatch in the Gulf of Mexico shrimp fishery, as well as discards of juveniles in directed red snapper fisheries. In 2008, NMFS issued a final rule to implement joint Amendment 27 to the FMP for the Reef Fish Resources of the Gulf of Mexico and Amendment 14 to the FMP for the Shrimp Fishery of the Gulf of Mexico,[3] which, among other things, allowed the implementation of seasonal closures of the Gulf shrimp fishery to reduce red snapper bycatch based on a 74% bycatch reduction target established in the final rule.

Overcapacity is another factor contributing to overfishing. Overcapacity is the difference between the estimated harvesting capacity and the commercial harvest quota for a fishery, which is assumed to be a target harvest level that will achieve the sustainability objectives for a fishery (NMFS, 2008a). For example, summer flounder and scup have been subject to overfishing since 2000; overcapacity in the Northeast summer flounder, scup, and black sea bass fishery was estimated to be 35% in 2004 (NMFS, 2008a). The Notice of Intent to prepare an environmental impact statement for Amendment 15 to the Summer Flounder, Scup, and Black Sea Bass FMP[4] suggested that overcapacity in the summer flounder and scup fisheries may be having negative impacts. Harvest privilege-based management, including limited access privilege programs (LAPP's) and similar programs, has a strong track record for reducing overcapacity (NMFS, 2008a). This occurs in part because, with an effective LAPP, fishermen are generally more willing and able to accept and adapt to quota reductions or other management actions taken to rebuild stocks and prevent or end overfishing of target and non-target species.

Finally, the United States also manages a number of stocks for which international fisheries make up the majority of the fishing mortality. For example, NMFS notified the Pacific and Western Pacific Fishery Management Councils on 15 December 2004 that overfishing was occurring on the bigeye tuna stock in the Pacific. Pacific bigeye tuna are exploited by foreign fishing fleets as well as the U.S. fleet, which accounts for only a small percentage of the Pacific bigeye tuna harvest. In 2004, the estimated bigeye tuna catch by U.S. commercial fisheries was 2.3% of the 2004 total Pacific-wide bigeye tuna catch. Overfishing in this case was a result of excessive international fishing pressure, and the capacity for unilateral action by the United States to prevent or end overfishing is limited. Management of the international bigeye tuna fishery is guided by the Western and Central Pacific Fisheries Commission and Inter-American Tropical Tuna Commission. These organizations have implemented catch limits to address bigeye tuna overfishing in recent years, but NMFS feels these measures are insufficient to end overfishing.

On 16 May 2007, NMFS approved Amendment 14 to the FMP for the Pelagic Fisheries of the Western Pacific Region, prepared by the Western Pacific Fishery Management Council. Amendment 14 included measures designed to address overfishing on bigeye tuna stocks. In addition, on 7 June 2007, NMFS approved Amendment 1 to the FMP for U.S. West Coast Fisheries for Highly

[3]Federal Register 73 FR 5117, 29 January 2008.

[4]Federal Register 71 FR 15384, 28 March 2006.

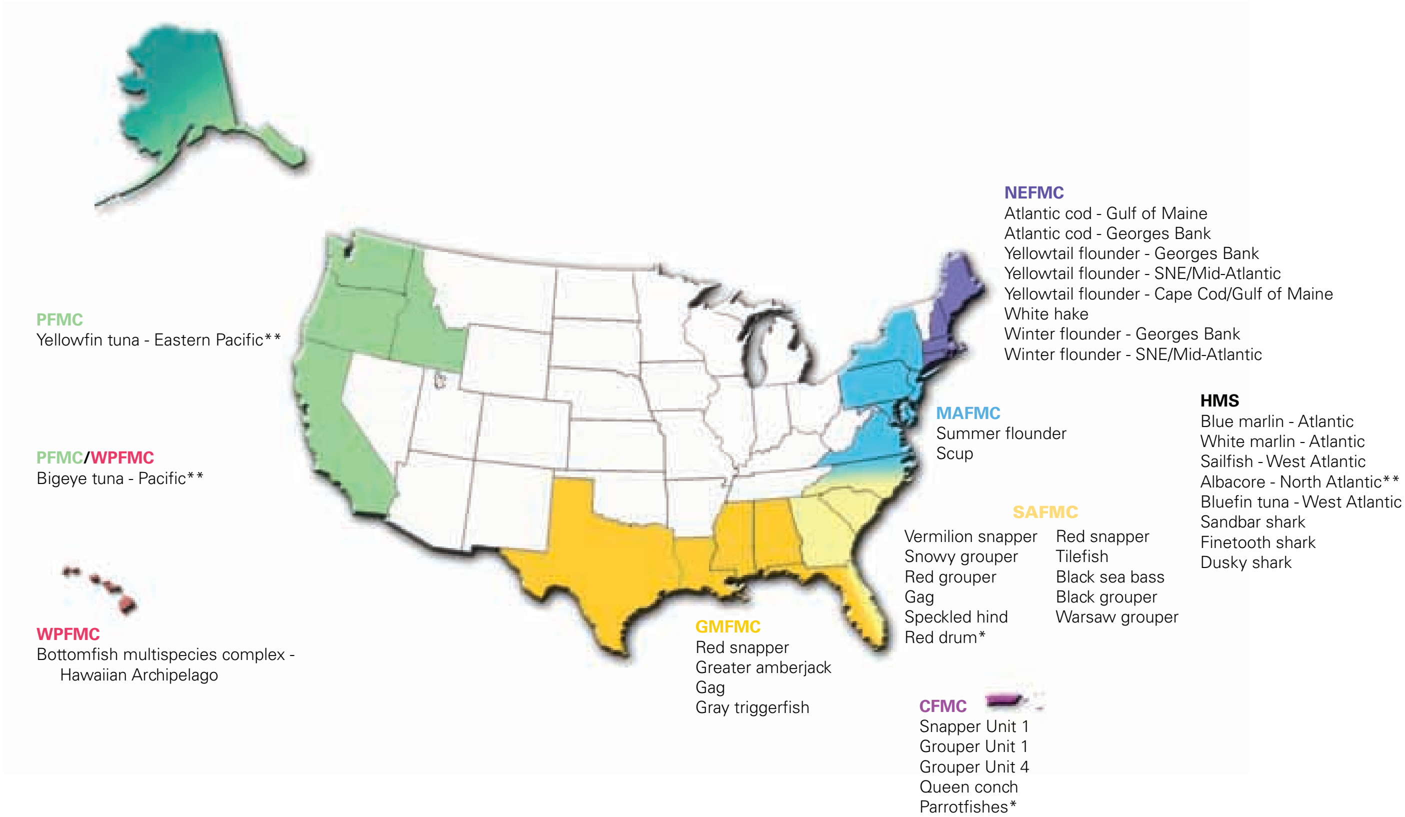

Figure 1
U.S. stocks subject to overfishing in 2007, reported by Fishery Management Councils (NMFS, 2008b). *Indicates stocks not included in the Fish Stock Sustainability Index (FSSI). **Indicates stocks where the U.S. harvest is a minor component of an international fishery.

Migratory Species, prepared by the Pacific Fishery Management Council to address overfishing of bigeye tuna stocks.

CURRENT SCOPE OF OVERFISHING

More than a decade after passage of the MSA, overfishing has ended for a number of stocks. For other stocks, overfishing has not ended, and recent stock assessments have added some new stocks to the list of overfishing stocks. In 2007, of 243 stocks and stock complexes under Federal jurisdiction with known status, 41 (17%) were listed as subject to overfishing[5] (NMFS, 2008b). This percentage is a decrease from 26% in 2000 (NMFS, 2001). A year-by-year summary of stocks subject to overfishing shows progress in ending overfishing for some stocks, but consistent overfishing for others (Table 1).

The 41 stocks and stock complexes currently subject to overfishing are managed under 11 different Federal FMP's (there are currently 46 Federal FMP's). All of the FMC's except the North Pacific FMC have at least one stock in their jurisdiction subject to overfishing (Figure 1). In some cases, the majority of the fishery occurs either in international waters or in waters of a U.S. state or territory, so Federal management in the EEZ alone cannot end overfishing. Most stocks subject to overfishing are in the Atlantic Ocean or Gulf of Mexico. For three of the stocks that are experiencing overfishing, the U.S. harvest or allocation is a minor component of an international fishery (Figure 1). For example, the U.S. allocation of albacore tuna in the Atlantic is less than 5% of the total allowable catch for the international fishery.

HOW THE UNITED STATES ADDRESSES OVERFISHING

The Secretary of Commerce (through NMFS) and the FMC's have implemented or begun development of management actions designed to reduce or end overfishing on the majority of the stocks that are currently experiencing overfishing. Typical

[5]Numbers differ from those reported in the National Overview, which analyzes only those stocks listed in *OLO* (a subset of the total stocks referred to here).

Table 1
U.S. stocks and stock complexes subject to overfishing, 1997–2007, by Fishery Management Council (FMC). Data are from published Reports to Congress on the Status of U.S. Fisheries (NMFS, 1997; 1998; 1999; 2001; 2002; 2003; 2004b; 2005; 2006; 2007b; 2008b), and as such are uncorrected. The North Pacific FMC is not listed because it did not have any stocks subject to overfishing in 1997–2007.

Stocks and stock complexes	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
New England FMC											
Sea scallop[1]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No
Haddock—Gulf of Maine	Unk	Unk	Yes	No	No	No	No	No	No	No	No
American plaice	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
Witch flounder	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No	No
Windowpane flounder—Gulf of Maine/ Georges Bank	Und	Und	Yes	No	No	No	No	No	No	No	No
Atlantic cod—Gulf of Maine	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Atlantic cod—Georges Bank	No	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Yellowtail flounder—SNE/Mid-Atlantic[2]	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Yellowtail flounder—Cape Cod/Gulf of Maine	Unk	Unk	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
White hake	Und	Und	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Winter flounder—SNE/Mid-Atlantic	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes	Yes
Yellowtail flounder—Georges Bank	No	No	No	No	No	No	No	No	Yes	Yes	Yes
Winter flounder—Georges Bank	Unk	Unk	Yes	No	No	No	No	No	Yes	Yes	Yes
Winter skate	Und	Und	Und	Und	Und	Und	Unk	Unk	No	Yes	No
New England/Mid-Atlantic FMC's											
Spiny dogfish	Und	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No
Monkfish—North[3]	Und	Und	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Monkfish—South[3]	Und	Und	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Mid-Atlantic FMC											
Black sea bass	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
Bluefish	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No
Northern shortfin squid	No	No	Yes	Yes	No	No	No	No	No	No	No
Tilefish	Und	Und	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
Scup	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Summer flounder	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
South Atlantic FMC											
Scamp	Yes	No	No	No	No	No	No	No	No	No	No
Red porgy	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No
Wreckfish	Unk	Yes	No	No	No	No	No	No	No	No	No
Nassau grouper**	Yes	Yes	Yes	No	No	No	No	No	No	No	No
White grunt	Yes	No	No	No	No	No	No	No	No	No	No
Vermilion snapper	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Red snapper	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Snowy grouper	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Tilefish	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Red grouper	Unk	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Black sea bass	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Gag	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Speckled hind	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Warsaw grouper	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Black grouper	Unk	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Red drum**	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
South Atlantic/Gulf of Mexico FMC's											
King mackerel—Gulf Group	Yes	Yes	Yes	No	No	No	No	No	No	No	No
Yellowtail snapper	Unk	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
Gulf of Mexico FMC											
Nassau grouper	Yes	Yes	Yes	No	No	No	No	No	No	No	No
Vermilion snapper	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Red drum	Yes	Yes	Yes	No	No	Yes	Yes	No	No	No	No
Red snapper	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Red grouper	Unk	Unk	Unk	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Greater amberjack	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes

Table 1

Continued from previous page.

Stocks and stock complexes	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Gulf of Mexico FMC (cont.)											
Gag	Unk	Yes	Yes	Yes	Yes	No	No	No	No	Yes	Yes
Gray triggerfish	Unk	Unk	Unk	Unk	Unk	Unk	Unk	Unk	Unk	Yes	Yes
Caribbean FMC											
Grouper Unit 2	Yes	Yes	Yes	No	No	No	No	No	No	No	No
Queen conch	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Grouper Unit 1	Yes	Yes	Yes	No	No	No	No	No	Yes	Yes	Yes
Grouper Unit 4	–	–	–	–	–	–	–	–	Yes	Yes	Yes
Parrotfishes**	–	–	–	–	–	–	–	–	Yes	Yes	Yes
Snapper Unit 1	–	–	–	–	–	–	–	–	Yes	Yes	Yes
Pacific FMC											
Lingcod	No	No	No	No	No	Yes	Yes	Yes	No	No	No
Shortspine thornyhead	No	No	No	No	No	No	No	Yes	No	No	No
Black rockfish	Unk	Unk	Unk	No	No	No	No	Yes	No	No	No
Pacific whiting	No	No	No	No	No	Yes	Yes	No	No	No	No
Darkblotched rockfish	Unk	Unk	Yes	Yes	No	No	No	No	No	No	No
Bank rockfish	Unk	Unk	Yes	No	No	No	No	No	No	No	No
Silvergrey rockfish**	Unk	Unk	Yes	Yes	No	No	No	No	No	No	No
Yelloweye rockfish	Unk	Unk	Unk	Yes	No	No	No	No	No	No	No
Yellowfin tuna—Eastern Pacific[4,5]	Und	Und	Und	Und	Und	Und	No	No	No	Yes	Yes
Petrale sole	No	No	No	No	No	No	No	No	No	Yes	No
Pacific/Western Pacific FMC's											
Bigeye tuna—Pacific[5]	Und	Und	Und	Und	Und	Und	Yes	Yes	Yes	Yes	Yes
Western Pacific FMC											
Bottomfish multispecies complex—Hawaiian Archipelago[6]	–	–	–	–	–	–	–	Yes	Yes	Yes	Yes
Yellowfin tuna—Central Western Pacific[5]	Und	Und	Und	Und	Und	Und	No	No	Yes	Yes	No
Highly Migratory Species											
Swordfish	Und	Yes	Yes	Yes	Yes	No	No	No	No	No	No
Blue marlin—Atlantic	Und	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
White marlin—Atlantic	Und	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sailfish—West Atlantic	Und	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bigeye tuna—Atlantic[5]	Und	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Albacore—North Atlantic[5]	Und	Und	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bluefin tuna—West Atlantic	Und	Und	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sandbar shark	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Finetooth shark	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Dusky shark	–	–	–	–	–	–	–	–	–	Yes	Yes
Large Coastal Shark Complex[7]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Unk	Unk

Unk = Unknown overfishing determination; i.e., an overfishing definition exists in the FMP but no determination of overfishing has been made relative to that definition.

Und = Undefined; i.e., no overfishing determination exists in the FMP.

Dash (–) denotes that the stock or complex/unit was not assessed as it is currently defined.

** denotes a stock not included in the Fish Stock Sustainability Index.

[1] Before 2003, this stock was listed as two stocks: Georges Bank and Mid-Atlantic. Only Mid-Atlantic had been listed as subject to overfishing.

[2] Before 2003, this stock was listed as two stocks, Southern New England and Mid-Atlantic. In 2000–02, only the Mid-Atlantic portion of the stock was listed as subject to overfishing.

[3] In 1999, the monkfish stocks were assessed as one stock.

[4] Even though this stock is shown to be under the jurisdiction of a single Council and under the management of a single FMP, it is acknowledged that both the Pacific and Western Pacific FMS's have jurisdiction over this stock, and it is managed under both the West Coast Highly Migratory Species FMP and the Western Pacific Pelagics FMP. The Pacific FMC is the lead Council for the purpose of reporting. Prior to 2004, this stock was listed as yellowfin tuna—Eastern Tropical Pacific and Central Western Pacific stocks (WPFMC jurisdiction).

[5] The U.S. harvest of this stock is a minor component of an international fishery.

[6] This complex contains up to 19 species. Prior to 2004, these species were listed as single stocks with an unknown overfishing determination.

[7] Although stocks were listed individually before 2005, large coastal sharks were assessed as a complex.

management actions include such measures as annual specifications, time/area closures, bag limits, limits on days at sea, trip limits, size limits, gear restrictions, and programs to reduce overcapacity. A few examples that highlight recent efforts to end or reduce overfishing are described below.

Overfishing of North Atlantic swordfish occurred during 1998–2001, but ended in 2002 and has not occurred since. Strong management measures implemented by the International Commission for the Conservation of Atlantic Tunas (ICCAT) and NMFS led to an end to overfishing. Specifically, all ICCAT member nations agreed to adopt a lower catch quota, and NMFS also closed nursery areas in the U.S. EEZ to pelagic longline fishing to protect juvenile swordfish.

To address overfishing of red snapper in the Gulf of Mexico, NMFS not only implemented bycatch reduction measures (described above), but it also reduced commercial and recreational quotas for red snapper, reduced the commercial minimum size limit for red snapper, reduced the recreational bag limit for red snapper, and prohibited the retention of red snapper under the bag limit for the captain and crew of a vessel operating as a charter vessel or headboat (through the same final rule).

In the Pacific Northwest, the lingcod stock was designated as overfished in 1999, with overfishing occurring for several years. Lingcod is one of more than 80 species managed under the Pacific Coast Groundfish FMP. A broad array of management tools—e.g. quotas, trip limits, depth restrictions, size limits, seasonal closures, and gear restrictions—have been applied in this fishery in recent years. Through a comprehensive approach that addressed fishing mortality from commercial, recreational, and tribal fisheries and also considered bycatch in nontarget fisheries, NMFS successfully ended overfishing of lingcod in 2005. Although 2009 was established as the end date for the lingcod rebuilding plan, the rebuilding target was reached several years ahead of schedule while avoiding a complete closure of lingcod fisheries.

Supporting and encouraging international efforts to end overfishing are critical to NMFS' ability to address overfishing. NMFS will need to work closely with the Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific (WCPFC) and the Inter-American Tropical Tuna Commission (IATTC) to end the overfishing of bigeye tuna and yellowfin tuna in the Pacific.

NMFS also faces a challenge to persuade ICCAT nations to adopt tough conservation measures to end overfishing of eastern Atlantic bluefin tuna. Although the United States is not a participant in eastern Atlantic bluefin fisheries, overfishing of this stock affects the availability of bluefin in U.S. waters due to the mixing of eastern and western stocks. In 2007, the United States called for ICCAT to implement a 3- to 5-year moratorium on the eastern Atlantic and Mediterranean bluefin tuna fishery. The proposed moratorium failed to win sufficient support at ICCAT's November 2007 meeting.

Strong and effective management measures have been accompanied by monitoring and tracking of stock status. Each year NMFS reports to Congress on the status of the U.S. fisheries, as mandated by the MSA. This report characterizes all managed marine fish stocks with known status under two broad categories: 1) subject to overfishing, and 2) overfished. In addition to the annual report, since the third quarter of 2005 NMFS has reported quarterly on the status of stocks. These reports are available online (http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm).

Ending overfishing is a key component of NMFS' Fish Stock Sustainability Index (FSSI), a performance measure of the sustainability of 230 fish stocks selected because of their importance to commercial and recreational fisheries (Table 2). These stocks represent about 90% of all commercial landings in the United States. The FSSI is a performance measure under the Government

Table 2

Fish Stock Sustainability Index (FSSI) scores as reported in quarterly updates on the status of U.S. stocks. The maximum possible FSSI score is 920, based on 230 stocks and four points per stock: one point for known status, one point for not subject to overfishing, one point for not overfished, and one point if biomass is at or above 80% B_{MSY}. More information on quarterly updates and FSSI scoring is available online (http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm).

Quarter and year	FSSI score
3rd quarter 2005	481.5
4th quarter 2005	495.5
1st quarter 2006	496
2nd quarter 2006	495
3rd quarter 2006	501
4th quarter 2006	506.5
1st quarter 2007	508.5
2nd quarter 2007	516
3rd quarter 2007	524
4th quarter 2007	531
1st quarter 2008	531

Performance and Results Act (GPRA), and NMFS' GPRA performance rating is tied to increases in the FSSI. The FSSI score increases as overfishing is ended and stock biomass increases. Additional and more comprehensive stock assessments also increase the FSSI score by increasing the number of stocks with known status. The maximum possible FSSI score is 920, based on 230 stocks and four points per stock. The FSSI score has increased from 481.5 in the 3rd quarter 2005 to 531 in the 1st quarter 2008, and the goal is to increase the score further as overfishing is ended.

OUTLOOK FOR ENDING OVERFISHING

Many of NMFS' efforts to end overfishing will revolve around implementing the MSRA. This new law is groundbreaking in several respects related to ending overfishing: it mandates the use of annual catch limits and accountability measures, provides for widespread market-based fishery management through limited access programs, strengthens law enforcement, and calls for increased international cooperation.

The NMFS also is using tools such as the *Annual Report to Congress on the Status of U.S. Fisheries*, quarterly updates, and the FSSI to get a more complete picture of overall trends in the sustainability of U.S. fisheries. These tools are helping us identify areas of progress, as well as areas needing attention.

The Administration is committed to ending overfishing and recognizes the importance of FMC action, and Secretarial action if necessary. This commitment, coupled with the annual catch limit measures in the MSRA, sets the tone for a new era of fishery management with a strong mandate to end overfishing and with increased accountability for results.

Although the MSRA provided for some sweeping changes to the management of our Nation's fisheries, Congress reaffirmed its confidence in the FMC system by maintaining it as the framework for management of U.S. fisheries. NMFS remains committed to working closely with the FMC's to end overfishing and to rebuild overfished stocks, while taking into account other important factors as mandated by law. In addition, NMFS will continue its commitment to work with our many partners and constituents to achieve sustainable fisheries, providing new opportunities for constituent feedback and collaboration. The ultimate result should be dynamic and responsive management that provides for long-term sustainability in U.S. fisheries. With successful implementation of the overfishing provisions in the MSRA, and with continued careful tracking and monitoring of overfishing status—along with sufficient resources to conduct needed stock assessments—we should see an end to persistent overfishing, and future instances of overfishing in our Nation's fisheries should be few and brief.

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Improving Fisheries Science with Advanced Sampling Technologies

Feature Article 2

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INTRODUCTION

The ability of the National Marine Fisheries Service (NMFS) to meet mandates to conserve and manage the Nation's living marine resources and promote a healthy marine environment is enhanced through implementation of advanced sampling technologies for providing accurate, precise, and timely population estimates of economically and ecologically important marine species. Conventional methods for monitoring and assessing marine populations and their habitat have relied primarily on surveys involving net sampling for physical capture of marine animals. Although net sampling operations are relatively inexpensive and necessary for species identification, even the largest nets sample only a very minute proportion of the ocean, necessitating a large number of hauls to adequately sample an area. Recent efforts have incorporated advanced sampling technologies that utilize remote sensing approaches such as acoustical and optical technologies. Net and trap sampling will continue to be a critical need for biological data requirements, particularly for age-based fisheries assessments. However, NMFS' evolving goals and mandates require development of survey operations that combine advanced sampling technologies with conventional methods to achieve multidisciplinary objectives in cost-effective ways. The integration of advanced sampling technologies with conventional sampling operations provides an optimal sampling strategy for investigating spatial and temporal variability of populations, ecosystem dynamics, and pelagic (open water), benthic (seafloor), and demersal (near seafloor) habitats.

Recognizing the need for a cohesive effort to improve the quality of assessments using advanced sampling technologies, NMFS established the Advanced Sampling Technology Working Group (ASTWG) to demonstrate leadership in the implementation of existing and new technologies. The ASTWG mission is:

> "To improve the accuracy and precision of living marine resource assessments by identifying information needs through the quantification and prioritization of components of uncertainty in stock assessments; identifying new technologies, innovative uses of existing technologies, and approaches that involve a combination of technologies to address these information needs; and facilitation and conducting research to develop these sampling technologies and their standardization implementation."

Advanced sampling technologies will play an increasing role in improving survey operations for assessing commercially important marine populations, monitoring and managing ecosystems, classifying essential fish habitat (EFH), delineating marine protected areas (MPA's), and exploring the ocean realm. Agency research vessels are presently being upgraded to integrate advanced sampling technologies into ongoing National Oceanic and

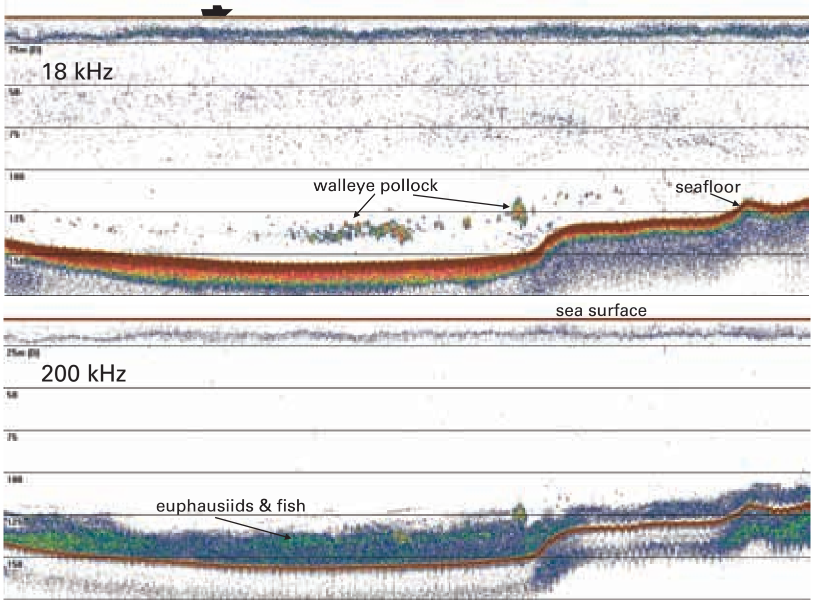


Figure 1

Acoustic echograms at frequencies of 18 kHz (upper panel) and 200 kHz (lower panel) covering about 4 n.mi. in Barnabus Trough, Alaska. Downward-facing transducers mounted on the ship's hull transmit sound pulses and receive echoes from the sea floor, fish, and zooplankton in the water column. These echograms display volume backscatter, which is representative of the number of organisms per cubic meter (i.e. density). Lower backscatter (lower organism density) is shown in blue and higher backscatter (higher organism density) in red. Echogram images are vertically exaggerated to highlight features and patterns. Differences between the two echograms highlight acoustic dependencies in fish and zooplankton scattering and potential uses for classification.

Atmospheric Administration (NOAA) surveys to achieve multidisciplinary objectives and minimize duplication of sampling efforts. For example, acoustic data can be collected concurrently with routine fisheries trawl surveys to estimate population abundances, continuously record fish and zooplankton distributions throughout the water column, map seafloor bathymetry, and characterize pelagic and benthic habitats. In this article, we describe examples of advanced technologies implemented within NMFS that provide effective approaches for achieving our strategic goals and crosscutting opportunities for intra-agency, inter-agency, industry, and academic partnerships.

ADVANCED SAMPLING TECHNOLOGIES

Most advanced sampling technologies operate by transmitting energy (acoustical or optical) into the water and then receiving energy scattered or reflected from objects in the water. The returning energy carries information about the objects, and the goal is to decipher this information to obtain measurements that are meaningful for biologists, ecologists, and fisheries managers. These technologies operate remotely, i.e. the instrumentation need not be located in close proximity to the species or habitat of interest. The remoteness of the instrumentation is dependent on the type of energy, where the operating frequency determines the sampling range and resolution. For example, optical and high-frequency acoustical instrumentation provide high spatial resolution, often less than 1 cm, but have limited sampling ranges of a few meters. Acoustical instrumentation operating at low frequencies can sample over scales of hundreds to thousands of meters, but provides lower-resolution data, from tens of centimeters to meters. Therefore, the selection of technologies will depend on the types of organisms or habitat to be surveyed, areal coverage, and the spatial and temporal resolution needed for target detection and classification. Recent initiatives have been devoted to integrating advanced sampling technologies into ongoing survey operations, evaluating new technologies, and developing innovative empirical and theoretical methods for quantitative data interpretation. The suite of available technologies provides a wide variety of options for surveying our living marine resources and their environment.

Acoustical technologies, such as single-beam echo sounders, SONAR (sound navigation and ranging), and multibeam systems, are efficient tools for sampling the water column and seafloor. Sound travels about 1,500 m per second (almost 5,000 feet per second) in water, and when a sound wave encounters an object, such as a fish or the bottom, an echo is generated (Figure 1). The first application of underwater acoustics was for navigation and obstacle (e.g. iceberg) avoidance. While using these SONAR and depth sounder systems, it quickly became apparent that aggregations of fish were readily detected. From the 1920's to the 1970's, echo sounders and SONAR were utilized extensively to locate fish and for qualitative investigations of fish behavior and distribution. Since the 1970's, advances in computer and electronic technologies have led to improvements in instrument performance and the development of quantitative methods that produce reliable, timely, and cost-effective population estimates. Fisheries acoustic methods are well established for quantitative population estimates, but further improvements can be made with species and habitat classification. There are other established acoustical technologies that have been routinely implemented during NOAA survey operations, such as acoustic doppler current profilers (ADCP) used for deriving current velocity profiles, or net mensuration sensors (Figure 2).

Optical technologies, such as underwater photography and video, laser-line scans, LIDAR (light detection and ranging), optical plankton counters (OPC), and video plankton recorders (VPR) are advantageous because they provide very high-resolution, in some cases photographic-quality, images. Optical methods can be used to survey fish and zooplankton in areas that cannot be surveyed using traditional net surveys, such as coral beds or rock reef habitats. Optical methods are also used to visually identify organisms, observe animal behavior in undisturbed environments and in the presence of fishing gear to understand variability in abundance estimates, and for habitat classification. Optical technologies are limited to sampling small areas—from a few meters to a few tens of meters—and in the case of photography and video, limited to the availability of natural or artificial light. As with acoustic technologies, there is a need for automated methods that can process and analyze large amounts of data.

Effective use of advanced sampling technologies in fisheries requires a multidisciplinary effort. System development and signal processing require engineering; data interpretation requires physics and biology; and applications to management require fisheries, biological, and ecological expertise. In addition, advanced sampling technologies currently require parallel biological sampling for verification of taxonomy and identification and for measures of length, weight, age, gender, and diet.

ADVANCED SAMPLING TECHNOLOGIES IN FISHERIES

Acoustics

Scientific echo sounders are the primary advanced sampling technology used by NMFS for quantitative measures of abundance and biomass and mapping spatial distributions of economically and ecologically important species. Beginning in the 1970's, the Alaska Fisheries Science Center (AFSC) pioneered the use of fisheries acoustics in the United States. Through collaboration with the academic community and industry, the first digital data collection and analysis system was developed and applied to fisheries acoustic assessments of Pacific hake and walleye pollock (Figure 1). This early echo sounder was a fairly complex collection of transmitting, receiving, and signal processing electronics, operating at a single frequency (38 kHz). In the ensuing years, echo sounders and analysis methods have improved, allowing for increased data collection and a better understanding of marine populations.

Fisheries management utilizes long-term time series of population abundance, which requires standardization of sampling methods, and in the case of advanced sampling technologies, calibration of the instruments. Scientific-grade echo sounders are calibrated to an absolute standard during each survey, providing a high level of confidence that the systems are operating properly and ensuring high-quality measurements. Calibration ensures long-term measurement consistency among surveys and ensures that changes in the acoustic population estimates are due to fluctuations in abundance, rather than changes in instrument performance.

Deriving population abundances requires surveying the entire distribution of a selected population at the appropriate spatial and temporal resolution. Since 1998, the Northeast Fisheries Science Center (NEFSC) has conducted an annual acoustic survey of Atlantic herring during the fall, when the offshore stock aggregates on Georges Bank to spawn. Combining historical commercial and scientific data with ongoing survey data has been an effective method for conducting acoustical surveys of the herring spawning stock biomass. Net hauls

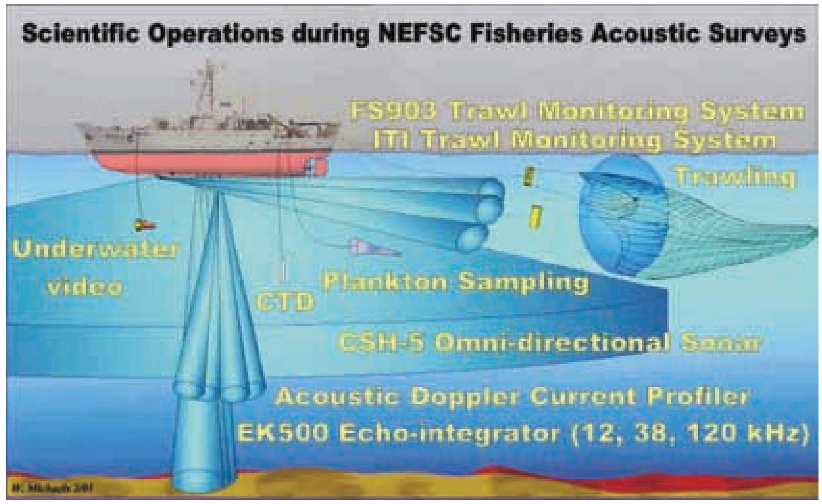


Figure 2
Acoustical systems used during routine acoustic surveys for pelagic fish. (Note: mention of trade names or commercial products does not imply endorsement by the National Marine Fisheries Service, NOAA.)

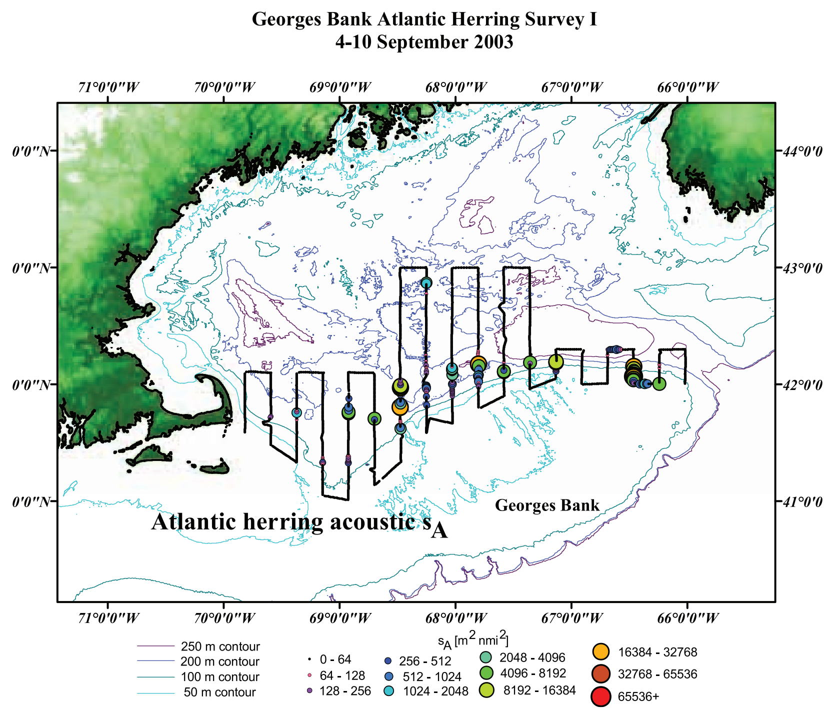
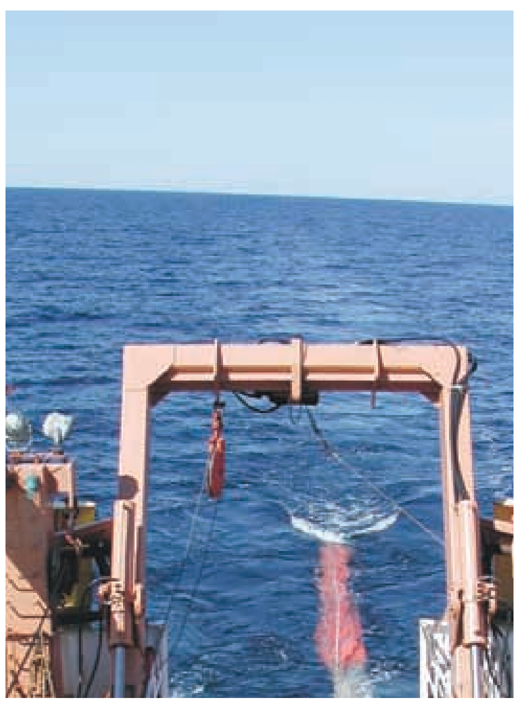


Figure 3

Spatial distribution of Atlantic herring as determined during an acoustic survey in the Georges Bank region in September 2003. Acoustic s_A is a measure of areal relative abundance, with larger numbers representing greater abundances of herring. Acoustic data are displayed in a geographic context using geographic information system (GIS) software.



NOAA Office of Marine and Aviation Operations

Figure 4

Pelagic trawl on board the NOAA ship *Miller Freeman*. Trawls are used to verify species composition of acoustic backscatter and to collect samples for obtaining biological information such as length, weight, age, gender, and diet of the targeted species.

are used in conjunction with acoustic sampling to obtain maturity, gender, age, diet, and length- and weight-frequency distributions. In addition to the biological and acoustical data, GPS (global positioning system), ship-borne sensors (e.g. sea-surface temperature), and electronic event logs are used to display and analyze the data (Figure 3). These data are used in concert to develop estimates of stock abundance in a given year.

Relating acoustic energy to taxonomic levels such as genus or species is a great challenge for fisheries acousticians. Difficulties in classification or identification are due to the anatomical and behavioral complexities of aquatic animals. For fish, echo characteristics depend on body shape (i.e. length and width), presence or absence of a swimbladder (a gas-filled organ inside the fish), shape of the swimbladder, gut fullness, gonad production, lipid content, and behavior. Additionally, the relationships between echo characteristics and these biological and behavioral characteristics are non-linear and often co-dependent. While difficulties assigning taxonomic identification to acoustic energy are not insurmountable, these complexities require collection of additional information. Classification of acoustic energy to taxonomic levels is most often verified from samples collected using nets (e.g. Figure 4), which are also used to collect biological information. Biological verification and sampling have also been improved through the use of underwater video technologies.

Acoustic technologies are effective at sampling pelagic animals, but often provide inadequate sampling at boundaries such as the sea surface or near the seafloor, especially when instrumentation is attached to a vessel's hull. The demersal habitat is especially important for a number of economically important species such as Atlantic cod in the Northeast, various grouper species in the Southeast, rockfish species in the Southwest and Northwest Regions, and walleye pollock in Alaska. Demersal fish are often associated with irregular topographic features such as sand waves and rocks or reefs (Figure 5). Positioning the acoustical transducer closer to the animals or seafloor alleviates many issues with acoustic sampling, but this process requires additional layers of technology such as pressure-tolerant housings and other specialized hardware to address data transfer issues. Nets are convenient to sample living marine resources, but are less effective in areas of irregular topography and provide limited information on behavior.

Optics

Underwater optical methods are used for directly observing and characterizing marine habitats, animal behavior, predator–prey interactions, and for enumerating various species in untrawlable regions (Figure 6). Optical methods include still photography, video, and laser-based systems. Photographic and video methods use cameras that typically have the ability to image under low-light conditions. Most photographic or video systems require some level of artificial light, although newer generation systems are able to produce quality images with very little ambient light. Artificial light has little to no effect for benthic habitat or seabed classification applications; however, the use of artificial light can be problematic when attempting to enumerate fish or quantify fish behavior, as many fish are either repelled by or attracted to light. Optical plankton counters (OPC) using laser technology and video plankton recorders (VPR) utilize laser (OPC) or photographic (VPR) technologies to enumerate and identify species and map zooplankton distributions. Utilizing optical methods for behavioral observations or species identification is an area of intense interest, and significant advances are being made in instrumentation and data interpretation and analysis (e.g. video mosaics, stereo imaging, and automated optic recognition).

ADVANCED SAMPLING TECHNOLOGIES IN FISH HABITAT STUDIES

An animal's habitat encompasses not only where it lives, but also the chemical, physical, and biological environments that surround the animal. Temperature, salinity, currents, and light are components of the physical environment commonly measured by fisheries scientists. The physical environment is important to fish as it directly influences where a fish lives, its metabolism, and its behavior. A common misconception is that habitat is associated with only the benthic environment. For pelagic animals, such as swordfish or tuna, characteristics of the seafloor play much less of a role in survival than do the properties and dynamics of the water column. Thus, it is critical that habitat studies incorporate all aspects of the environment.

The marine environment is a dynamic habitat. Temperature can dramatically change at thermal fronts and create boundaries for fish that prefer

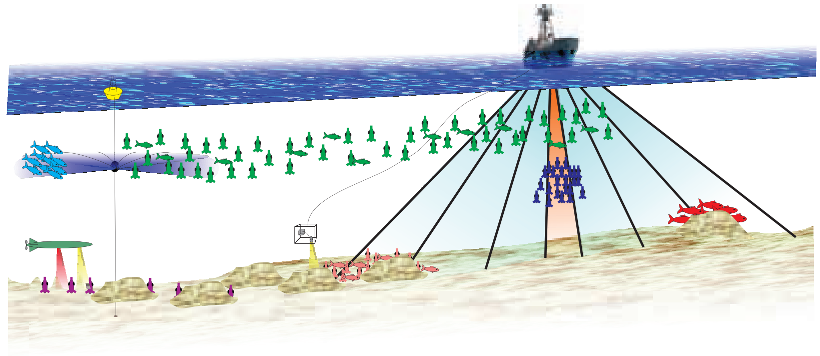
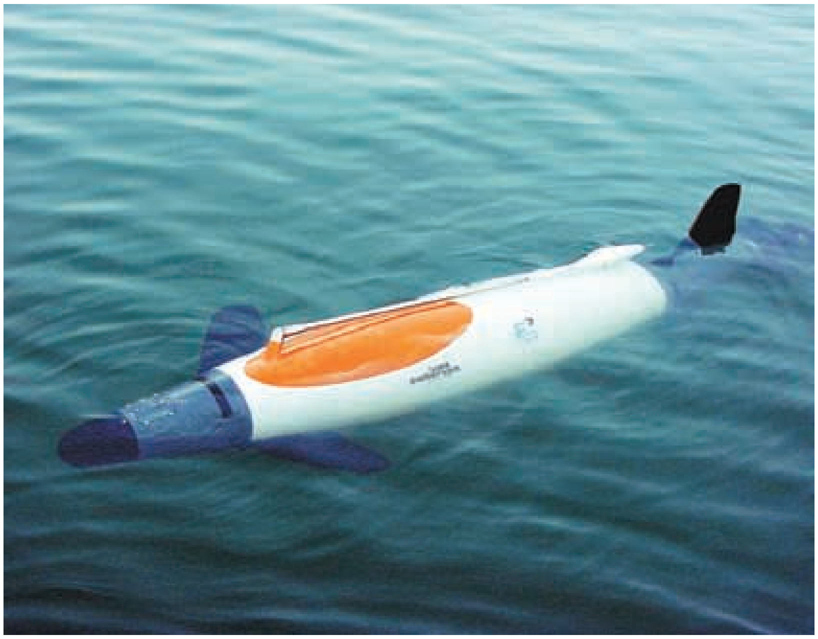


Figure 5
Ship-borne and alternative-platform-deployed acoustical and optical technologies for surveying fish in pelagic and demersal regions. Multibeam sonars (blue fan-shaped beams) significantly increase sampling volume over single-beam echo sounders (orange beam). Stationary transducers sample at one location over time, providing information on short- to long-term behavior, and are often attached to buoys for power and data storage and transmission. Autonomous underwater vehicles, towbodies, and remotely operated vehicles position acoustical and optical instrumentation near the seafloor, improving detection and quantification of fish at boundary surfaces.

NMFS

Figure 6
Image of Atlantic herring and a blue shark feeding on the herring, taken from underwater video in the Gulf of Maine.



Sias Patterson, Inc.

Figure 7

Fetch3X autonomous underwater vehicle (AUV) recently purchased by NMFS. The AUV is outfitted with a Falmouth Scientific CTD sensor that measures conductivity, temperature, and depth, Videre Design FireWire stereo camera system and Ocean Imaging Systems strobe, and a Simrad EK60 scientific echo sounder, for acoustical and optical investigations of pelagic and benthic habitats. (Note: mention of trade names or commercial products does not imply endorsement by the National Marine Fisheries Service, NOAA.)

certain temperatures. These fronts are affected by wind and currents and can shift vertically as well as horizontally. Predators are constantly on the move to find new food, prey fish are constantly searching for food or avoiding predators, and plankton is carried about with the currents. Light levels change from day to night, with phase of the moon, and with the seasons. The seafloor is constantly changing due to currents, biological influences such as burrowing animals, and human-induced manipulations. Because of these forces, organisms are not evenly distributed throughout the oceans; they form patches that change in response to their environment. Detecting these patches and studying how they interact with their environment requires a large field of view and concurrent physical, chemical, and biological measurements at similar resolutions and extents. Traditional sampling provides important information on marine habitats, but often the data are not at the necessary spatial and temporal resolution to improve our understanding of ecosystem dynamics. Advanced sampling technologies provide continuous high-resolution measurements that give us the ability to characterize marine habitats and detect changes in the marine environment.

Multibeam sonars use an array of narrow beams, typically in a fan shape, to significantly increase the field of view of the water column and sea floor, and are useful in multiple applications (Figure 5). Because multibeam systems are the standard tool for charting navigable waters, they are in widespread use along the U.S. coasts. Bathymetric data can be used to study the association of demersal and benthic fish with seafloor topographic features, from sand waves to seamounts. Acoustic backscatter from the seafloor can be used to classify and map the type of bottom (e.g. mud, sand, or rock), which plays an important role in where fish live and spawn. In the pelagic realm, multibeam data provide three-dimensional images of fish schools. These three-dimensional images are used to characterize schooling behavior and may improve the ability to identify acoustic echoes. Multibeam sonar can also be deployed at stationary sites to monitor behavior and predator–prey interactions.

THE FUTURE OF ADVANCED SAMPLING TECHNOLOGIES

Advancements in sampling technologies will continue to come from collaborations among the engineering, physics, and biological disciplines. As engineers develop more accurate, precise, and robust instrumentation, and physicists advance characterization and interpretation of the data, biologists are able to gain an improved understanding of living marine resources and their habitats. There is great potential for improving our ability to effectively monitor, manage, and forecast changes of our living marine resources by integrating advance technologies into existing survey operations, utilizing alternative platforms, and developing new data processing and interpretation methods.

Alternative Platforms

The fisheries research vessel is the ubiquitous platform for conducting living marine resource surveys, and it is necessary for conventional net sampling operations to obtain standardized indices of abundance and biological samples. Vessels can accommodate a diverse group of scientists who can conduct a variety of operations for durations of days to weeks or even months. While vessels will continue to be invaluable for fisheries surveys, ships can be costly to operate and are limited to areas where the vessel can safely navigate. Advanced technologies aboard alternative platforms such as remotely operated vehicles (ROV's), autonomous underwater vehicles (AUV's; Figure 7), and stationary arrays or buoys (Figure 5; Box 1) complement sampling from vessels by providing coverage in areas or times when vessel-deployed instrumentation is not practical, or for positioning the instrumentation closer to the animals or habitat being surveyed. Sampling over the entire range of a population at fine temporal and spatial resolution has the potential for significantly improving population estimates and ultimately for advancing our ability to predict the dynamic nature of fisheries populations.

Multiple Frequencies

Acoustic-based fish abundance estimates are currently derived solely from 38 kHz data. While this method has been successful for providing population estimates for several semi-demersal and pelagic species when used in conjunction with biological sampling, a single frequency is not sufficient for objective classification or identification. Increasing the bandwidth (i.e. increasing the acoustical frequency spectrum) is necessary to improve our ability to classify or identify acoustical targets. Two ways to increase the number of frequencies are to add echo sounder systems operating at different frequencies (multiple discrete frequencies) or to use broadband signals. Broadband signals transmit acoustic energy over a wide frequency spectrum and may be ideal for remote identification, but are presently not always able to sample to the depths required.

Most fisheries research vessels have multiple echo sounders operating at different frequencies (e.g. Figure 1) and these data are routinely archived and used for subjective classification of the species being surveyed. While such classification has proven successful for estimating abundances of selected species (e.g. walleye pollock, Pacific hake, and Atlantic herring), more objective methods to classify or identify target species are needed to avoid biases and to achieve consistency in data interpretation. A number of classification schemes have been proposed over the years that range in complexity from simple relationships to more involved neural networks. Complex schemes are advantageous because they are able to incorporate more information, but can be less intuitive to understand or apply. Simple schemes rely on fewer variables, but can be robust and straightforward to apply in the field (Figure 8). Regardless of the algorithms, development of robust and accurate classification methods to objectively identify species remains the ultimate goal of advanced technologies.

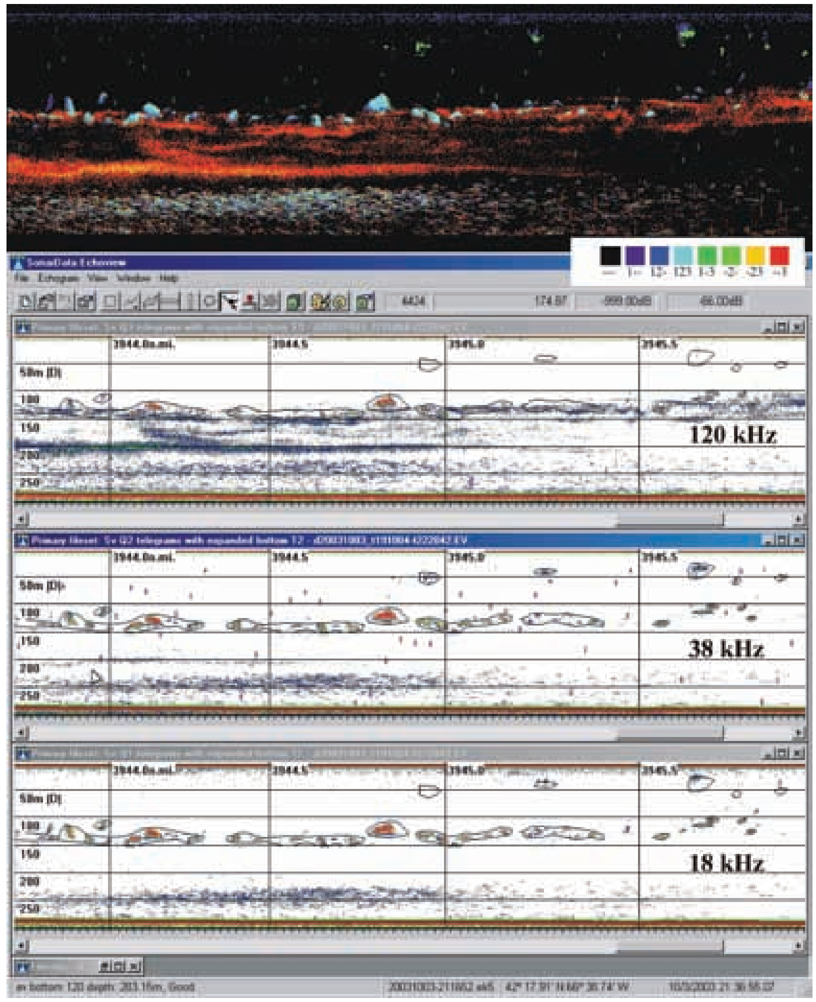
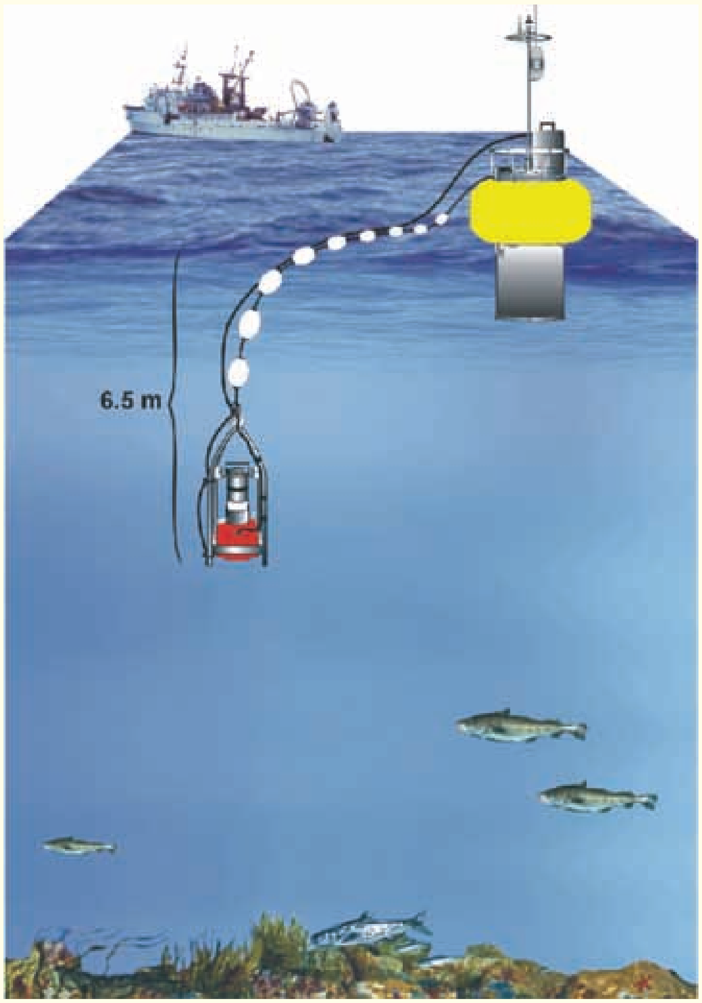


Figure 8
Classification of acoustic backscatter using three-frequency (18, 38, and 120 kHz) echo sounder data (lower panels) highlighting distributional patterns of fish and zooplankton in the Gulf of Maine. The upper panel displays the results of a simple classification algorithm where the presence or absence of backscatter from each frequency is color-coded. For example, backscatter present only in the 120-kHz echogram ("- - 3" in the color key) is represented as red, and backscatter present at all three frequencies is represented as light blue ("123" in the color bar). The light blue patches in these echograms are Atlantic herring.

Acoustic Modeling

Translating acoustical energy to meaningful biological measurements requires establishing a relationship between the reflected energy and the biological measurement. These relationships are obtained by building statistical regressions such as echo amplitude to fish length regressions from in situ (in the natural environment) or ex situ (labo-

Box 1: Fish behavior and vessel noise



Acoustical studies of fish behavior suggest that fish may exhibit a diving or fright response to noises generated by a vessel conducting surveys as well as during trawling operations. It is unknown whether this type of response is typical. If it is, however, there is a strong possibility that when survey/trawling operations are used to directly estimate population size, those estimates may be biased. For example, if the fish move away from the path of the vessel or dive to the bottom before the ship passes over them, they may not be detected by acoustic surveys. During trawl-based surveys, if fish dive into the mouth of a trawl, the effective headrope height of the trawl may be much different than the actual measured headrope height, and estimates of abundance based on area swept by the trawl may be in error. The new, acoustically quiet Fishery Survey Vessels (FSV's) currently being added to the NOAA fleet will reduce the bias caused by noise responses of target species and provide more accurate survey data for stock assessments.

A free-drifting acoustic buoy was designed and constructed by researchers from the Alaska Fisheries Science Center to evaluate the response of fish to vessel and trawl noise (see figure above). The buoy contains an echo sounder and split beam transducer operating at 38 kHz, and other instrumentation to facilitate remote operation of the buoy. An acoustic buoy is an ideal device to measure the response of fish to vessel and trawl noise because it can be rapidly deployed and recovered from the support vessel under adverse sea conditions, and it can monitor the response of fish in an undisturbed state (before the vessel/trawl passes the buoy), disturbed state (at the closest point of approach between the vessel/trawl and buoy), and during recovery to the undisturbed state (as the vessel/trawl moves away from the buoy). This allows scientists to evaluate whether avoidance reactions exist for different species of fish under many different environmental conditions.

D. Chevrier, NEFSC.

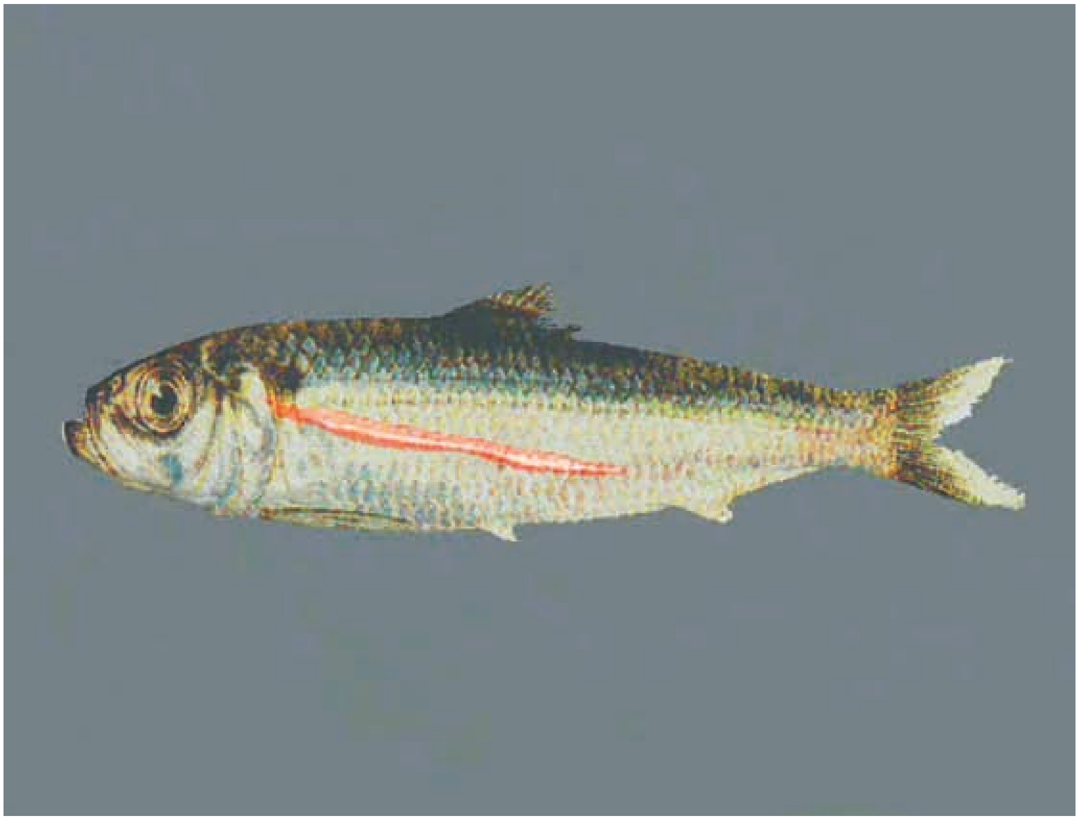


Figure 9
Three-dimensional image of an alewife and its internal swimbladder (elongated red object) derived from a computed tomography (CT) scan. A digital picture of the alewife was superimposed on the CT scan and made translucent to show the swimbladder.

ratory) measurements. Regressions derived from these measurements are advantageous because they usually incorporate the natural conditions in which the animals are surveyed. However, these measurements are difficult to obtain and often require accumulating years of data to develop a robust relationship. In addition, these statistical relationships are limited in their ability to predict outside of the conditions used to develop the relationship, such as when the fish vertically migrate, grow, feed, or develop gonads.

Mathematical models have been developed over the past few decades to predict the echo characteristics of marine animals. These models vary in their complexity and the information required for calculations. Because marine animals have complex anatomy and shapes, developing models that predict echo characteristics is difficult. In general, acoustic models are approximations that use geometric approximations of animal anatomy and shape to generate echo characteristics. Anatomical measurements of fish are obtained from dissections or x-rays, or, recently, computed tomography (CT) images (Figure 9). In spite of the complexities, models have been developed that are able to calculate echo amplitude over a wide range of frequencies and fish anatomies, thus improving our ability to predict echo characteristics over a wide range of conditions. While these models hold great promise, verification requires precise acoustic and biological measurements, as well as monitoring the behavior of the organism. Incorporating acoustic models in acoustic surveys is an area of ongoing research, and will aid in translating acoustic energy to biological measurements and in remote classification of species.

Deep-sea Coral Ecosystems of the United States

Feature Article 3

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INTRODUCTION

Coral reefs are among the most spectacular ecosystems on the planet, supporting such rich biodiversity and high density of marine life that they have been referred to as the rainforests of the sea. The coral reefs that most people think of are found in warm shallow waters, generally within recreational diving depths (30 m or less). However, other coral ecosystems thrive on continental shelves, slopes, canyons, ocean ridges, and seamounts around the world, sometimes thousands of meters below the ocean's surface. These communities are structured by deep-sea corals, also referred to as cold-water corals, and are distributed across a wide range of depths and latitudes, in both temperate and tropical oceans.

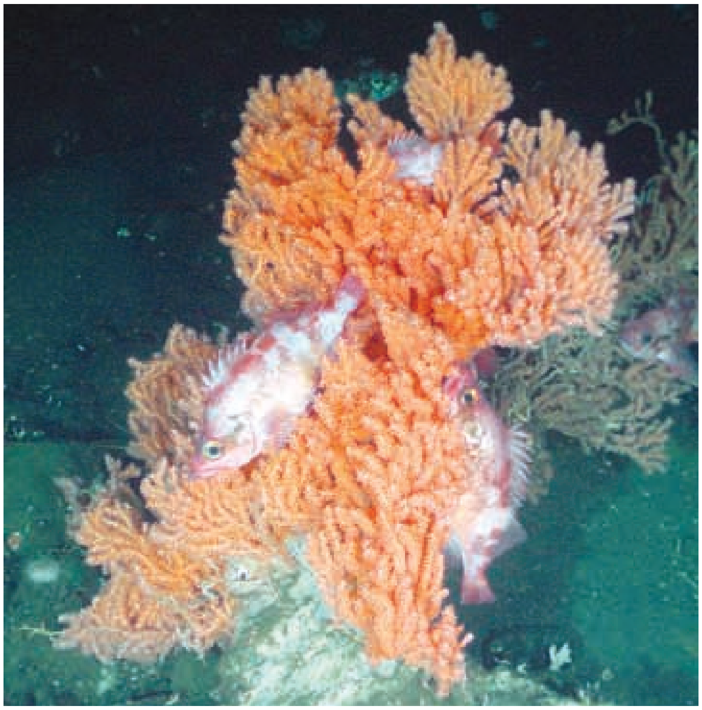
Research over the last decade has revolutionized our understanding of these deep-sea coral ecosystems and spurred calls for their protection. In 2006, the U.S. Congress included provisions for research and conservation of deep-sea corals in the reauthorization of the Magnuson-Stevens Fisheries Conservation and Management Act, our Nation's primary fisheries law, and the United Nations General Assembly passed major resolutions designed to help protect deep-sea corals and other vulnerable marine ecosystems on the high seas. In 2007, the National Oceanic and Atmospheric Administration (NOAA) published *The State of Deep Coral Ecosystems of the United States* (Lumsden et al., 2007), the first major peer-reviewed assessment of deep-sea coral ecosystems in U.S. waters and the source for this chapter.

Major Groups of Structure-Forming Deep-Sea Corals

Corals are a taxonomically and morphologically diverse collection of animals in the Phylum Cnidaria with rigid skeletal structures composed of calcium carbonate or a horn-like proteinaceous substance. Deep-sea corals lack symbiotic algae (zooxanthellae) characteristic of most reef-building shallow-water tropical corals (Table 1). Deep-sea corals occur in cold oceanic waters worldwide from near the surface to 6,000 meters in depth; however, most are found between 50 and 2,000 meters.[1] Unlike their shallow-water relatives, which rely heavily on photosynthesis by their symbionts to produce food, deep-sea corals assimilate plankton and organic matter for much of their energy needs. They generally grow much more slowly than their shallow-water counterparts.

Deep-sea corals include both reef-building and non-reef-building corals. While more than 90% of shallow-water stony corals (Order Scleractinia) are colonial structure-forming species (many contributing to coral reefs), there are at most 14 species of azooxanthellate deep-water scleractinians in the world that can be considered structure-forming species, 13 of which occur in U.S. waters (Cairns, 2001, 2007). These structure-forming species can occur as individual small colonies or they may form aggregations that can create vast reef complexes tens

[1]The term "deep-sea" usually refers to depths greater than 200 m; however, structure-forming corals that lack symbiotic zooxanthellae occur over a broader range of depths.



NOAA, Olympic Coast National Marine Sanctuary

Rockfish among primnoid corals in Olympic Coast National Marine Sanctuary.

of kilometers across and tens of meters in height over time (Freiwald et al., 2004). *Lophelia pertusa* and *Oculina varicosa* are the most important stony corals that form reef-like structures in U.S. waters. Other species of deep-sea corals, including black corals (Order Antipatharia), gold corals, *Gerardia* species, octocorals (gorgonians, true-soft corals, and sea pens), and lace corals (Family Stylasteridae, Class Hydrozoa) do not form reefs, but often have branching tree-like forms and either occur singly or form thickets of many colonies.

Importance of Deep-sea Coral Communities

As our understanding of deep-sea coral ecosystems has increased, so has our appreciation of their value. Deep-sea coral communities can be hot spots of biodiversity in the deeper ocean, making them of particular conservation interest. Stony coral reefs, as well as thickets of sea fans or black corals and aggregations of lace corals, often have large assemblages of associated fauna. This high biodiversity is intrinsically valuable and may provide significant opportunities for chemical and biological research on marine organisms. For example, deep-sea bamboo corals are being investigated for their medical potential in bone grafts and other biomedical applications (Ehrlich et al., 2006).

Strong associations have been observed between certain commercially important fishes and structure-forming deep-sea coral habitats. In Alaska, commercially valuable species of rockfish, shrimp, and crabs are associated with coral habitat, appar-

Table 1
Comparison of tropical shallow-water and deep-water structure-forming stony corals (modified from Freiwald et al., 2004; Hourigan et al., 2007).

Parameter	Tropical shallow-water stony corals	Deep-water stony corals
Depth range	0–100 m	39–2,000 m
Temperature	18–31° C	4–13° C
Distribution	Tropical and subtropical seas from 30° N to 30° S latitude.	Tropical to subpolar, at least from 71°N to 56° S latitude.
Symbiotic algae	Yes	No (however, several species of *Oculina* and *Madracis* have a facultative relationship with zooxanthellae in shallow populations)
Growth rates	1–10 mm per year for massive slow-growing corals 50–150 mm per year for faster-growing branching corals	1–20 mm per year for three branching species; growth rates for other species are unknown
Number of reef-building species	Approximately 650	Approximately 6–14
Nutrition	Photosynthesis, zooplankton, and suspended organic matter	Zooplankton and possibly suspended organic matter
Primary threats	Overfishing & destructive fishing Pollution & siltation Coastal development Over-harvest of corals Recreational misuse Diseases Climate change (coral bleaching, ocean acidification, and storm intensity)	Bottom-tending fishing gear Oil and gas exploration and production Pipelines and cables Climate change (ocean acidification and possible changes in currents and temperatures)

ently using it for protection from predators and as a feeding area (Krieger and Wing, 2002; Stone, 2006). In the Gulf of Mexico, a number of fish species are closely associated with *Lophelia* reefs (Sulak et al., 2008). Koenig (2001) found a relationship between the abundance of economically valuable fish (e.g. grouper, snapper, sea bass, and amberjack) and the condition of *Oculina* coral. These *Oculina* coral reefs off Florida have been identified as essential fish habitat for Federally managed species, as have gorgonian-dominated deep-sea coral communities in Alaska and along the West Coast. In other cases, however, the linkages between commercial fisheries species and deep-sea corals remain unclear (Auster, 2005) and may be indirect.

Deep-sea gorgonian and stony coral species have proven useful in reconstructing historical global climate and oceanographic conditions (Risk et al., 2002; Williams et al., 2006). Skeletons of living deep-sea corals have been dated at more than 1,000 years old, and dead corals forming deep banks have been radiocarbon-dated at more than 40,000 years old. Stable isotopes and trace elements incorporated in the skeletons of deep-sea corals can provide a record of past temperatures, and analyses of deep-sea coral skeletal microchemistry allow researchers to reconstruct past oceanic conditions.

MAJOR DEEP-SEA CORAL COMMUNITIES IN U.S. WATERS

The U.S. Exclusive Economic Zone (EEZ) extends 200 n.mi. (370 km) offshore, covering 11.7 million square kilometers in the Pacific, Atlantic, and Arctic Oceans. This broad geographic range includes a wide variety of deep-water ecosystems, most of which have not been explored. Despite growing knowledge of the distribution of deep-sea coral communities and regional differences in the types of corals that structure these communities and associated organisms, the majority of the U.S. EEZ has not been surveyed, mapped, or characterized.

Important deep-sea coral communities have been identified in every U.S. region. Most deep-sea coral groups, with the exception of sea pens, occur primarily on hard substrata, especially near the Continental Shelf break, along the Continental Slope, and on oceanic islands and seamounts.

Currently, it is impossible to ascertain the overall extent of deep-sea coral communities, much less their condition or conservation status, since so many of the deeper areas that these communities inhabit have been insufficiently explored or have not been explored at all. There is also very limited information on the species composition and condition of some Continental Shelf habitats prior to the inception of trawl fisheries. Therefore, the following discussion on trends in distribution should be viewed with caution.

Pacific

Alaska: The U.S. EEZ around Alaska includes the Gulf of Alaska, Aleutian Islands, and Eastern Bering Sea in the Pacific, and the Chukchi and Beaufort Seas in the Arctic. Deep-sea corals appear to be rare in the Arctic, but they are an important structural component of other Alaska marine ecosystems (Stone and Shotwell, 2007). Gorgonian deep-sea corals reach their highest diversity in the United States in the Aleutian Islands, often forming structurally complex “coral gardens” with lace corals, sponges, and other sedentary taxa. Gorgonians are also the most important structure-forming corals in the Gulf of Alaska, with species of the genus *Primnoa* reaching 5–7 m in size, while the Bering Sea has dense aggregations of soft corals and sea pens on the Continental shelf and slope, respectively. The region is relatively depauperate in stony corals; those that do occur appear as solitary cups and do not form true coral reefs.

U.S. West Coast: The deep-sea coral communities off the Washington, Oregon, and California coasts share many similarities with those farther north along the Pacific coasts of British Columbia and Alaska (Hourigan et al., 2007). Understanding of the spatial distribution of these communities has benefited from relatively extensive NOAA trawl survey catch records, supplemented by museum collections and underwater vehicle exploration (Whitmire and Clarke, 2007). Gorgonians are the most abundant and diverse structure-forming deep-sea corals along the West Coast (Whitmire and Clarke, 2007). There appear to be biogeographic differences in the distributions of certain deep-sea coral groups within the region. Gorgonians appear to be most abundant south of Point Conception

S. W. Ross, K. Sulak, M. Nizinski

Deep-water *Lophelia* coral reef community in the southeast United States.

and north of Cape Mendocino. Black corals appear abundant between Cape Mendocino and Canada, and are less common in Alaska.

U.S. Pacific Islands: The U.S. Pacific Islands represent diverse oceanic archipelagos scattered across wide areas of the Pacific and encompassing several different biogeographic regions. They do not have continental shelves or slopes, but represent emergent and non-emergent seamounts—many highly isolated from other areas. Aside from the Hawaiian Archipelago, almost nothing is known of the deep-sea coral resources in the U.S. Pacific Islands. The first submersible explorations of American Samoa and the U.S. Line Islands were begun in 2005, and surveys of additional areas in the U.S. Pacific are needed. Octocorals and black corals are the principal structure-forming species on deep Hawaiian slopes and seamounts (Parrish and Baco, 2007). While the Hawaiian Archipelago shares some species with Alaska and the West Coast, it likely has a relatively high number of endemic species. Understanding of the unique deep-sea coral assemblages in Hawaii has benefited from information gathered in association with commercial harvests of deep-sea corals—including gold (*Gerardia* species) and pink (*Corallium* species) precious corals and the shallower black corals (*Antipathes* species). Monitoring in support of management has provided perhaps the most extensive studies of growth and recruitment rates for any deep-sea coral taxa.

Atlantic

Northeast United States: This region has among the longest histories of both deep-sea scientific research and extensive trawl fisheries. Gorgonians represent the predominant structure-forming deep-sea coral taxa in this region, and they appear to be most numerous on hard substrates associated with canyons along the shelf and Georges Bank slopes, and on the New England Seamount chain (Packer et al., 2007). Though *L. pertusa* has been reported occasionally, no major reef-like formations have been recorded from U.S. waters in this region.

Southeast United States: Within U.S. waters, deep-water scleractinian coral reefs probably reach their greatest abundance and development in the Atlantic south of Cape Hatteras (Ross and Nizinski, 2007). The deep reef-forming coral *L. pertusa* is the major structural component of reefs on the Continental Slope and Blake Plateau from North Carolina to Florida. These reefs provide habitat at depths from 370 to at least 800 m for a well developed faunal community that appears to differ from the surrounding non-reef habitats (Ross and Nizinski, 2007). The world's only known *Oculina varicosa* reefs are found in 70–100 m depths off east-central Florida. Because of their shallow depth and occurrence on the Continental Shelf, *Oculina* banks may be atypical of deeper coral communities. However, their accessibility has facilitated a more comprehensive understanding of the ecology of the corals, the role of the reefs as essential fish habitat, and the impacts of trawl fishing on these resources (Koenig, 2001; Reed et al., 2007; Ross and Nizinski, 2007). Gorgonians are common in the region, but relative to the northeast and West Coast much less is known (or at least less information has been systematically collated) concerning the region's octocoral and black coral resources.

Northern Gulf of Mexico: The northern Gulf of Mexico is home to significant *L. pertusa* reefs, though their structure appears to differ from that observed in the southeast United States (Brooke and Schroeder, 2007; Sulak et al., 2008), growing primarily on carbonate and clay substrates rather than mounds of dead coral. Despite extensive environmental studies associated with oil and gas development in the Gulf, knowledge of the distribution of deep-sea coral reefs is limited to a handful of sites where targeted studies have been conducted. Each area, from Pourtales Terrace in the Florida Straits to sites in the northwestern Gulf of Mexico, represents unique habitat types. As in the southeast, limited information is available concerning the distribution of the gorgonian and black coral resources that occur in this region. Recent remotely operated vehicle (ROV) surveys focused on the reefs and banks of the northwestern Gulf of Mexico at depths of 50–150 m have resulted in expanded knowledge of the distribution of deep-water biological communities, including black corals, gorgonians, and sponges. The communities are more widespread and densely populated than reported thus far. These studies are ongoing, and are being led by NOAA's Flower Garden Banks National Marine Sanctuary.

U.S. Caribbean: The U.S. Caribbean includes the waters surrounding Puerto Rico, the U.S. Virgin Islands, and Navassa Island, and represents a small part of the larger Caribbean ecosystem. It has not been well studied with respect to deep-sea corals (Lutz and Ginsburg, 2007) and the primary information comes from scientific collections—most from other areas of the wider Caribbean. In U.S. waters, limited ROV and submersible studies have been conducted off Navassa Island and Puerto Rico, revealing scleractinian, black, and gorgonian corals, but distributions have not been rigorously documented.

CONSERVING U.S. DEEP-SEA CORAL ECOSYSTEMS

Threats to Deep-sea Coral Communities

Deep-sea corals are generally slow-growing and fragile, making them and their associated communities vulnerable to human-induced impacts, particularly physical disturbance. The level and types of threats affecting these ecosystems differ regionally (Table 2), as do the management actions that have been adopted to address impacts from fisheries.

Disturbances to deep-sea coral communities from bottom-tending fishing gear, especially bottom trawl gear, are the best documented (Freiwald et al., 2004; Stone, 2006; Reed et al., 2007) and are considered the major threat to deep-sea corals in most U.S. regions where such fishing is allowed (Hourigan et al., 2007; Table 2). With the exception of a few areas (e.g. the Oculina Banks), the full extent of habitat degradation resulting from these threats is largely unknown. In such complex habitats as deep sea-coral communities, recovery rates could be extremely slow (decades to centuries), if at all.

	Regions						
Threats	Alaska	West Coast	Pacific Islands	Northeast	Southeast	Gulf of Mexico	Caribbean
Bottom trawl fishing impacts	High	High	NA	High	High	Low-Medium	NA
Other bottom fishing impacts	Low-Medium	Low	Low	Low-Medium	Low	Low	Low
Deep-sea coral harvest	NA	NA	Medium	NA	NA	NA	NA
Oil and gas development	Low	Low	NA	NA	NA	Medium	NA
Cable deployment	Low	Low	Unknown	Low	Low	Low	Unknown
Sand and gravel mining	Low	NA	NA	Low	Low	Low	NA
Invasive species	Unknown	Unknown	Medium	Unknown	Unknown	Unknown	Unknown
Climate change	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown

Table 2

Summary of perceived levels of current threats to deep coral communities for U.S. regions. NA = Not Applicable (i.e. this threat is prohibited or does not occur anywhere within that region). Source: Hourigan et al. (2007). Note that these threat levels are derived from expert opinions and reflect only the occurrence of these stressors in a region, and their potential, if unmitigated, to damage deep coral communities they might encounter. The threat levels do not indicate the actual impacts of each stressor, which will likely vary widely within and among regions.

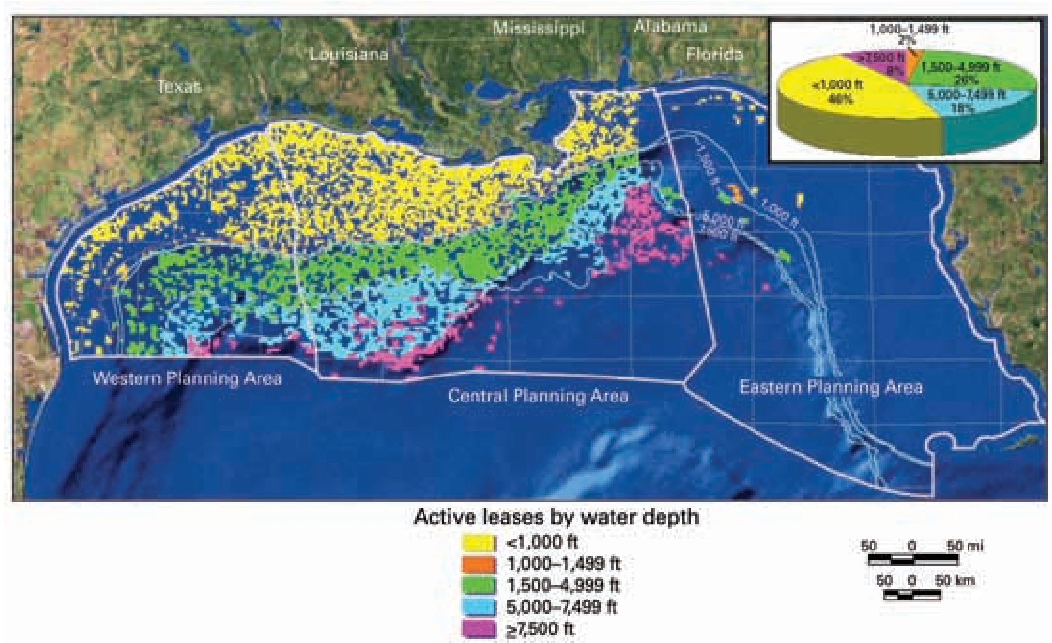


Figure 1
Map of the Gulf of Mexico showing active leases by water depth in 2007. Courtesy of the Minerals Management Service.

Other activities that can directly impact deep-sea coral communities include coral harvesting; oil, gas, and mineral exploration and extraction; and submarine cable/pipeline deployment (Freiwald et al., 2004; Hourigan et al., 2007). Hawaii is the only jurisdiction where precious coral harvests are allowed. It is also the only place where an invasive species, the snowflake coral, has been identified as a current threat, having overgrown and killed over 50% of commercial black coral colonies in one location. Oil and gas exploration and development in the Gulf of Mexico, where approximately 98% of all active U.S. oil and gas leases are located, is increasingly conducted in deeper waters and has been identified as a moderate threat to deep-sea coral communities in that region (Figure 1). Climate change and ocean acidification represent potentially serious threats that have not been adequately studied.

Managing Impacts to U.S. Deep-sea Coral Communities

Most deep-sea corals in U.S. waters occur in the EEZ, beyond the jurisdiction of individual states. Fisheries in the EEZ are managed by the National Marine Fisheries Service (NMFS) under fishery management plans prepared by eight regional Fishery Management Councils (FMC's) in accordance with the Magnuson-Stevens Fishery Management and Conservation Act.[2] In 2006, the Act was reauthorized, directing NOAA to establish a Deep-sea Coral Research and Technology Program and authorizing the designation of zones to protect deep-sea corals from damage caused by fishing gear under fishery management plan discretionary provisions.

NMFS and the FMC's have been active in protecting deep-sea coral habitat, relying on tools such as closed areas and gear modifications to address fishing impacts. In 1983, the Western Pacific FMC recommended and NMFS implemented a prohibition on the use of trawl gear, bottom-set longlines, and bottom-set gill nets—all identified as threats to deep-sea corals—within all 3.9 million km^2 of seafloor habitat waters in the EEZ surrounding the U.S. Pacific Islands. The following year, the South Atlantic FMC recommended establishment of the world's first area to protect deep-sea corals (the Oculina Bank Habitat Area of Particular Concern off Florida). Despite these steps, incomplete protection and lack of sufficient enforcement resulted in continued destruction of much of the *Oculina* habitat by 2001 (Reed et al., 2007), with dam-

[2]16 U.S.C. 1801 et seq.

age attributed to bottom trawling. Expansion of the protected area, requirements for use of vessel monitoring systems, and enhanced enforcement since 2001 provide hope for the remaining reefs.

Recent research has begun to reveal the extent and ecological importance of deep-sea coral communities, as well as the threats they face, greatly accelerating conservation action. In 2005, the New England and Mid-Atlantic FMC's recommended and NMFS approved closures of Oceanographer and Lydonia Canyons (approximately 400 km^2), on the southern flank of Georges Bank, to bottom trawling and gillnetting for monkfish. In 2006, NMFS approved FMC recommendations to protect almost 1.5 million km^2 of vulnerable benthic habitats in the Pacific. In 2008, additional habitat conservation efforts were underway through the North Pacific, New England, and South Atlantic FMC's.

In addition to the FMC's, NOAA's National Marine Sanctuary Program has responsibilities for protection and management of natural resources within the boundaries of National Marine Sanctuaries, eight of which are known to contain deep-sea corals. The goals of the National Marine Sanctuaries Act[3] include maintaining the natural biological communities in the National Marine Sanctuaries, and protecting—and where appropriate—restoring and enhancing natural habitats, populations, and ecological processes. New oil and gas development is currently prohibited in all National Marine Sanctuaries, although leases in place before sanctuary designation are allowed to continue. Deep-sea coral communities also occur in the Papahānaumokuākea Marine National Monument in the Northwestern Hawaiian Islands and are likely to occur in certain National Parks and National Wildlife Refuges, especially in Alaska and the Pacific Remote Island Areas.

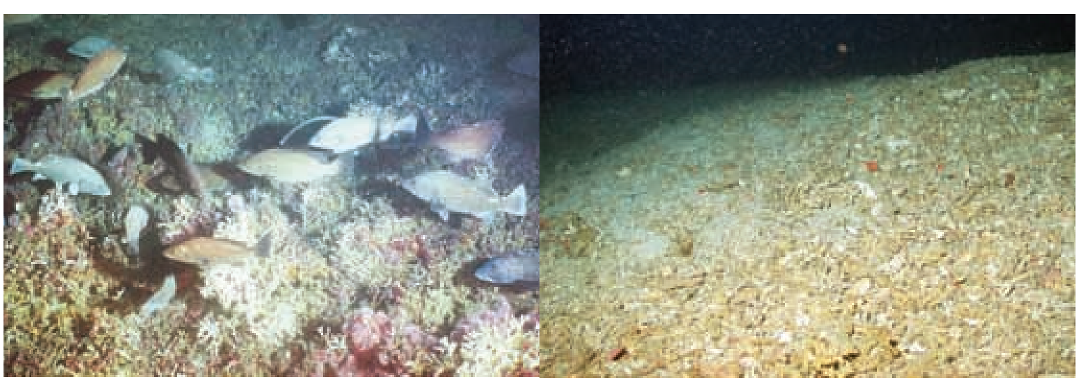
Mineral resource exploration and extraction activities, including oil and gas exploration in Federal waters, are managed by the Minerals Management Service (MMS) in the U.S. Department of the Interior. The MMS regulates the impact of mineral resource activities on the environment through an Environmental Studies Program and an Environmental Assessment Program. These programs provide scientific and technical information to support decisions and monitor environmental impacts of exploration, development, and production of mineral resources.

[3]16 U.S.C. 1431 et seq.

DEEP-SEA CORAL RESEARCH PRIORITIES

Over the past few years, NOAA has increased activities to locate, study, and protect deep-sea corals. The following research priorities common to most or all U.S. regions have been identified as having the potential of contributing to better understanding and improved management of deep-sea coral ecosystems. This is not a comprehensive list of scientific research needs and is not in order of importance.

Habitat Mapping and Characterization: The highest priority in every region is to locate, map, characterize, and conduct a baseline assessment of deep-sea coral habitats. The locations of deep-sea coral habitats are not well known, making it difficult, if not impossible, to adequately manage associated resources.



Left: Grant Gilmore, Dynamac Corp.; right: Lance Horn, NURC/UNCW

Left: Commercial groupers on healthy *Oculina* deep-sea coral habitat off the East Coast of Florida. Right: Trawled *Oculina* habitat.

Victoria O'Connel, Alaska Department of Fish and Game

Juvenile rockfish in Alaskan red tree coral (*Primnoa* species).

Modeling the Distribution of Deep-sea Coral Habitats: Modeling the distribution of deep-sea coral habitats will facilitate the geographic targeting of future research efforts and the identification of areas that should be managed with greater precaution, in the absence of expensive ground-truthed data.

Data Mining and Data Management: Because of the high cost of new exploratory surveys, there is a priority on mining data from museum collections or past submersible surveys focused on other subjects (e.g. geology or fish) to yield distributional data for corals at a low cost. These may also provide qualitative baselines for assessing change. There is also a need to better manage existing information to enhance research collaboration and access to data for management purposes.

Monitoring: Monitoring is key to understanding the state of resources and gaining clues to processes that may affect change and recovery from damage. However, in contrast to shallow reefs, the costs associated with observing deep-sea coral communities are much higher. As a result, most deep-sea coral communities have likely not yet been discovered, much less have baselines developed or repeated surveys begun. To date, monitoring of deep-sea corals in U.S. waters has been limited to the relatively shallow Oculina Banks off Florida, and black and precious corals in selected locations off Hawaii. These studies have yielded valuable life-history and ecological information on those coral species.

Understanding the Biology and Ecology of Deep-sea Coral Species: The basic taxonomy of deep-sea coral taxa, their biogeography, and the processes that may contribute to distributions and endemism are poorly known. Needs include: genetic studies to understand recruitment dynamics and resilience to disturbance; the study of factors influencing reproduction, recruitment, and recolonization rates; and study of patterns and processes of growth and mortality for key coral species.

Biodiversity and Ecology of Deep-sea Coral Communities: Structure-forming deep-sea corals have been shown to provide important ecosystem functions in the deep sea environment, especially as habitat for numerous other species. In addition to conducting species inventories and quantifying the associations between corals, other invertebrates, and fish, this may include characterizing trophic dynamics within deep-sea coral communities, and studies on the life history of associated species. Understanding the ecological function of these communities and their importance for Federally managed species is a management priority.

Understanding Effects of Climate Change and Ocean Acidification: Deep-sea corals may provide windows into past environmental conditions in the deep ocean, as well as clues for prospective analyses of future changes that may result from climate change. Deep-sea coral communities may also be uniquely vulnerable to ocean acidification (changes in ocean chemistry associated with increased atmospheric CO_2 from the combustion of fossil fuels).

Fishery Impacts: Since fishing impacts are currently the major threat to these communities in U.S. waters and around the world, it is especially important to gain a comprehensive understanding of fishing effort and distribution with respect to the location of deep-sea coral habitat. Coral bycatch in trawl surveys and commercial fisheries has proven valuable in mapping coral resources and interactions with fisheries.

Other Anthropogenic Stressors: Many other human activities are also expanding into deeper waters. Documenting their effects on seafloor habitats provides a foundation for developing sound policy and making wise management decisions. Additionally, there is a need for basic research to understand recently recognized threats to these ecosystems, such as invasive species.

CONCLUSIONS

Although this article has highlighted regional variability and the many gaps in our knowledge of deep-sea corals and the communities they structure, there has been tremendous progress in our understanding of these ecosystems over the last decade. Though a comprehensive inventory of deep-sea coral habitats is not possible at the present time, these communities appear to be more widespread in deeper waters of the U.S. EEZ than previously thought. Impacts from fishing gear, especially bottom trawl gear, are currently the greatest threat to deep-sea coral habitat, and we may never know the true extent of past fishing-related impacts on Continental Shelf ecosystems. However, deeper coral habitats (>500 m) appear to be relatively undisturbed, and increased appreciation of these coral communities by Federal management agencies, regional fishery management councils, and the public has resulted in major conservation actions on a geographic scale that was previously unprecedented. Continued progress in conservation will require sustained mapping and research efforts, as well as application of scientific and management lessons learned across the Nation's varied regions.

It is clear that other biogenic habitats in deep water also deserve study. In particular, sponges may contribute to habitat complexity in much the same way as do deep-sea corals. We know even less about the biology and ecology of deep sponges and their habitats. As NOAA moves forward with partners to better understand deep-sea coral communities, these other types of deep-sea communities also deserve attention.

Understanding and conserving habitats of high biological diversity, such as deep-sea coral habitats, is taking on increasing importance as NOAA moves towards an ecosystem approach to managing the Nation's living marine resources. Deep-sea coral habitats were highlighted for special attention in the 2006 reauthorization of the Magnuson-Stevens Fisheries Conservation and Management Act. In a similar vein, conservation of these vulnerable

Andy Bruckner

Pink coral (*Corallium*) jewelry for sale in Japan. Pink and red precious corals have been valued for jewelry and art objects for over 5,000 years.

marine ecosystems on the high seas has become a major subject of international negotiations.

For more in-depth information on the state of our knowledge of deep-sea coral communities, please see *The State of Deep Coral Ecosystems of the United States* (Lumsden et al., 2007).

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Conservation and the Endangered Species Act: The National Marine Fisheries Service's Cooperative and Proactive Approaches

Feature Article 4

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INTRODUCTION

In signing the Endangered Species Act (ESA) into law on 28 December 1973, President Richard M. Nixon noted,

> "Nothing is more priceless and more worthy of preservation than the rich array of animal life with which our country has been blessed. It is a many-faceted treasure, of value to scholars, scientists, and nature lovers alike, and it forms a vital part of the heritage we all share as Americans" (Wooley and Peters, 1999–2009).

The ESA evolved from two earlier pieces of legislation, the Endangered Species Conservation Act of 1969 and the Endangered Species Preservation Act of 1966.[1] However, it was President Nixon's signing of the 1973 law that set in motion a comprehensive national program to protect wildlife threatened with extinction.

Today, the ESA is arguably one of the most important and most controversial of the Federal environmental protection laws. Controversy generally arises from the regulatory nature of ESA programs and the length of time that is often required to recover listed species. However, in recent years the National Marine Fisheries Service (NMFS) has placed additional emphasis and resources into recovery and conservation programs. Most notable among these programs are a cooperative program that involves state partners in the recovery of listed species (Section 6 Program) and a newly developed program that addresses species of concern before population declines warrant ESA protection (Species of Concern Program). In this article we review how these two programs are currently working to recover listed species and conserve species of concern before listing under the ESA becomes necessary.

BACKGROUND: IMPLEMENTATION OF THE ENDANGERED SPECIES ACT OF 1973

Currently, there are 1,925 threatened and endangered species listings under the ESA, with 1,351 of those species found in the United States or its waters, and the remainder occurring in international waters or foreign countries. NMFS and the U.S. Fish and Wildlife Service (USFWS) share responsibility for implementing the ESA but have divided jurisdiction over most species. In general, USFWS manages terrestrial and freshwater species, while NMFS manages marine species, including most anadromous fishes (species such as salmon that reside in salt water and return to fresh water to spawn). Under the ESA, species include any subspecies of fish or wildlife or plants, and any distinct population segment of vertebrate fish or wildlife which interbreeds when mature.[2] Two poli-

[1]H.R. 9424 (Endangered species preservation) Public Law 89-669 (80 Stat. 926).

[2]Section 3 of the ESA (16 U.S.C. 1532).

An exposed male sockeye salmon (*Oncorhynchus nerka*).

cies provide guidance on the definition of distinct population segments for Pacific salmon (NMFS, 1991) and other vertebrate species (NMFS, 1996). At the present time, NMFS is responsible for 66 listed species.[3]

In order to receive protection under the ESA, a species must first be listed as endangered or threatened. A species is considered endangered if it is "in danger of extinction throughout all or a significant portion of its range," and a species is considered threatened if it "is likely to become an endangered species within the foreseeable future."[4] The ESA requires that listing decisions be based solely on the best scientific and commercial data available. The ESA also requires NMFS or USFWS to determine whether any species is endangered or threatened because of any of the following factors:

- present or threatened destruction, modification, or curtailment of the species' habitat or range;
- overutilization for commercial, recreational, scientific, or educational purposes;
- disease or predation;
- inadequacy of existing regulatory mechanisms; and
- other natural or manmade factors affecting the species' continued existence.

Once a species is listed as endangered, it is generally protected from take (defined as harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect) by any individual or organization. This take prohibition may also be, and often is, extended to threatened species by regulation.

Because habitat loss and modification is a major threat to many imperiled species, the ESA requires that critical habitat be designated for species listed under the ESA. Critical habitat includes specific areas within the geographical range occupied by the species at the time of listing containing physical or biological features essential to conservation that may require special management considerations or protection; and specific areas outside the geographical range occupied by the species if NMFS determines that the area itself is essential for conservation. Maps of critical habitat can be found at http://www.nmfs.noaa.gov/pr/species/criticalhabitat.htm.

Additionally, under Section 7 of the ESA, Federal agencies are obligated to

> "Ensure that any action authorized, funded, or carried out by such agency . . . is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat . . . which is determined . . . to be critical."[5]

[3]A complete list of threatened and endangered species currently under NMFS' jurisdiction can be found in Appendix 7 and is also available at http://www.nmfs.noaa.gov/pr/species/esa.htm.

[4]Section 3 of the ESA (16 U.S.C. 1532).

[5]Section 7 of the ESA (16 U.S.C. 1536).

In order to meet this requirement, Federal agencies consult with NMFS on any activities that may affect a listed species under NMFS jurisdiction (known as an interagency or Section 7 consultation). The ESA also requires Federal agencies to use their authorities to carry out programs for the conservation of species. This section of the ESA provides NMFS with a powerful tool for working with a number of Federal agencies to design programs and activities in a manner that provides for the conservation of listed species.

To promote the recovery of a species once it has been listed, a recovery plan is prepared that identifies the conservation measures necessary to recover the species. Most recent plans can be found online at http://www.nmfs.noaa.gov/pr/recovery/plans.htm. NMFS works with other Federal agencies, state and local governments, and private entities to implement the measures in these plans. One means of supporting such measures is through funding associated with cooperative agreements with the states under Section 6 of the ESA.

COOPERATION WITH STATES: THE ESA SECTION 6 PROGRAM

States play an essential role in the conservation and recovery of endangered and threatened species. Protected species under NMFS' jurisdiction may spend part or all of their lifecycles in state waters, and success in conserving these species depends in large part on working cooperatively with state agencies. In Section 2 of the ESA, Congress declared that

> "Encouraging the states and other interested parties, through Federal financial assistance and a system of incentives, to develop and maintain conservation programs which meet national and international standards is a key to meeting the Nation's international commitments and to better safeguarding, for the benefit of all citizens, the Nation's heritage in fish, wildlife, and plants."[6]

Under the authority of Section 6 of the ESA, NMFS is explicitly authorized to work cooperatively with states[7] and provide Federal assistance to support the development of state conservation programs for listed marine and anadromous species (Box 1). States may also receive support for monitoring of candidate and recently recovered species.[8] Section 6 requires state matching (at 10% to 25%) of Federal funding, thereby leveraging what are typically very limited Federal dollars. This program also capitalizes on the existing expertise and knowledge of state natural resource agencies and their existing intrastate partners to better protect and recover the listed species that reside within a particular state. Because of its emphasis on cooperative partnerships, the Section 6 Program is an excellent example of the type of Federal–state partnership articulated in President George W. Bush's 2004 Executive Order 13352, Facilitation of Cooperative Conservation.

The mechanism for formalizing these Federal–state partnerships is a Section 6 cooperative agreement. A state interested in entering into a cooperative agreement submits information to NMFS regarding the state's legal authorities and conservation programs for threatened and endangered species. Once a state's conservation program is

Box 1

States currently holding ESA Section 6 agreements with NMFS; year effective noted in parentheses.

Delaware (2007)	New Jersey (2004)
Florida (2003)	New York (1992)
Georgia (1990)	North Carolina (2000)
Hawaii (2006)	Puerto Rico (2003)
Maine (2005)	South Carolina (1984)
Maryland (1998)	U.S. Virgin Islands (2003)
Massachusetts (1996)	Washington (2008)

[6]Section 2(5) of the ESA.

[7]The term "state" is used here as defined in Section 3 of the ESA and therefore includes U.S. territories.

[8]Candidate species are those species that are actively being considered for listing under the ESA, but are not yet the subject of a proposed rule (50 CFR 424.02). NMFS' definition of a candidate species includes petitioned species that are actively being considered for listing as endangered or threatened under the ESA, as well as those species for which NMFS has initiated an ESA status review that it has announced in the Federal Register.

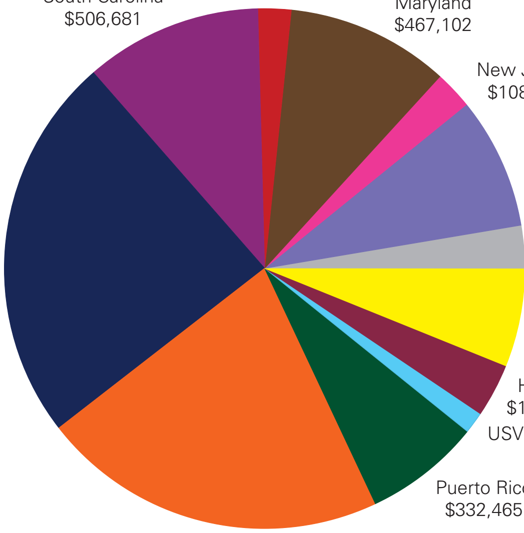

Figure 1 (above)
Total funding through the Protected Species Cooperative Conservation Grant Program by state for Fiscal Year (FY) 2003–07 grant cycles; amounts include funding awarded but not yet obligated for out-years of multiyear projects, which extend into FY2009. Maine and Hawaii each submitted proposals for the first time to the FY2007 grant cycle. Funding decisions for the FY2008 cycle had not yet been finalized when this article was prepared.


FWCC

Photo (below)
A newborn smalltooth sawfish (*Pristis pectinata*) measuring 812 mm (total length) captured as part of the Florida Fish and Wildlife Conservation Commission's long-term monitoring project.

found to be adequate and active in accordance with the criteria of Section 6(c) of the ESA, the state, through its respective natural resources agency or agencies, enters into an agreement with NMFS. The state then becomes eligible to receive Federal funding to support development of conservation programs for listed species and monitoring of candidate and recovered species residing within that state. NMFS and the states often work together to identify priority projects that address a particular state's needs, recovery actions identified in a NMFS recovery plan, or both. Currently, NMFS holds agreements with 14 states, the newest agreement being with Washington, which was signed in 2008 (Box 1). Since NMFS received new funding from Congress in Fiscal Year (FY) 2003 to support this program, the number of ESA Section 6 agreements has more than doubled. NMFS anticipates that this program will continue to grow at a pace of at least one new agreement per year until all eligible states are included in the program.

Using the funding provided by Congress in 2003 and thereafter, NMFS instituted the Protected Species Cooperative Conservation Grant Program. This grant program has provided between $750,000 and $950,000 annually to support conservation of endangered, threatened, and candidate species (Figure 1). Funded projects have involved development and implementation of management plans, scientific research, and public education and outreach efforts. Project budgets have ranged in size from small management measures costing several thousand dollars to large multiyear research projects costing hundreds of thousands of dollars. Funding has supported work for most of the listed species that occur within the waters of partner states, particularly sea turtles, sturgeons, and smalltooth sawfish (Figure 2). A complete list of previously funded projects is available at http://www.nmfs.noaa.gov/pr/conservation/states/funded.htm.

An excellent example of a small, cost-effective management project is the ongoing work being conducted in the U.S. Virgin Islands (USVI) to reduce injury and mortality of leatherback sea turtles as a result of boat collisions. The USVI Division of Fish and Wildlife (DFW) has documented an increase in the number of injured and stranded leatherbacks during several recent nesting seasons in the area of Sandy Point National Wildlife Refuge, the largest nesting beach for leatherbacks in the United States and the first sea turtle nesting beach ever to be proposed as critical habitat (FWS,1978; Figure 3). During this same time period, off the southern shore of the refuge, there has also been an increase in boat traffic associated with the seasonal mutton snapper fishery. Observation of propeller wounds on leatherbacks confirms that the injuries are often the result of boat strikes. Although there are speed restrictions in this area, most boaters are unaware of these restrictions or are unaware of the presence of endangered leatherbacks so close to shore. To address this issue, the DFW has partnered with the West Indies Marine Animal Research and Conservation Service (WIMARCS) to install marker buoys around Sandy Point Wildlife Refuge, establish a no-wake zone, and increase local fishermen and recreational boaters' awareness of the presence of leatherbacks in this area. With no available territorial funding, funding through the Protected Species Cooperative Grant ($41,859) is essential to conducting this project.

Large, multiyear research projects supported through this grant program include ongoing long-term monitoring of the endangered smalltooth sawfish in Florida. The U.S. population of smalltooth sawfish has been extirpated from most of its range and was listed as endangered in 2003 (NMFS, 2003). In the United States, smalltooth sawfish once ranged from Texas to Florida and up the Atlantic coast to Cape Hatteras; smalltooth sawfish are now mainly found only around the southern part of Florida. NMFS has provided over $200,000 through the Protected Species Cooperative Conservation Grant Program to the Florida Fish and Wildlife Conservation Commission (FWCC) to

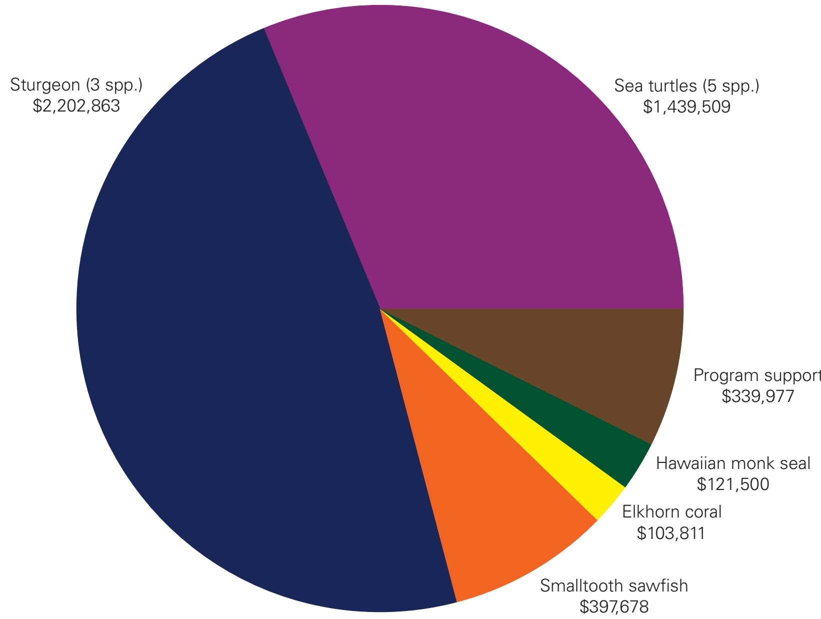

Figure 2 (above)

Grants awarded under the Protected Species Cooperative Conservation Grant Program by species for Fiscal Year (FY) 2003–07 grant cycles. Amounts include funding awarded but not yet obligated for out-years of multiyear projects, which extend into FY2009. Sea turtle species include green, leatherback, Kemp's ridley, loggerhead, and hawksbill. Sturgeon species include shortnose, Atlantic, and Gulf sturgeon. Program support includes funding for workshops, meetings, and general program development. Elkhorn coral first became eligible to receive funding during the FY2005 grant cycle after it became a candidate for listing in June 2004 (NMFS, 2004).

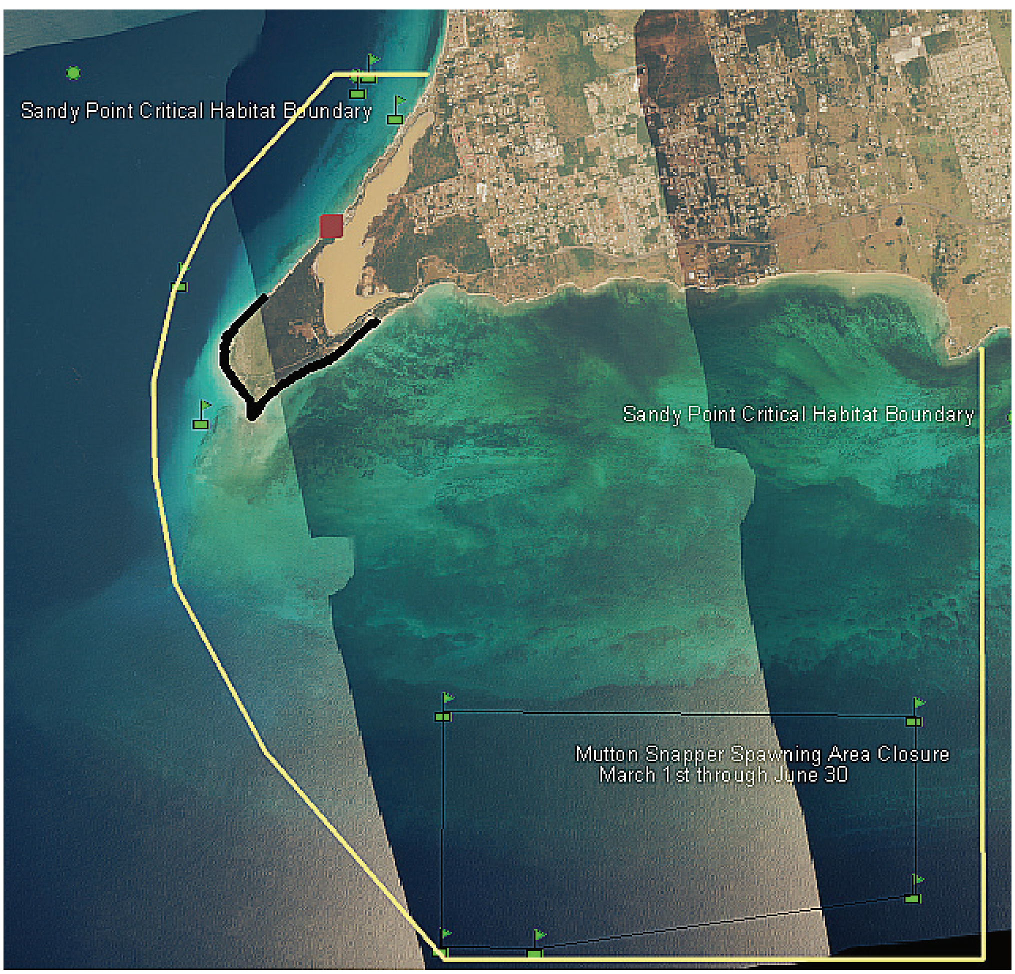

Figure 3 (left)

Critical habitat (yellow lines) for leatherback sea turtles consists of both a nesting beach (bold black line) and waters adjacent to Sandy Point, St. Croix, up to and inclusive of waters from the 100-fathom curve shoreward to the level of mean high tide. The mutton snapper closed area is shown within this critical habitat. Map courtesy of WIMARCS.

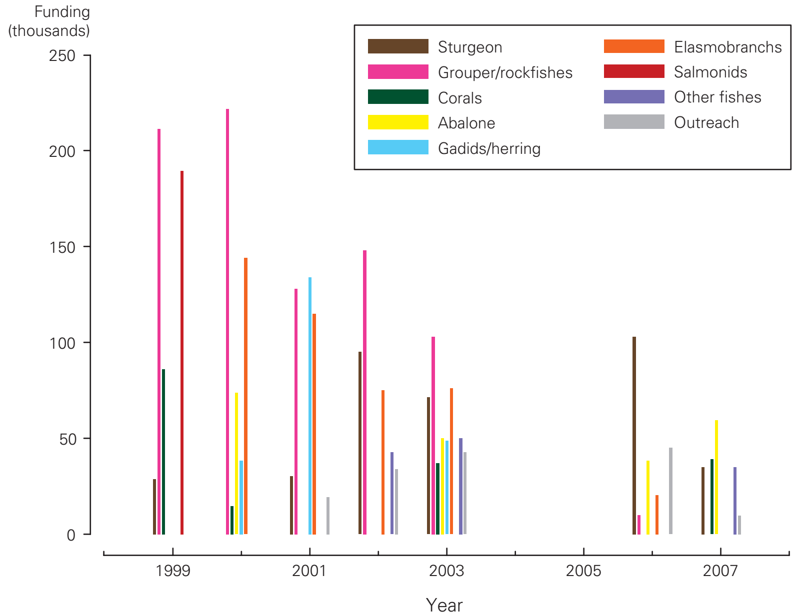

Figure 4
Fiscal year 1999–2007 allocation of species of concern research and outreach funds (in thousands of dollars).

continue monitoring this species and to examine the movements and distribution of smalltooth sawfish in relationship to physical characteristics of the habitat. Results of this research will be valuable in NMFS' effort to identify and designate critical habitat for this species.

PROACTIVE CONSERVATION: THE SPECIES OF CONCERN PROGRAM

In addition to the conservation efforts being made through the Section 6 Program, NMFS is also engaged in proactive conservation efforts that address species potentially at risk before protections of the ESA can or should be applied. In April 2004 NMFS established the Species of Concern Program specifically to 1) identify species potentially at risk; 2) identify data deficiencies and uncertainties in species' status and threats; 3) increase public awareness about these species; 4) stimulate cooperative research efforts to obtain the information necessary to evaluate species status and threats; and 5) foster voluntary efforts to conserve these species before ESA listing becomes warranted. Species of Concern are defined as those species about which NMFS has some concerns regarding status and threats, but for which insufficient information is available to indicate a need to list the species under the ESA (NMFS, 2004). Currently, there are 42 species of concern (see fact sheets at http://www.nmfs.noaa.gov/pr/species/concern/ and a list in Appendix 7). Boxes 2, 3, and 4 provide information about a few of these species of concern and current efforts to conserve them.

Before establishing the Species of Concern Program, NMFS maintained many of these species on its list of candidate species. However, most of these species did not fit NMFS' definition of a candidate species, and a species of concern list was considered a better way of highlighting these species for conservation purposes. Neither candidate species nor species of concern designations carry any procedural or substantive protections under the ESA.

NMFS funds conservation efforts for species of concern through one of two mechanisms: 1) an annual allocation among NMFS Regions and Science Centers for research and outreach projects, and 2) the newly established Proactive Species Conservation Grant Program, which funds states and other non-Federal management entities for on-the-ground conservation efforts. The information gained and conservation actions taken through these projects are designed to benefit the species by addressing known threats to their existence.

From FY1999 through FY2007, NMFS has provided over $2.7 million to NMFS Regional Offices and Science Centers for research and outreach projects through its annual allocation (Figure 4). Some of the species groups that have benefited from these funds include corals, sturgeon, salmonids, and groupers. Table 1 lists the 7 projects that were funded with the $178,316 available for FY2007.

The Proactive Species Conservation Grant Program is a competitive grant program that provides funds to states, counties, or other non-Federal entities with management authority over a species of concern so that they can conserve these species. An applicant submits a proposal that must meet certain criteria. The main evaluation criteria are importance/relevance and applicability; technical/scientific merit; overall applicant qualifications and project costs; and outreach and education. In FY2006 (the inaugural year of the grant program) and FY2007, $490,000 was available each year and was awarded in two separate grants: a Mississippi Department of Natural Resources (MDNR) project on the saltmarsh topminnow, *Fundulus jenkinsi*

($143,095), and a Maine Department of Marine Resources project on Atlantic sturgeon, Atlantic salmon, and rainbow smelt ($836,905). Neither of these 5-year projects is far enough along to discuss results, but some details on the MDNR project are provided in Box 3.

SUMMARY

While the ESA is highly regulatory in nature, NMFS has established programs that take cooperative and non-regulatory approaches to conserving listed species and species of concern. In particular, NMFS has made small, but increasingly significant, steps in developing both the ESA Section 6 and the Species of Concern programs. Federal funding through these programs has supported research, management, and outreach projects for over a dozen species in about a dozen states. For the external partners, Federal support through these programs has been invaluable, because other funds are largely unavailable for this work.

The Section 6 Program has been, and continues to be, a critical component of recovery efforts for listed species. Work supported through this program often directly addresses recovery priorities identified in NMFS Recovery Plans. Since the beginning of 2006, NMFS has drafted or revised 13 recovery plans, including new recovery plans for white abalone and smalltooth sawfish. As the number of state partners engaged in this program increases, so too will the number of species and recovery actions implemented for these species. Continuing to invest in the Section 6 Program means continuing to invest in recovery efforts for species listed under the ESA.

Although still in its infancy, the Species of Concern Program has evolved from a small amount of agency research and outreach effort into a national program that engages external partners in proactive conservation efforts. Funding remains limited for this program, but over time and with some demonstrated success in preventing the need to protect species of concern under the ESA, this program is expected to grow. Overall, these proactive efforts will serve to increase our knowledge of potentially at-risk species and provide a measure of protection before more costly and cumbersome regulatory mechanisms are required.

Table 1
Projects funded for Fiscal Year 2007 Science Center and Region projects through the Proactive Species Conservation Grant Program.

Project	Funding
Black abalone status review and population assessment	$25,000
Estimating the size of green sturgeon populations	$35,000
SOC national education and outreach proposal	$9,751
Biological relevance of morphologically indistinguishable but genetically distinct pinto abalone	$34,426
Field surveys in Hawaii for Hawaiian reef coral, *Lingula reevii*, and inarticulated brachiopod, *Montipora dilatata*	$16,150
Using meta-analysis to determine the status of the U.S. population of sand tiger shark, *Carcharias taurus*	$35,000
Coral recovery planning	$22,989

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Box 2: Green sturgeon (Northern DPS)

Year Identified as a Species of Concern: 2003
Other Conservation Designations: International Union for Conservation of Nature and Natural Resources—Near Threatened; American Fisheries Society—Endangered; California—Species of Greatest Conservation Need

The green sturgeon is an ocean-oriented sturgeon found in nearshore waters from Baja Mexico to Canada. It is anadromous and spawns in the spring. Green sturgeon differ from co-occurring white sturgeon by the number of side-body scutes (23–30, compared to >38 for white sturgeon), the presence of 1–2 scutes behind the dorsal fin (white sturgeon have none), and a longer snout with barbels closer to the mouth. While many green sturgeon are olive-green dorsally, they can also be gray or golden brown. Green sturgeon can reach 7 feet in length and 350 pounds, and feed mainly on burrowing shrimps. Two distinct population segments (DPS's) have been defined under the ESA—a northern DPS that spawns in the Klamath and Rogue Rivers and a southern DPS that spawns in the Sacramento River (Figure 5). The southern DPS was listed as threatened in 2006, while the northern DPS was identified as a species of concern because of remaining uncertainties in its status.

An 88% decline in commercial landings of all sturgeon occurred from 1887–1901. The best contemporary abundance indicator for the northern DPS appears to be the Klamath Tribal salmon gillnet harvest, in which green sturgeon are bycatch (Figure 6). Data from this fishery indicates that catch has declined slightly over 20+ years, with 200–400 fish taken per year. Spawning populations in the Eel and Trinity Rivers in California have been lost. In addition to historical overfishing, threats to green sturgeon include habitat destruction and alteration from water devel-

Figure 5
Distribution of the northern and southern DPS's of green sturgeon. Map courtesy of S. Lindley, NMFS.

Box 2: Green sturgeon (continued)

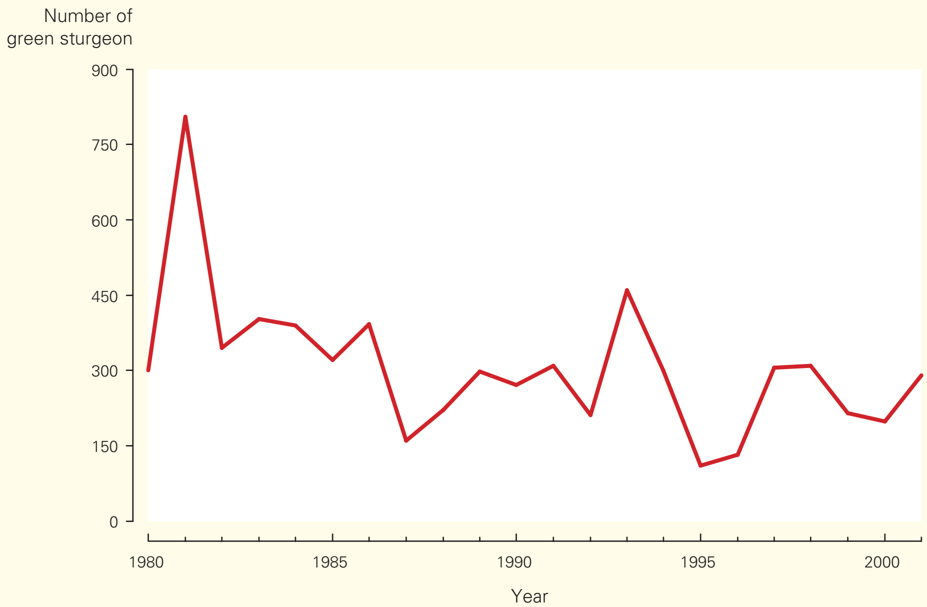


Figure 6

Catch of green sturgeon in the Yurok Tribal salmon gillnet fishery on the Klamath River. Data courtesy of NOAA.

opment, dams, and land-use practices in the Sacramento and Klamath Rivers. Green sturgeon also have many characteristics that make them vulnerable including large size, late maturity, low reproductive productivity, and long life span.

The Species of Concern Program has funded recent projects entitled Modeling the Freshwater Habitat of Green Sturgeon from Sightings Data; Marine Migration and Estuary Use of Green Sturgeon; and Seasonality and Habitat Use of Green Sturgeon in Washington Estuaries. The marine migration study found that green sturgeon migrate north in the fall into Canada, often as far as the north end of Vancouver Island, and return south in the spring. The Washington estuary project indicated that green sturgeon use estuaries throughout their migratory range, and use them in the summer when estuary water temperature is at least 4°F warmer than coastal marine waters (Moser and Lindley, 2007). Overall, these projects suggest a higher risk than previously expected of green sturgeon ending up as bycatch in other fisheries due to their frequent and long-distance movements.

Box 3: Saltmarsh topminnow

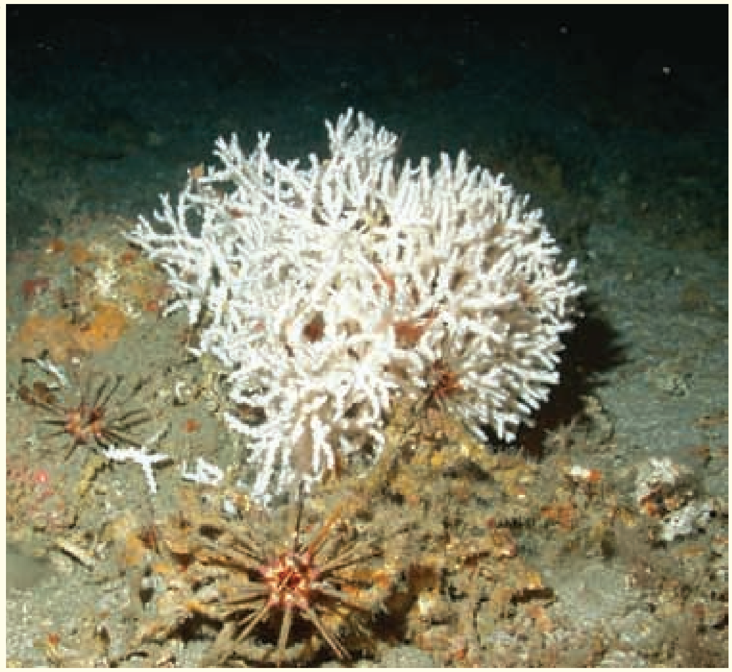
Year Identified as a Species of Concern: 1991
Other Conservation Designations: International Union for Conservation of Nature and Natural Resources—Not Evaluated; American Fisheries Society—Threatened in Florida, Vulnerable elsewhere; Florida, Louisiana, Mississippi—Species of Greatest Conservation Need

The saltmarsh topminnow is endemic to brackish water estuaries, coastal salt marshes, and backwater slough areas from Galveston Bay, Texas, to Escambia Bay in the western panhandle of Florida. It is one of the smallest members of the topminnow/killifish family (Fundulidae), seldom exceeding 1.75 inches total length, with most individuals ranging from 1 to 1.4 inches. They have cross-hatching on the back and sides that may be gray-green or fainter, and 12–30 dark round spots are often arranged in rows along the midside of the body from above the pectoral fin to the base of the caudal fin. Females become slightly larger than males. Saltmarsh topminnows are tolerant to salinities of 1–20 parts per thousand (ppt). Abundance is highest in *Spartina* and *Juncus* salt marshes with salinity of <12 ppt and depths of 1–2 feet. They belong to the guild of species that mostly uses the edge (rather than the interior) of saltmarshes adjacent to tidal creeks. Other pupfishes (Family Cyprinodontidae) use the marsh interior more. No information is available on diet or feeding habits. Breeding occurs from March to August in shallow flooded marshes. Few adults survive beyond breeding in their second year of life.

Abundance has likely declined as a result of extensive loss of habitat. Habitat alteration, dredging, and marsh erosion are the most serious threats to this species. The conversion of marsh to deeper, open water eliminates important feeding, sheltering, and breeding areas. Dock and other construction along marsh edges may prevent saltmarsh topminnows from accessing flooded marsh. Hurricanes have further reduced available saltmarsh habitat.

In 2006 and 2007 the Species of Concern Program provided the Mississippi Department of Marine Resources (MDMR) $143,095 for the study *Fundulus jenkinsi*, Saltmarsh Topminnow: Conservation Planning and Implementation. The MDMR is working cooperatively with The Nature Conservancy and the University of Southern Mississippi on this project. Sampling of saltmarsh topminnow began in March 2007 and continues quarterly using Geographic Information Systems (GIS) to map the species distribution and abundance. In later years of this 5-year project, the MDMR will use this information to focus conservation efforts in areas found to be most important to the species. Bulkhead construction is popular in the areas suspected to be important saltmarsh topminnow habitat; if the research indicates that these areas are in fact important to this species, then the state could address threats to the species through its permitting process. This project is also being conducted in collaboration with three National Estuarine Research Reserves (NERR's) in the area. NERR's are also collaborations between NOAA and the states.

Box 4: Ivory bush coral


NMFS

Year Identified as a Species of Concern: 1991
Other Conservation Designations: International Union for Conservation of Nature and Natural Resource—Not Evaluated

Ivory bush coral, which is more commonly known by its scientific name, *Oculina varicosa*, is endemic to the southeastern United States and ranges from Cape Hatteras, North Carolina, through the Gulf of Mexico and Caribbean, although the main population occurs off east-central Florida. Colonies are arborescent, with highly clumped, irregular, bushy branches; branches average 1/4 inch in diameter, and colonies can be 4–5 feet tall. Colonies are found to depths of 500 feet on limestone rubble, low-relief limestone outcrops, and high-relief, steeply sloping prominences. Colonies are semi-isolated, patchy, and low-growing in shallow water, or form larger, massive coalescing aggregates (thickets) with substantial topographic relief in depths over 160 feet. Shallow-water colonies are golden to brown due to symbiotic algae (zooxanthellae), and have shorter, stout branches with closely-spaced corallites. Deep-water colonies are lavender to white in color (they lack symbiotic algae) and have thinly tapered branches. The deeper individuals have an approximately 50% faster growth rate than shallow individuals. The taxonomy of the *Oculina* genus is unclear, and there is debate whether the deep-water and shallow-water forms are the same species. *Oculina* filter-feed on planktonic organisms. *Oculina* serves as a keystone species by providing important habitat; over 300 species of invertebrates have been found living in its branches. The abundances of economically valuable fishes (e.g. grouper, snapper, sea bass, and amberjack) are often higher in areas with high *Oculina* coral cover.

The Species of Concern listing is based on well-documented declines in the Oculina Banks area, which lies off the central east coast of Florida. Banks containing partially dead colonies of *Oculina* were first observed in the late 1970's. Submersible surveys performed in 1995–1997 indicated extensive habitat damage. Damage to corals in the Oculina Banks area has resulted from the use of mechanical fishing gear, including dredges, bottom long lines, trawl nets, and anchors. As of 2001, it was estimated that only 10% of *Oculina* coral habitat there remained intact. Colonies may also be negatively impacted by sediments and red tides.

In 1984, the South Atlantic Fishery Management Council established the 122 mi^2 Oculina Habitat Area of Particular Concern (HAPC), the world's first protection granted specifically to deep coral habitat. In 2000, the South Atlantic Council expanded the Oculina HAPC to 397 mi^2 and prevented trawling in that area. Current research is focusing on clarifying the uncertain taxonomy of this species. Systematic monitoring of the Oculina Banks area began in 2005, and the Species of Concern Program recently provided partial funding for an update of the species' status.

Part 3
Living Marine Resources

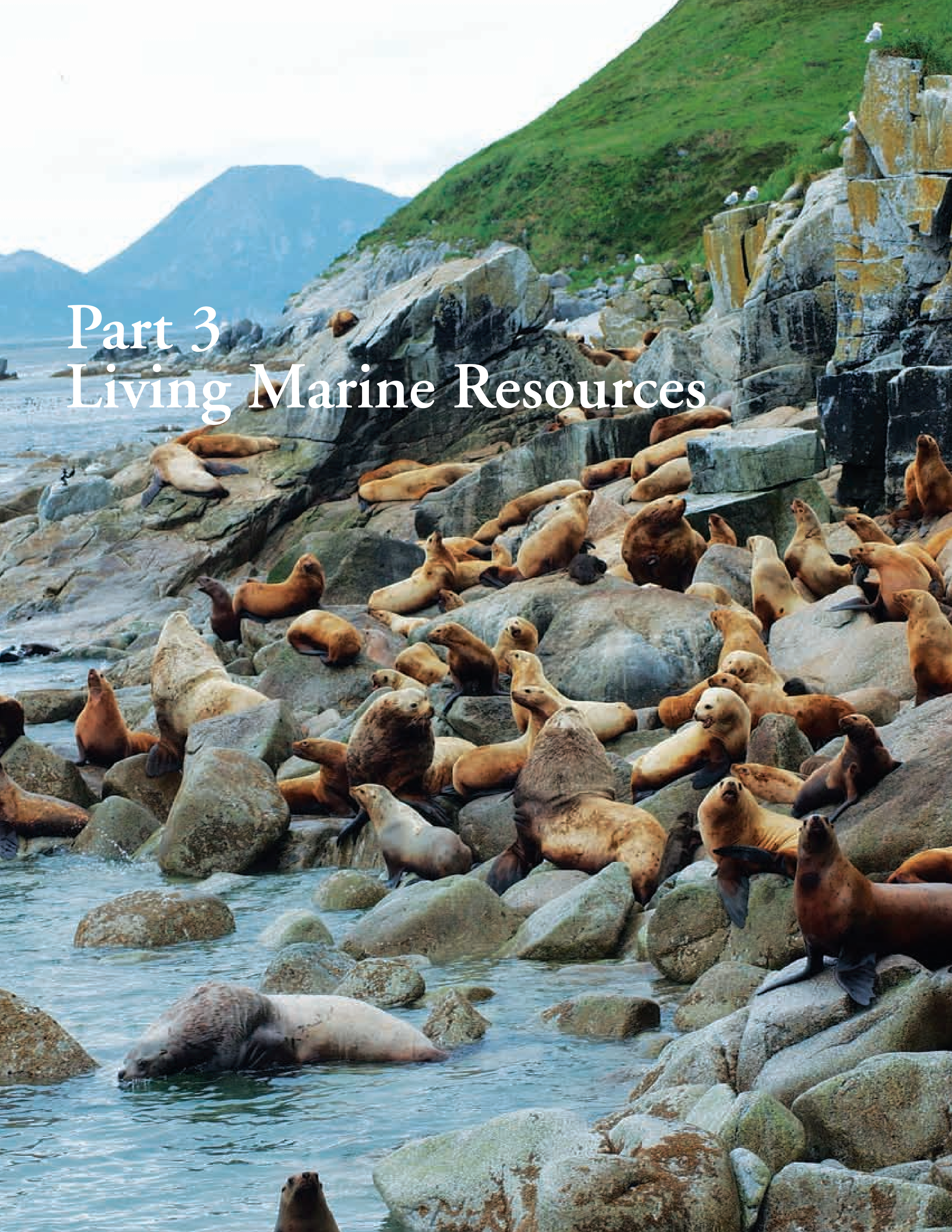


Photo on previous page: Steller sea lion rookery in Alaska. Photo courtesy of Carolyn Gudmundson.

Northeast Demersal Fisheries

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Photo above: School of haddock.

INTRODUCTION

Northeast groundfish fisheries include about 35 stocks, primarily in New England waters and also off the Mid-Atlantic states. In New England, groundfish fisheries are dominated by members of the cod family (Atlantic cod, haddock, hakes, and pollock), flounders, and goosefish (also known as monkfish). Other important species in the complex include dogfish and skates. Mid-Atlantic groundfish fisheries are primarily for summer flounder, scup, goosefish, and black sea bass.

Groundfish fishermen use various fishing gears including otter trawls, gillnets, traps, and set lines. Otter trawling is the predominant fishing method employed throughout the region, although many vessels participating in groundfish fisheries switch gears seasonally. In 2006, 1,545 vessels possessed multispecies limited-access permits to participate in groundfish fisheries in the Northeast Region. Recent average yield (RAY; 2004–06; includes United States, Canada, and recreational) of mixed groundfish was just over 160,000 metric tons (t; Table 1-1). This level is about one-half of the sustainable yield, primarily due to reductions in catch quotas while many stocks rebuild from overfishing in previous years.

Northeast groundfish resources occur in mixed-species aggregations that result in significant bycatch interactions among fisheries targeting different species or species groups. Management of the fishery is complex due to differences in mesh size, gear type, minimum landing (fish) size, quotas, and seasonal and year-round closure regulations set by the various regional management bodies: New England Fishery Management Council (NEFMC), Mid-Atlantic Fishery Management Council (MAFMC), Atlantic States Marine Fisheries Commission (ASMFC), individual states, and Canada. The principal species of New England groundfish are managed under the Northeast Multispecies Fishery Management Plan (FMP), as well as peripherally

Table 1-1
Productivity in metric tons (t) and status of northeast U.S. demersal fisheries resources.

Species/stock	Recent average yield (RAY)[1]	Current yield (CY)	Sustainable yield (MSY)	Stock level relative to B_{MSY}	Harvest rate	Stock status
Principal groundfish						
Acadian redfish	487	1,946	8,200	Below	Not overfishing	Rebuilding
American plaice	1,627	3,666	4,900	Below	Not overfishing	Overfished
Atlantic cod[2,3,4]						
Gulf of Maine	5,298	5,146	16,600	Below	Overfishing	Overfished
Georges Bank	5,080	7,458	35,200	Below	Overfishing	Overfished
Atlantic halibut	24	Unknown	300	Below	Unknown	Overfished
Haddock[2,3,5]						
Gulf of Maine	1,430	1,279	5,100	Below	Not overfishing	Overfished
Georges Bank	18,228	49,829	52,900	Below	Not overfishing	Overfished
Ocean pout[6]	294	38	1,500	Below	Not overfishing	Overfished
Pollock[2,3,7]	7,860	12,005	17,600	Below	Not overfishing	Rebuilding
Red hake						
Gulf of Maine / N. Georges Bank	165	Unknown	2,000	Below	Unknown	Not overfished
S. Georges Bank / Mid-Atlantic	354	Unknown	Unknown	Unknown	Undefined	Not overfished
Silver hake						
Gulf of Maine / N. Georges Bank	466	Unknown	Unknown	Below	Not overfishing	Not overfished
S. Georges Bank / Mid-Atlantic	6,475	Unknown	Unknown	Below	Not overfishing	Not overfished
White hake[2,8]	2,625	2,056	4,200	Below	Overfishing	Overfished
Windowpane flounder[6]						
Gulf of Maine / Georges Bank	652	389	1,000	Near	Not overfishing	Not overfished
S. New England / Mid-Atlantic	385	173	900	Below	Not overfishing	Overfished
Winter flounder[2,3,9]						
Gulf of Maine	441	Unknown	1,500	Below	Not overfishing	Not overfished
Georges Bank[6]	2,038	1,424	3,000	Below	Overfishing	Not overfished
S. New England / Mid-Atlantic	3,035	2,481	10,600	Below	Overfishing	Overfished
Witch flounder	2,659	5,511	4,400	Near	Not overfishing	Not overfished
Yellowtail flounder[2,10]						
Cape Cod / Gulf of Maine	450	650	2,300	Below	Overfishing	Overfished
Georges Bank	4,330	3,000	12,900	Below	Overfishing	Overfished
S. New England / Mid-Atlantic	934	146	14,200	Below	Overfishing	Overfished
Subtotal, principal groundfish	65,337	105,122	206,595			
Dogfish and skates						
Skates[11]	41,575	Unknown	Unknown	Undefined		
Spiny dogfish[2,3,12]	6,451	1,800	Unknown	Undefined	Not overfishing	Rebuilding
Subtotal, dogfish and skates	48,026	43,375	43,375			

under provisions of the ASMFC's Northern Shrimp FMP, while other species are managed either directly or indirectly under other FMP's.

Groundfish fisheries in New England were traditionally managed by indirect methods such as restrictions on mesh sizes, minimum fish lengths, and some area closures. Regulatory measures currently in place for the major New England groundfish stocks include effort controls through allowable days at sea coupled with closed areas, trip limits, and target levels for total allowable catch. The Summer Flounder, Scup, and Black Sea Bass FMP includes provisions for catch quotas aimed at rebuilding these stocks.

Extensive historical data for Northeast demersal fisheries have been derived from both fishery-dependent (i.e. catch and effort monitoring) and fishery-independent (i.e. NOAA fishery research vessel surveys since 1963) data collection programs. Beginning in 1989, an at-sea observer program has been conducted aboard a subset of commercial fishing vessels to document discard rates and collect high quality, high-resolution data on the groundfish catch. Some of the Northeast demersal

Table 1-1
Continued from previous page.

Species/stock	Recent average yield (RAY)[1]	Current yield (CY)	Sustainable yield (MSY)	Stock level relative to B_{MSY}	Harvest rate	Stock status
Other finfish						
Atlantic hagfish[13]	844	Unknown	Unknown	Unknown		
Black sea bass[3]	2,200	3,100	Unknown	Below	Not overfishing	Rebuilding
Cusk[2,13,14]	263	Unknown	Unknown	Unknown		
Goosefish (monkfish)[2,15]						
Northern stock	10,800	7,737	Unknown	Above	Not overfishing	Overfished
Southern stock	10,500	3,667	Unknown	Above	Not overfishing	Overfished
Scup[3]	6,955	8,977	Unknown	Below	Overfishing	Overfished
Spot[3]	1,588	Unknown	Unknown	Unknown	Unknown	Unknown
Summer flounder[3]	13,484	10,704	21,444	Above	Overfishing	Overfished
Tilefish	918	905	2,000	Below	Not overfishing	Rebuilding
Weakfish[3]	1,013	6,538	Unknown	Unknown	Unknown	Unknown
Wolffishes[13]	106	Unknown	Unknown	Unknown		
Subtotal, other finfish	48,671	44,429	56,264			
Total	162,034	192,926	306,234			
U.S. Subtotal	147,168	157,287	263,977			

[1] 2004–06 average. Includes foreign and recreational landings.
[2] Includes more than 100 t/year of foreign (Canadian) landings.
[3] Includes more than 100 t/year of recreational landings.
[4] U.S. portion of RAY is 8,852 t.
[5] U.S. portion of RAY is 8,836 t.
[6] CY represents landings only.
[7] U.S. portion of RAY is 6,190 t.
[8] U.S. portion of RAY is 2,543 t.
[9] U.S. portion of RAY is 5,407 t.
[10] U.S. portion of RAY is 5,250 t.
[11] Consists of barndoor, clearnose, little, rosette, smooth, thorny, and winter skates. Collectively, the status of the species complex cannot be determined.
[12] 2004–05 average; discards not yet estimated for 2006.
[13] Harvest rate and stock status are not available for this stock.
[14] U.S. portion of RAY is 78 t.
[15] U.S. portion of RAY is 21,300 t.

stocks (Atlantic cod, yellowtail flounder, haddock, American plaice, and summer flounder) are among the best understood and most thoroughly assessed fishery resources in the United States.

SPECIES AND STATUS

Principal Groundfish

The principal groundfish group includes important species in the cod family (Atlantic cod, haddock, silver hake, red hake, white hake, and pollock), flounders (yellowtail, winter, witch, windowpane, Atlantic halibut and American plaice), ocean pout, and Acadian redfish. Recent (2004–06) yields of these 14 species (representing 23 stocks) have averaged about 65,000 t (78% U.S. and 22% Canadian), compared to a combined sustainable yield of about 207,000 t (Table 1-1). Current yields are lower than the sustainable yield because many of these stocks are considered overfished and currently rebuilding. Total ex-vessel revenue from the principal U.S. groundfish commercial landings has dropped in recent years and was $83 million in 2006, compared to $107 million in 2003. The groundfish complex also supports important recreational fisheries for summer flounder, Atlantic cod, winter flounder, and pollock, representing about 10% of the total catch of these species.

The research vessel survey abundance index[1] for this group of species declined rapidly during


B. F. Figuerido

Silver hake.

[1] An aggregate index of abundance used to monitor resource trends; computed as the sum of the individual species stratified mean catch-per-tow values, smoothed to compensate for between-year variability.

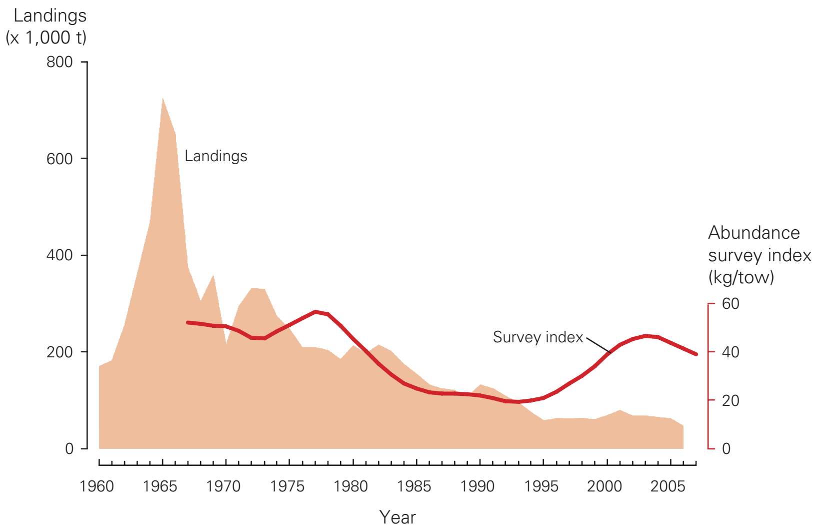

Figure 1-1

Landings in metric tons (t) and abundance survey index (kg/tow) of principal groundfishes, 1960–2007.

the 1960's and early 1970's (Figure 1-1), reflecting substantial increases in exploitation associated with the arrival of distant-water fleets. Many stocks in this group declined sharply during that period, notably Georges Bank haddock, most silver and red hake stocks, and most flatfish stocks. By 1974, indices of abundance for many of these species had dropped to the lowest levels ever recorded.

Groundfish partially recovered during the mid-to-late 1970's because of reduced fishing effort associated with increasingly restrictive management under the International Commission for the Northwest Atlantic Fisheries in the early 1970's, and implementation of the Magnuson Fishery Conservation and Management Act in 1977 (Mayo et al., 1992). Cod and haddock abundance increased markedly, stock biomass of pollock increased more or less continually, and recruitment and abundance also increased for several flatfish stocks. The aggregate abundance index began to increase through the late 1970's, but then subsequently declined, reaching new lows in the late 1980's and early 1990's. The 1989 and 1990 abundance values were slightly higher than the previous two years, primarily due to recruitment of moderate 1987 year-classes of Atlantic cod, haddock, and yellowtail flounder. However, subsequent abundance indices declined, due in large part to the rapid depletion of the 1987 yellowtail flounder year-class and declining cod abundance. The overall index of abundance of the principal groundfish and flounders reached a 30-year low in 1992, but has subsequently more than doubled (Figure 1-1) owing to rebuilding efforts. The most recent changes in the aggregate abundance index are strongly influenced by substantial increases since 1996 of the biomass index for Acadian redfish in the Gulf of Maine, but also reflect increased biomass of haddock and yellowtail flounder on Georges Bank, and cod in the Gulf of Maine (NEFSC, 2001; NEFSC, 2005; Mayo and Terceiro, 2005; TRAC, 2007a,b).

Landings of most groundfish species declined substantially during the mid 1990's. For many stocks, landings continue to remain relatively low as a result of generally poor recruitment and continued restrictions on effort, low trip limits, and additional area closures in the Gulf of Maine. However, relatively strong year-classes produced in 1997 for Georges Bank yellowtail flounder, in 1998, 2000, and 2003 for Georges Bank haddock, and in 2003 for Gulf of Maine cod, combined with sharp reductions in fishing mortality, have led to improved conditions for these stocks (NEFSC, 2005).

Dogfish and Skates

Dogfish and skates make up a significant part of the aggregate groundfish stock biomass in the Northeast. Of the two dogfish species, spiny dogfish make up a much larger proportion than smooth dogfish. Seven species of skates, including little, winter, barndoor, clearnose, thorny, rosette, and smooth occur on the Northeast shelf; of these, winter, little, and thorny skates account for most of the landed catch.

As catches of principal groundfish declined, reported landings of skates and spiny dogfish increased markedly from 2,600 t in 1978 to 29,700 t in 1992, and peaked at 41,700 t in 1996 (Figure 1-2). Annual landings declined to a low of 15,500 t in 2005 and averaged 17,200 t during 2005–06, primarily as a result of continued restrictions on spiny dogfish landings. Discards of these species in fisheries directed towards other species are at least equivalent to the amounts landed and sometimes exceed the landings. The abundance of skates and dogfish increased throughout the 1970's and 1980's, peaked in 1990, declined through 2000, and has since increased (Figure 1-2). Estimates of spiny dogfish exploitable and spawning stock biomass in 2002 were about one-half of the maximum level observed in 1985 (NEFSC, 2006). However, the restrictions on dogfish landings have resulted in an increase in spawning stock biomass through 2007. Trends in biomass for most skate species indicate decreases or stability in the last 5 years (NEFSC, 2007).

Other Finfish

Other groundfish species include those taken primarily as bycatch in fisheries directed at the principal groundfish species, as well as those that are targeted directly. In the Gulf of Maine, goosefish (also known as monkfish), cusk, and wolffishes are taken primarily as bycatch. In the Mid-Atlantic area, goosefish, scup, weakfish, black sea bass, spot, tilefish, and several other species are landed both in directed fisheries and as bycatch. As a group, other finfish can be characterized as generally overexploited; individually, some have landings well below their long-term mean as a result of being depleted, while for others, recent landings have exceeded their long-term mean due to overfishing. Some of these stocks are managed indirectly by other FMP's; for example, cusk and wolffishes are taken in various groundfish fisheries managed under the Northeast Multispecies FMP. Other stocks are managed directly under FMP's. Goosefish has been managed under a single-species FMP since 1999. Scup and black sea bass represent major directed fisheries as well as components of the summer flounder directed fishery, with all three species managed under a single FMP.

In recent years, goosefish has become one of the most important species in the Northeast region and is currently the top-ranked groundfish species in both landings and value. U.S. landings increased from less than 600 t annually during 1964–72 to about 8,800 t during 1980–1988, and then peaked at 28,300 t in 1997 with ex-vessel revenue of $35 million. Landings have declined steadily since 2003 due to regulatory changes, and averaged 18,300 t during 2004–06. The value of goosefish landings peaked at $53.4 million in 2000, but has since declined to $33.5 million in 2006. The marked increase in goosefish landings during the 1990's resulted from a diversion of fishing effort from principal groundfish stocks, increased market demand for the species, and resulting higher prices. The most recent assessment (Northeast Data Poor Stocks Working Group, 2007) indicated that the goosefish resource is not overfished and overfishing is not occurring. However, the assessment had significant uncertainties due to poorly understood life history parameters and application of a newly-developed model. Intensive cooperative industry vessel surveys conducted during 2001 and 2004 provided significant new information, and biological studies are underway to improve understanding of life history of goosefish.

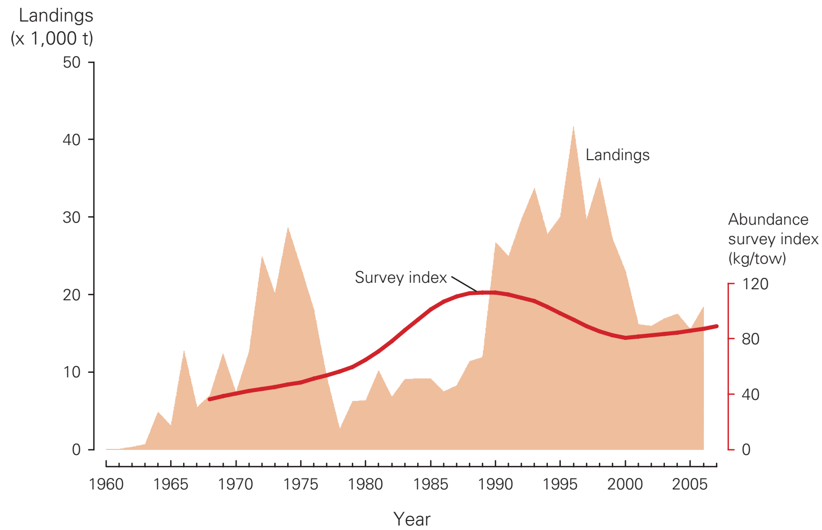

Figure 1-2
Landings in metric tons (t) and abundance survey index (kg/tow) of dogfish and skates, 1960–2007.

Summer flounder, one of the most valuable groundfish species in the Mid-Atlantic area, is the focus of both commercial and recreational fisheries with about 60% of the landings commercial and 40% recreational. Prior to the implementation of management measures in 1988, stock abundance had been steadily declining due to excessively high fishing mortality rates. However, spawning stock biomass increased substantially from 1989 to 2006 (Terceiro, 2006) and fishing mortality has declined since 1997. The recent average yield was about 13,500 t during 2004–06, compared to a sustainable yield of nearly 21,500 t (Table 1-1).

Atlantic hagfish, common in U.S. waters between the Gulf of Maine and North Carolina, support a small commercial fishery (six vessels in 2005) and can be a problem in hook and gillnet fisheries where they feed on caught fish. Hagfish

Goosefish lying camouflaged on a rocky reef on Georges Bank.

landings are exported to Asia where the skin is used to make "eel skin" leather products and the meat is used for food. Landings are uncertain because reporting is not required, but appear to have increased substantially during the 1990's. During 2004–06, reported annual landings averaged 844 t (Table 1-1), a decline from 2001–03. Ex-vessel revenues were over $1,200,000 for landings of 1,340 t in 2004. Currently, the hagfish fishery is not managed, as there is no FMP in place. Based on a recent review (NEFSC, 2003), little is known about the condition of hagfish stocks, although the biological characteristics of the species (e.g. low fecundity, potentially delayed sexual maturity, and years with apparently no reproduction) indicate that hagfish may be vulnerable to overfishing. Collection of basic biological and fishery data for hagfish is ongoing and a stock assessment is planned for the near future.

ISSUES

Management Concerns

During most of the 1980's and early 1990's, New England groundfish harvests were regulated by indirect controls on fishing mortality such as mesh and minimum fish size restrictions and some area closures. Amendment 5 to the Northeast Multispecies FMP, implemented in March 1994, marked the beginning of an effort reduction program to address the Magnuson-Stevens Fishery Conservation and Management Act (MSA) requirement to eliminate the overfished conditions of Atlantic cod, haddock, and yellowtail flounder. The regulatory package included a moratorium on new vessel entrants, a schedule of reduction in days at sea for trawl and gillnet vessels, increases in regulated mesh size, and expanded closed areas to protect haddock. Since December 1994, three large areas (Closed Areas I and II on Georges Bank and Nantucket Lightship Closed Area; Figure 1-3) have been closed to protect the regulated groundfish stocks. In May 1998, a large portion of the western Gulf of Maine was also closed to afford protection for several additional groundfish stocks.

Amendment 7 to the Northeast Multispecies FMP was developed and implemented in 1996 to accelerate the existing days-at-sea reduction schedule and impose other restrictions, including the creation of three year-round closed areas and a system of seasonal closures in the Gulf of Maine. Amendment 9, implemented in 1999, established overfishing definitions and rebuilding objectives to meet the requirements of the MSA. The Multispecies FMP has also been modified by a series of framework adjustments which enacted increases in codend mesh size, as well as trip limits and area closures, to achieve specific management objectives for cod in the Gulf of Maine and on Georges Bank. Trip limits were also imposed on Georges Bank haddock catches.

A groundfish vessel buyback program was initiated in 1995, first as a pilot project and later as a comprehensive fishing-capacity reduction project. The program was designed to reduce excess fishing capacity and provide economic assistance to fishermen adversely affected by the collapse of the groundfish fishery if they voluntarily chose to permanently remove their vessels from the fishery. The vessel buyback program, which concluded in 1998, successfully removed 79 fishing vessels at a cost of nearly $25 million and resulted in an approximate 20% reduction in fishing effort in the Northeast groundfish fishery.

In December 2001, as a result of a lawsuit filed by the Conservation Law Foundation and several other environmental groups, a Federal district court ruled that the National Marine Fisheries Service had failed to comply with the MSA's overfishing and rebuilding provisions, and failed to accurately account for bycatch and to minimize bycatch mortality in the groundfish fishery. To bring the Northeast Multispecies FMP into full compliance with the MSA, the NEFMC developed Amendment 13, which was implemented in May 2004. Amendment 13 established a new days-at-sea baseline for each individual operator, and allowed only 60% of those days to be directed at regulated species in fishing years 2004 and 2005, with further reductions scheduled through 2009. The remaining 40% of days can only be used in Special Access Programs that minimize the catch of overfished stocks or in directed fishing where it can be otherwise demonstrated that bycatch of overfished stocks is minimal. Amendment 13 also established a formal rebuilding plan for overfished groundfish stocks based on re-estimated biomass and fishing mortality reference points (NEFSC, 2002). Framework 42 was implemented in 2006 to adjust the rebuilding schedules following assessment results obtained at the August 2005 Groundfish Assessment Review Meeting (NEFSC, 2005). The NEFMC is currently developing Amendment 16 to the Northeast Multispecies FMP to implement further rebuilding adjustments based on revised biological reference points and status of 19 stocks through 2007.

The joint MAFMC-ASMFC Summer Flounder FMP was initially approved in 1988 but was subsequently modified by a series of amendments to include scup and black sea bass, as well as revised overfishing definitions. This FMP has a strategy to reduce fishing mortality to the level producing maximum yield per recruit for summer flounder (i.e. F_{max}, used as a proxy for F_{MSY}). The FMP uses commercial landings quotas (allocated by state and season), recreational harvest limits, and possession/size limits to achieve this goal. Increased recruitment levels, combined with lower fishing mortality rates during 1993–2002, have resulted in significant increases in stock biomass.

Transboundary Stocks and Jurisdiction

Significant catches are taken from transboundary stocks of Atlantic cod, haddock, yellowtail flounder, and pollock in Canadian waters on Georges Bank and in the Gulf of Maine. During 2004–06, 15% of cod, 21% of pollock, 8% of yellowtail flounder, and 55% of haddock landings were taken by Canadian fishermen. Stock assessment activities between the United States and Canada have been coordinated on an informal basis for decades, but in 1998 a formal joint stock assessment and peer review process for transboundary stocks was initiated under the auspices of the Transboundary Resources Assessment Committee (TRAC). Both countries have continued to independently prepare management advice on the basis of jointly prepared and reviewed assessments.

Further coordination efforts led to the formation in 2000 of a bilateral government–industry committee, the Transboundary Management Guidance Committee (TMGC), to provide a linkage between fisheries and their respective management bodies. This committee is charged with recommending harvesting strategies and harvest levels consistent with each country's management strategies. The TMGC also developed a United States–Canada Resource Sharing Agreement for the joint management of cod and haddock on Eastern Georges Bank and yellowtail flounder on all of Georges Bank, which was formally implemented in Amendment 13 to the Northeast Multispecies

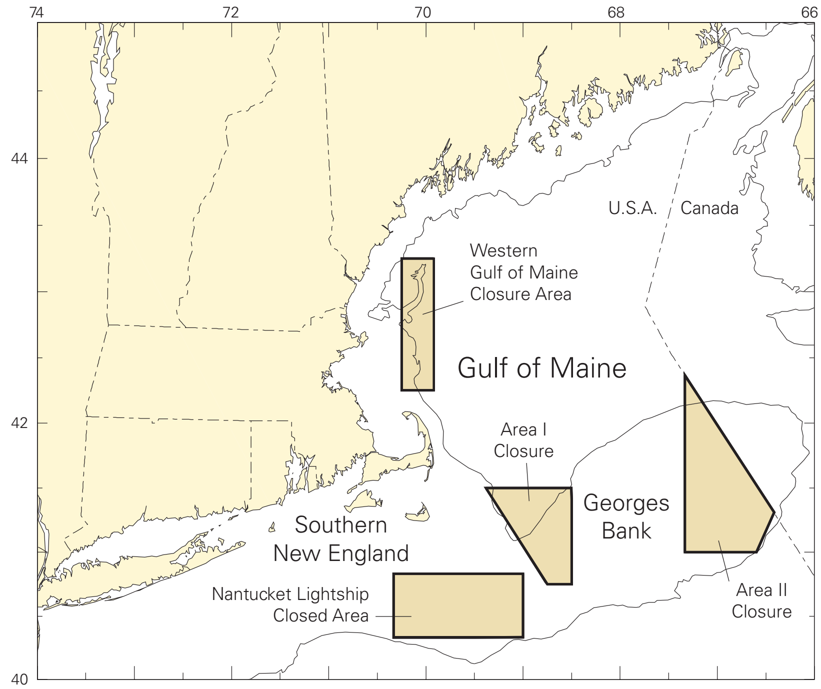

Figure 1-3
Areas closed year-round to protect New England groundfishes.

Wolf fish hiding amongst the rocks in Stellwagen Bank National Marine Sanctuary.

FMP. Under the agreement, country-specific quotas are applied annually for each of the three stocks based on an agreed total allowable catch (TAC) sharing formula.

Stock Recovery

Fishing effort restrictions were first implemented in 1994 under Amendment 5 to the Northeast Multispecies FMP through days-at-sea allocations based on either individual vessel or fleet-level performance criteria. Since 1995, the number of vessels in these two permit categories has fluctuated due to changing stock status, new regulations, and vessel buyback programs. Total allocations of days at sea have also changed according to a prescribed schedule of reductions in Amendments 5 and 7. As a result, the total number of permitted vessels in the individual vessel category declined between 1995 and 1998. The number of permitted vessels and their allocated days remained relatively unchanged in 1998–2001. The total number of vessels in the fleet category, however, rose between 1995 and 1996 when the fixed-gear sector (gillnets and longline) was included following the adoption of Amendment 7. The vessel buyback reduced the total number of fleet vessels in 1998, but neither effort allocation nor number of permitted vessels changed much through 2001. Measures enacted following implementation of Amendment 13 will generally result in a substantial reduction in overall effort, depending on the usage rate of fishing time in the Special Access Programs and in other fisheries that do not target the overfished stocks. At the same time, Amendment 13 allows for leasing or transfer of days at sea between comparable vessels, which could lead to further consolidation of the fleet.

After a decade of direct-effort control measures and many indirect controls on exploitation, several of the groundfish stocks regulated by the Northeast Multispecies FMP have begun to recover and are approaching biomass levels not seen for many decades (e.g. Acadian redfish and Georges Bank haddock). Thus, although total fishing effort may decline, the catch per day-at-sea may increase as stocks continue to recover and approach a level that will allow harvest rates equal to the sustainable yield. Summer flounder spawning stock biomass, regulated by fishing quotas that shut down the fishery when attained (known as a hard TAC level), has increased eight-fold over the last decade. Indications are that the biomasses of scup and black sea bass have also increased.

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Northeast Pelagic Fisheries

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Unit 2

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INTRODUCTION

Northeast pelagic fisheries target small schooling species in the U.S. Exclusive Economic Zone, particularly Atlantic mackerel, Atlantic herring, bluefish, and butterfish.[1] The fisheries on these stocks are seasonal and reflect fish migration patterns and temporal availability. Generally, these species overwinter in relatively warm offshore waters of the Mid-Atlantic Continental Shelf and move southward to avoid seasonal cooling of northern nearshore waters. This is followed by a return northward and inshore migration during the spring and summer to feed and reproduce.

Various fishing gears, including bottom trawls, midwater trawls, gillnets, and seines are used to harvest pelagic species in the Northeast Region. During 2004–06, total landings averaged 229,633 metric tons (t; Table 2-1), 70% by the United States and 30% by Canada. This includes recreational landings (bluefish and Atlantic mackerel) of about 7,666 t.

During the early 1970's, the principal Northeast pelagic species (Atlantic mackerel and Atlantic herring) were exploited heavily by foreign fleets. As a result, stock sizes and fishery yields declined to record low levels by the late 1970's. Abundance has since increased due to the exclusion of foreign fleets, resulting in lower harvest rates and improved recruitment. Stock sizes for these species are currently at historically high levels.

Northeast pelagic fisheries are managed under three fishery management plans (FMP's): Atlantic mackerel by the Mid-Atlantic Fishery Management Council's (MAFMC) Atlantic Mackerel, Squid, and Butterfish FMP; bluefish by the joint MAFMC and Atlantic States Marine Fisheries Commission's (ASMFC) Atlantic Bluefish FMP; and Atlantic herring, in coordination with the ASMFC, by the New England Fishery Management Council's Atlantic Sea Herring FMP.

[1]For taxonomic consistency, longfin and shortfin squid are included in Unit 4: Northeast Invertebrate Fisheries.

Photo above: Butterfish.

Atlantic herring on a sorting table aboard a NMFS survey vessel.

SPECIES AND STATUS

Northeast pelagic fisheries are dominated by four species: Atlantic mackerel, Atlantic herring, bluefish, and butterfish. The abundance of mackerel and herring is presently above average, while that of bluefish is near or above average and that of butterfish is below average.

Long-term population trends for pelagic species, as measured by research vessel survey data, have fluctuated considerably during the last 25 years (Figure 2-1). The combined abundance index for mackerel and herring reached minimal levels in the mid-to-late 1970's, reflecting pronounced declines for both and a collapse of the Georges Bank herring component, but subsequently increased steadily and peaked in 2001, declined somewhat, and remained relatively flat since then.

Atlantic Mackerel

The Atlantic mackerel stock recovered during the mid 1980's, and the most recent stock assessment (NEFSC, 2007) indicated that the spawning stock biomass reached 2.3 million t in 2005. Abundance indices from research vessel surveys have remained fairly stable in recent years, suggesting that stock biomass remains relatively high. Recent annual landings were about 106,219 t (Table 2-1), of which 49% was taken by the United States.

Atlantic Herring

The Atlantic herring stock complex in the Northeast Region is still somewhat underutilized as a whole, but the inshore Gulf of Maine component is considered fully utilized (NEFSC, 2007). Total landings of herring in 2003 were 115,000 t, up from 104,000 t in 2002. The U.S. catch accounted for 82% of the 2004 landings. Recent average landings totaled about 112,240 t (Table 2-1). The U.S. coastal stock complex consists of two major stock components, the Gulf of Maine and Georges Bank. Canadian catches off New Brunswick have also been included in a combined stock analysis since these fish mix with those from the other stocks during portions of the year. The Georges Bank stock component collapsed in 1976 after intensive exploitation by foreign fleets during the 1960's and early 1970's. A total allowable catch of 60,000 t was in effect for the nearshore portion of the Gulf of Maine in 2006.

Table 2-1

Productivity in metric tons (t) and status of Northeast pelagic fisheries resources.

Species/Stock	Recent average yield (RAY)[1]	Current yield (CY)	Sustainable yield (MSY)	Stock level relative to B_{MSY}	Harvest rate	Stock status
Atlantic herring[2]	112,240	194,000	194,000	Above	Not overfishing	Not overfished
Atlantic mackerel[3]	106,219	335,000	148,000	Above	Not overfishing	Not overfished
Bluefish[4]	9,706	16,916	51,890	Below	Not overfishing	Rebuilding
Butterfish	1,468	4,545	12,175	Below	Not overfishing	Overfished
Total	229,633	550,461	406,065			
U.S. Subtotal	160,335	481,162	336,766			

[1]2004–06 average. Includes foreign and recreational landings.
[2]Includes significant foreign (Canadian) landings; the U.S. portion of the RAY is 96,706 t.
[3]Includes significant foreign (Canadian) and recreational landings; the U.S. portion of the RAY is 52,455 t.
[4]Includes significant recreational landings.

Bluefish

Bluefish landings peaked in 1981 at 51,400 t, but have declined to a recent annual average of only 9,706 t (Table 2-1). About 68% of recent bluefish catches have been taken by recreational fishermen. During 2004–06, recreational and commercial landings increased slightly over the 2001–03 period. Currently, bluefish stock abundance is above average.

Butterfish

The butterfish stock is currently below average abundance (NEFSC, 2007). Butterfish landings have declined significantly in recent years, primarily due to reduced export demand and low stock size.

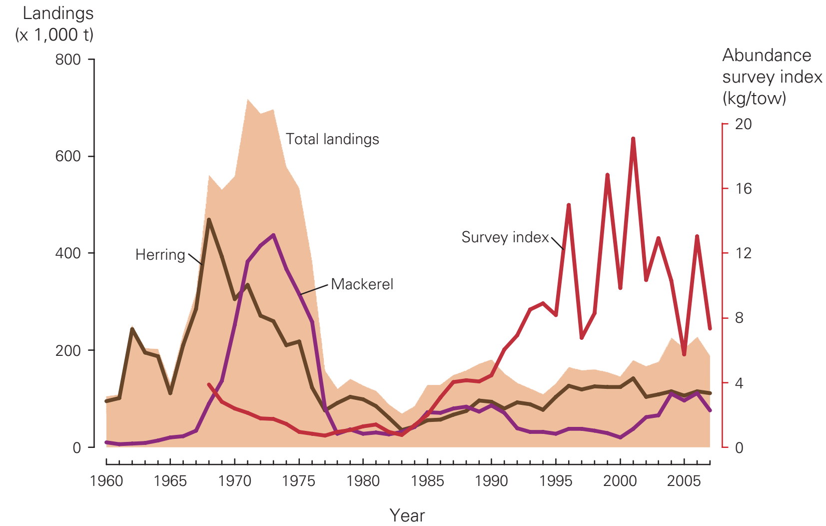


Figure 2-1
Landings in metric tons (t) and abundance survey index (kg/tow) of principal pelagic stocks, 1960–2007.

ISSUES

Scientific Advice and Adequacy of Stock Assessments

Although historical catch data are generally adequate for assessment purposes (with the possible exception of bluefish), stock assessments for Northeast pelagic resources are somewhat imprecise. This is due to the highly variable trawl survey indices of abundance used for calibrating cohort analysis models; the short lifespan of butterfish; and current low exploitation rates for mackerel and herring. The development of more precise assessments will require the use of hydroacoustic, midwater trawl, and improved bottom trawl surveys to estimate herring and mackerel abundance, and alternative types of sampling methods to estimate bluefish abundance. Efforts to improve stock assessments for Atlantic herring began in 1997 with the implementation of autumn hydroacoustic surveys aimed at indexing herring spawning concentrations. Research is currently underway to estimate the size of herring spawning groups from these surveys.

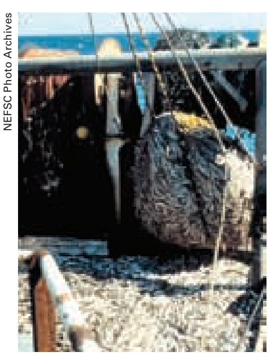
Fleet Capacity

Although total yields of mackerel and herring can be increased to some extent (Table 2-1), fishery expansion is limited by low export demand for herring and bycatch considerations for both species. In any case, overall fleet capacity in the mackerel and herring fisheries in the region has been reached.

Bycatch and Multispecies Interactions

Aggregations of schooling fish, like Northeast pelagics, are utilized as prey items by a wide variety of predatory fish, marine mammals, and birds, and form an important link in many marine food chains. In winter, the directed fisheries for Atlantic mackerel and herring have historically taken some marine mammals as incidental catch, including pilot whales and common dolphins. An intensification of these fisheries to harvest the full sustainable yield of these resources could result in greater marine mammal interactions and incidental takes. Choosing appropriate time–area closures to prevent marine mammal–fishery interactions could keep such incidental takes to a minimum.

NEFSC Photo Archives



Atlantic mackerel on the deck of a trawler.

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Atlantic Anadromous Fisheries

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Unit 3

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INTRODUCTION

The anadromous fishes of the Northeast Atlantic are a diverse group and include river herrings (alewife and blueback herring), American shad, hickory shad, striped bass, Atlantic salmon, sturgeons (Atlantic sturgeon and shortnose sturgeon), sea lamprey, and rainbow smelt. Regulation of these stocks is diverse as well. The Atlantic States Marine Fisheries Commission (ASMFC) has implemented fishery management plans (FMP's) for shad, river herrings, and Atlantic sturgeon. Shortnose sturgeon is Federally listed as endangered under the Endangered Species Act (ESA) and managed under a 1998 recovery plan that identifies a recovery strategy and associated tasks. The Gulf of Maine Distinct Population Segment of Atlantic salmon was listed as endangered in 2000 and is managed under a 2005 recovery plan. All other U.S.-origin Atlantic salmon are managed through a New England Fishery Management Council (NEFMC) FMP and by the North Atlantic Salmon Conservation Organization (NASCO). Striped bass are regulated under an ASMFC FMP and by special Congressional authority under the Striped Bass Conservation Act (implemented by the National Marine Fisheries Service and the U.S. Fish and Wildlife Service).

Recent average landings (2004–06) of Atlantic anadromous species are over 16,000 metric tons (t; Table 3-1, Figure 3-1). This level is higher than a decade ago, but far below historic levels. The recent increase is due to increased striped bass landings; other anadromous species remain low or in decline. Several species have regional importance to recreational fisheries, including American shad, striped bass, and rainbow smelt. Recreational landings are dominated by striped bass, with average landings in recent years exceeding 10,000 t annually. All recreational fisheries for sea-run Atlantic salmon in the United States are closed, with the exception of catch-and-release angling in Maine's Penobscot River. There is a coast-wide moratorium in both

Photo above:
Alewife in the Nemasket River, Massachusetts.

Table 3-1

Productivity in metric tons (t) and status of Atlantic anadromous fisheries resources.

Species/Stock	Recent average yield (RAY)[1]	Current yield (CY)	Sustainable yield (MSY)	Stock level relative to B_{MSY}	Harvest rate	Stock status
American shad	367	Unknown	Unknown	Below	Unknown	Unknown
Atlantic salmon	0	Unknown	Unknown	Below	Not overfishing	Overfished
Atlantic sturgeon	0	Unknown	Unknown	Below	Not overfishing	Overfished
River herrings[2]	333	Unknown	Unknown	Unknown	Unknown	Unknown
Striped bass[3]	15,933	Unknown	16,427	Below	Not overfishing	Not overfished
Total	16,633	16,633	17,127			

[1]2004–06 average; includes recreational landings.

[2]Includes alewife and blueback herring, with some localized stocks; the status of aggregate harvest and stock cannot be determined.

[3]Includes significant recreational landings.

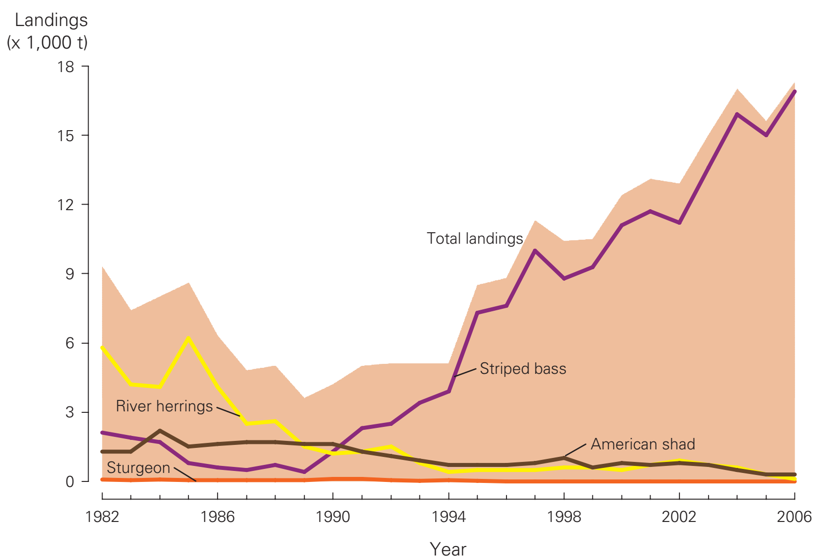

Figure 3-1

Landings in metric tons (t) of anadromous stocks, 1982–2006. Atlantic salmon mariculture production is not included (see Figure 3-2).

Federal and state waters for Atlantic sturgeon.

Landings of most Atlantic anadromous species have declined greatly in recent years. River herring catches peaked in 1965 at about 28,000 t coast-wide, declined to less than 500 t, and are remaining at this relatively low level (Table 3-1). Likewise, commercial landings of American shad peaked at over 2,500 t in 1970, but now average around 500 t as well (Table 3-1). Striped bass commercial landings exceeded 6,000 t in 1973, but by 1985 had declined to less than 1,000 t. Following several years of strict management restrictions and reduced annual landings, striped bass populations have recovered and support increased commercial landings that have averaged around 3,000 t annually since 1999. Currently, domestic fisheries for U.S.-origin Atlantic salmon are closed to capture (catch and release only) and foreign fisheries are under conservation-based quotas. However, sea-cage rearing (aquaculture) of Atlantic salmon in Maine averaged over 11,000 t annually between 1995 and 2001 but has declined to lower levels since, due to revised management plans to reduce disease risks that include fallowing as a key component.

SPECIES AND STATUS

Unlike most of the offshore resources in the Northeast region, Atlantic anadromous stocks are greatly influenced by human non-fishing activities in the coastal zone. Alteration of river migration routes, thereby blocking access to historic spawning grounds, and pollution have been major factors in the decline of Atlantic salmon, sturgeons, river herrings, and shad. Today, anadromous species face continued threats from coastal development and pollution; when considered along with reduced population sizes, recovery of some stocks is uncertain.

River Herrings (Alewife and Blueback Herring)

River herrings is the name commonly applied to two species, alewife and blueback herring. The coastal ranges of the two species overlap, with blueback herring found from Nova Scotia to Florida, and alewife from Labrador to South Carolina (Haas-Castro, 2006a). In coastal rivers where both species are present, catches of fisheries targeting these species are typically mixed. Both species are anadromous, migrating upriver from coastal habitats to spawn during the spring. Alewives are known to live as long as 10 years and reach a length of 36 cm. Blueback herring may live for about 7 or 8 years and reach a maximum length of about 32 cm.

The river herring fishery is one of the oldest documented fisheries in North America. It was exclusively a U.S. inshore fishery until the late 1960's when foreign fleets began to fish for river herrings off the Mid-Atlantic coast, with catches sometimes exceeding 25,000 t. A sharp decline in catches began in the early 1970's and has continued to the present, with total landing levels of less than 1,000 t annually since 1993 (Figure 3-1). Currently, the principal methods of harvesting river herrings include fish weirs, pound nets, and gill nets. Recreational fishing on these species is minimal.

ASMFC prepared a comprehensive coastwide FMP for shad and river herrings to facilitate cooperative management and restoration efforts between the coastal states in 1985 (amended in 1999; ASMFC, 1999). Restoration efforts have involved habitat improvement, fish passage, stocking, and transfer programs. In response to the decline in landings and population abundance, fisheries managers have expressed a need for a more quantitative assessment of river herring. At present, there is limited information available on which to base regulations, but additional data is being collected under provisions of the FMP Amendment I that will provide a better understanding of resource status and a stronger basis for regulatory actions (ASMFC, 2002). A benchmark assessment of river herring populations is scheduled to be completed in 2012. Amendment 1, Technical Addendum 1, and Addendum I to the FMP for American Shad and River Herring (ASMFC, 1999, 2002) are the current management documents for alewife and blueback herring. At present, the Commission is developing an amendment to the FMP intended to address declines in river herring stocks by controlling fishing mortality. At present, all jurisdictions must maintain existing or more conservative recreational regulations for river herring. In 2006, NMFS listed river herring as a species of concern (NMFS, 2007). Four states—Massachusetts, Rhode Island, Connecticut, and North Carolina—have closed their river herring fisheries in response to declining stocks within their waters.

Louise Kane, NOAA Restoration Center

Restoration partners and volunteers collect migrating river herrings to move them in trucks above dams to their spawning grounds.

American Shad

American shad are anadromous members of the Clupeid family. They are found between southern Labrador and northern Florida (Haas-Castro, 2006b). An introduced stock of American shad occurs along the Pacific coast as well. American shad are highly migratory, feeding at sea along the Canadian coast, particularly the Bay of Fundy, in large pelagic schools during the summer, traveling southward along the Continental Shelf during the winter, and then returning to natal rivers to spawn in the spring. Life history patterns vary among individual populations of shad and depend on the latitudinal location of their natal rivers. Most shad remain in the ocean for 4 years before returning to their natal river for their first spawning, although the mean age at first spawning increases to 5 for the more northerly populations. After spawning, American shad north of Cape Hatteras begin a feeding migration and may later return to their rivers to spawn for several subsequent years; more southerly members of the species typically die after a single spawning.

Most major rivers along the Atlantic coast have historically supported spawning stocks of American shad. Shad have been exploited for their meat as well as their roe since the late 19th century and are harvested primarily by gillnets in a coastal intercept fishery. Recreational angling occurs and is locally significant; however, no comprehensive data are available. Commercial landings remained around 3,000 t during the 1960's, but began to decline in the early 1970's; annual landings since 1999 have been below 900 t (Figure 3-1). Overfishing has been blamed for declines in abundance in the Hudson and Connecticut Rivers, as well as in rivers in Maryland, North Carolina, and Florida. However, dam construction along many larger rivers throughout North America has led to an almost complete disappearance of shad in many watersheds and the loss of their associated fisheries. Additionally, pollution in the lower Delaware River has been cited as the primary cause for the past decline of the fishery in that system.

The ASMFC has implemented a coast-wide FMP for American shad and river herring to facilitate cooperative management and restoration plans between the states. Restoration efforts include habitat improvement, fish passage, stocking, and transfer programs. Despite improved runs in some major river systems such as the Susquehanna, Delaware, and Connecticut Rivers, the coast-wide abundance of American shad remains well below historic levels. The 1985 FMP was amended in 1999 with specific measures to control exploitation of American shad populations (ASMFC, 1999). Amendment 1, Technical Addendum 1, and Addendum I to the FMP for American Shad and River Herring are the current management documents for American shad (ASMFC, 1999, 2002). Amendment 1 established a 5-year phase-out of the ocean-intercept fishery for American shad, which closed the fishery by 1 January 2005. In addition, Amendment 1 set fishing mortality targets for specific American shad in-river fisheries and implemented a creel limit of 10 fish daily in recreational fisheries. At present, the Commission is developing an amendment to the FMP in response to the 2007 American shad assessment.

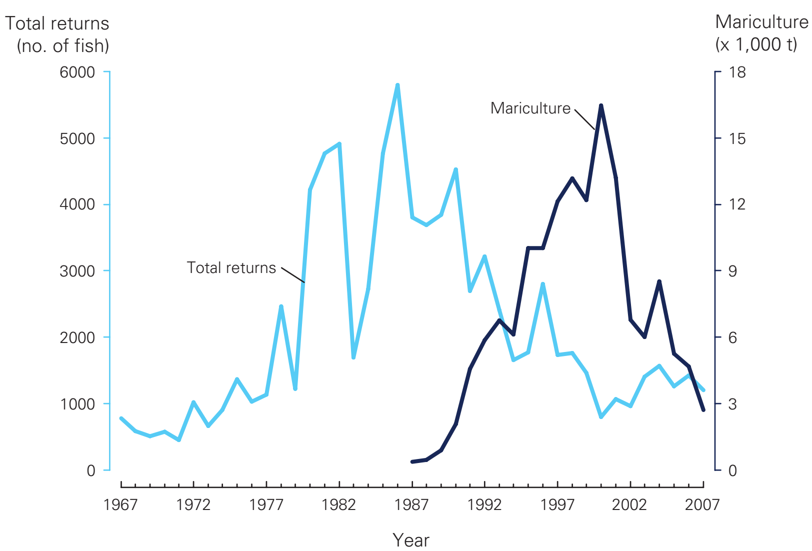

Figure 3-2
Number of Atlantic salmon returning to U.S. rivers and mariculture production in metric tons (t), 1967–2007.

Atlantic Salmon

Atlantic salmon reside in freshwater streams as juveniles for 2 or 3 years before migrating to the sea, where U.S. populations typically remain for 2 winters (Kocik and Sheehan, 2006). While at sea, U.S. stocks generally undergo extensive migrations to waters off Canada and Greenland before returning to their natal rivers in June and spawning in November. In the United States, Atlantic salmon were once indigenous from the Housatonic River, Connecticut, northward to tributaries of the St. John River, Maine. As a consequence of industrial and agricultural development, all native runs south of the Kennebec River in Maine were extirpated (Fay et al., 2006). The only remaining populations with documented substantial natural reproduction occur in eight small (<100 km) rivers in eastern Maine; these populations are perilously small, with total run sizes of less than 100 spawners annually since 2005. The Penobscot River in Maine retains the largest sea-run U.S. population, averaging about 1,100 returns annually for the past 10 years. The Penobscot population is almost exclusively supplemented by hatchery production (i.e. little natural reproduction is occurring) but is genetically linked to ancestral stocks and thought to be locally-adapted to that watershed (Fay et al., 2006).

The abundance of Atlantic salmon stocks in U.S. rivers is represented by direct counts of adult returns (Figure 3-2). U.S. population abundances, as for most stocks throughout North America, have declined during the past decade, and domestic fisheries in U.S. waters are all closed with the exception of very limited catch-and-release in the Penobscot River. Distant-water commercial gillnet fisheries off Canada and Greenland, which previously exploited U.S. stocks in the high seas, are now regulated more stringently under the auspices of NASCO. Canadian interception fisheries have been closed, and the Greenland fishery is quota-controlled to allow for adequate spawning escapement. Despite these conservation measures, the overall abundance of Atlantic salmon throughout North America continues to decline, and several southern populations may go extinct if they are not supplemented with hatchery fish. Current population recovery efforts in Maine focus on stocking, although expanded efforts in habitat management and conservation are also occurring under the current recovery plan. Restoration efforts, in the form of stocking and fish passage construction, are underway in the Connecticut, Pawcatuck, Merrimack, and Saco Rivers. Most stocking programs operate in a river-specific fashion, collecting broodstock from juveniles or adults in these river systems after 1.5 to 5 years of natural rearing. However, donor stocks are used for the Merrimack and Saco River programs (from the Penobscot River) as well as the Pawcatuck River program (from the Connecticut River).

In the face of declining natural populations, the Atlantic salmon aquaculture industry has grown to fill the production void. In eastern Maine, companies typically rear fish to smolt stage in private freshwater facilities, transfer them into anchored net pens or sea cages, feed them until they reach market size, and then harvest the fish. As a fledgling industry in the early 1980's, growth was rapid and by 1995 annual production exceeded 10,000 t in round weight, peaking in 2000 at over 16,000 t (Figure 3-2). Fallowing to eradicate diseases and changing management practices, however, have reduced annual production to below 5,000 t in recent years, though some rebuilding is expected.

Striped Bass

Four primary stocks of striped bass occur along the Atlantic coast, in the Hudson River, Delaware Bay, Chesapeake Bay, and Roanoke River, North Carolina (Shepherd, 2006). Striped bass stocks historically have supported important commercial and recreational fisheries, with recreational harvests often equaling or exceeding commercial landings (Figure 3-3).

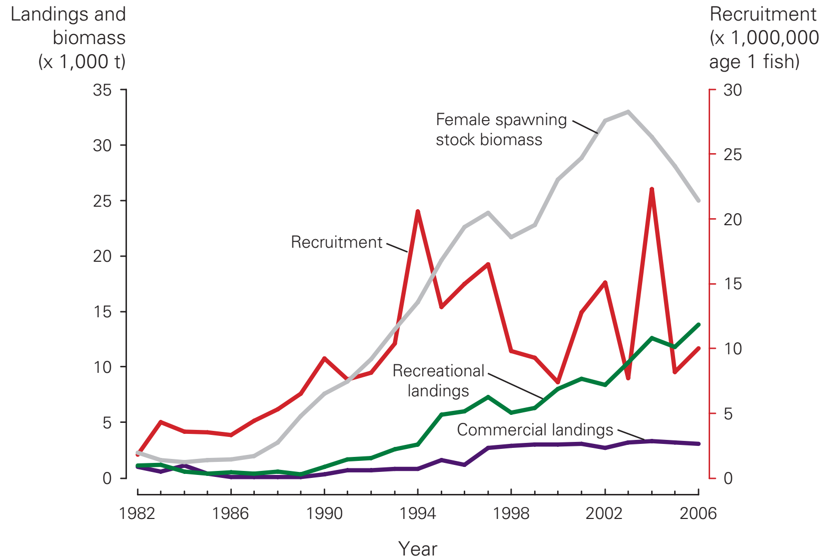

Figure 3-3
Striped bass landings and female spawning stock biomass in metric tons (t) and recruitment in number of fish at age 1, 1980–2006.

Commercial fisheries use a variety of gears including haul seines, trawls, pound nets, gillnets, and hook-and-line. Commercial landings peaked in 1973 and began to steeply decline thereafter. This decline, coupled with consistently poor recruitment indices in the Chesapeake Bay, required highly restrictive management actions taken by ASMFC in the mid 1980's to conserve and recover the stocks. Improved recruitment and reduced fishing mortality allowed the stocks to rebound to abundance levels similar to the years prior to the decline, and the fishery was partially reopened in 1990. The ASMFC declared Atlantic striped bass fully rebuilt in 1995, permitting further relaxation of management restrictions on the commercial and recreational fisheries.

A recent assessment of the striped bass coastal complex (NEFSC, 2008) indicates that the current level of fishing mortality is below the threshold level, but slightly above the target mortality established in Amendment 6 to the FMP. The large recreational fishery, which includes removals from both landings and discards, accounts for the majority of the fishing mortality. The recent average yield (2004–06) is about 16,000 t (Table 3-1); of that, 80% is attributed to recreational landings. The female spawning stock biomass increased steadily after 1984, reaching a peak in 2003 at 33,000 t, but declined to 25,000 t in 2006. Spawning stock biomass remains well above the threshold biomass of 14,000 t and has resulted in the production of historically large year-classes in 2001 and 2003 (Figure 3-3). This high recruitment should foster continued population growth under targeted levels of fishing mortality.

Atlantic and Shortnose Sturgeon

Sturgeon species are distributed along the east coast of the United States and Canada from Florida to New Brunswick. Atlantic and shortnose sturgeons are two species native to this range. Both species supported a substantial commercial fishery during the late 1800's, but today only remnant populations remain. Sturgeons have been adversely affected by degradation of rivers, starting during the industrial revolution, and from overfishing. Recovery is hampered by the lack of effective fish passage facilities at dams, bycatch of sturgeon in other directed fisheries, and poor habitat conditions.

The life history patterns for the two species of sturgeon are very similar. Both are benthic (bottom) feeders and consume a variety of crustaceans, bivalves, and worms. Atlantic sturgeon migrate from the marine environment to fresh water to spawn during late winter through early summer, with migrations occurring later in the year at higher latitudes. Shortnose sturgeon are considered amphidromous[1] in the northern part of their range—juveniles and adults regularly enter estuarine environments during various times of the year, but adults migrate to freshwater spawning areas, predominantly in their natal rivers. In waters where the species co-occur, the shortnose sturgeon tends to begin its migration earlier than the Atlantic sturgeon. For Atlantic sturgeon, spawning generally occurs in the lower sections of rivers, below the fall line. In populations of shortnose sturgeon that have free access to the total length of a river (e.g. no dam within the species' range in the river), spawning areas are located at the most upstream reach of the river used by sturgeon. The two species are long-lived, with lifespans exceeding 20 years.

Eileen McVey, NOAA Central Library

Juvenile Atlantic sturgeon in a conservation culture project at the University of Florida, Department of Fisheries and Aquatic Sciences Program.

Maturing late in life, sturgeons are highly fecund and show increases in egg production as females grow larger. The most obvious difference between Atlantic and shortnose sturgeon is their adult size; shortnose sturgeon reach body lengths of approximately 100 cm (40 in) whereas Atlantic sturgeon can attain more than twice that length.

Shortnose sturgeon was listed as endangered throughout its range in 1967 under the Endangered Species Preservation Act of 1966 (a predecessor to the Endangered Species Act of 1973). The species' status was last officially examined in 1987; the status review was never finalized but information was used to develop a recovery plan for the shortnose sturgeon in 1998. Research and monitoring programs and conservation actions by Federal, state, and private entities have been ongoing. As a result, new information is available, and a new status review is ongoing, with expected completion in 2009.

Atlantic sturgeon was commercially harvested throughout much of its range through the early 1990's under ASMFC management plans. Managers believe that overharvesting of sturgeon continued through the 1990's until ASMFC and Federal agencies implemented a coast-wide moratorium in 1998. The result has been cessation of targeted fisheries for sturgeon (Figure 3-1). Because the population has been severely overfished, the ASMFC Interstate FMP for Atlantic Sturgeon calls for a rebuilding of 20 year-classes, which is estimated to take about 40 years from 1998. In 2005, NOAA updated the Atlantic sturgeon status review to reevaluate whether this species required protection under the ESA. The Status Review Team (SRT) determined that Atlantic sturgeon populations function within five distinct population segments (DPS's) from the Gulf of Maine unit in the north to the South Atlantic unit in the south (ASSRT, 2007). The most significant threats to all of the DPS's are bycatch mortality, poor water quality, lack of adequate state and/or Federal regulatory mechanisms, and dredging activities. Additional stressors that are unique to some DPS's include habitat impediments and ship strikes. This additional information is currently being used to determine whether listing is warranted under the ESA.

[1]Amphidromous fish move between fresh and salt water during some part of their life cycle, but not for breeding.

ISSUES

Transboundary Stocks and Jurisdiction

The interception of U.S.-origin Atlantic salmon in commercial fisheries off Canada and western Greenland was thought to be an impediment to the restoration of runs and U.S. fisheries. However, beginning in 1992, the largest portion of the Canadian fishery was closed. Likewise, the Greenland fishery quota, set to meet spawning escapements to North American rivers, should provide adequate protection. If these conservation tools, implemented through NASCO, remain in place, the threat of the interception fisheries to U.S. stocks should be greatly reduced.

The St. Croix International Waterway Commission was established by the Maine and New Brunswick legislatures to plan for a heritage management plan for the St. Croix boundary corridor in 1987. This commission is often in the center of U.S.–Canada anadromous fish issues, especially those related to Atlantic salmon and river herrings, and facilitates a unified approach to management. The passage of river herrings to upstream lakes remains a controversial issue, with U.S. Federal agencies and Canada supporting restoration of access for river herrings while some state agencies and tribal entities in Maine are concerned about impacts on smallmouth bass fisheries and understanding the historical extent of herring distribution.

Endangered Species Concerns

Anadromous Atlantic salmon throughout their U.S. range are at low levels of abundance. The Gulf of Maine DPS of Atlantic salmon has been listed as endangered under the ESA. The remaining populations in the Gulf of Maine tributaries and those of the Penobscot River represent the last naturally spawning populations in the United States.

Shortnose sturgeon is listed as endangered throughout its entire range. The recently completed status review of Atlantic sturgeon resulted in a delineation of five DPS's; three of these are at critically low levels of abundance, and the review recommended ESA protection (ASSRT, 2007). A formal decision is pending but active research and protection measures are moving forward. NMFS is committed to improving the health of these species to make them viable populations with sustainable fisheries through its partnership with the states and other Federal partners as well as non-governmental organizations.

Management Controls

An issue of particular concern for striped bass is the potential impact of discard mortality. Recreational fishing effort for striped bass currently far exceeds commercial effort, and over 90% of the recreational catch was released alive during the last decade. Even with high survival rates of catch-and-release striped bass, the potential for hooking mortality in recreationally caught fish may reduce the conservation benefit of large minimum-size regulations. As striped bass populations increase, another concern is the greater likelihood of striped bass bycatch in commercial fisheries targeting other species. There is a desire among all parties not to reverse the progress made in rebuilding the severely depleted spawning stocks in Chesapeake Bay.


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A recreational angler prepares to release an undersize striped bass from the pier at Pirates' Cove Marina in Manteo, North Carolina.

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Northeast Invertebrate Fisheries

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4

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Photo above:
An American lobster resting on the sea floor off the coast of Rhode Island.

INTRODUCTION

Fisheries for offshore invertebrates, including crustaceans and mollusks, are the most valuable fisheries in the Northeast Region, with U.S. landings averaging 126,600 metric tons (t) per year (Table 4-1) and ex-vessel revenues averaging $884 million per year during 2004–06. The American lobster fishery ranked first in value, with average annual ex-vessel revenues of $406 million during 2004–06. The sea scallop fishery ranked second, with average annual revenues of $379 million. Landings of all other offshore invertebrates contributed roughly $98 million in additional revenue annually.

Several different Fishery Management Plans (FMP's) regulate the offshore harvest of invertebrate species in the region. These include the Atlantic Surfclam and Ocean Quahog FMP and Atlantic Mackerel, Squid, and Butterfish FMP (developed by the Mid-Atlantic Fishery Management Council), and the Atlantic Sea Scallop FMP and Deep-Sea Red Crab FMP (developed by the New England Fishery Management Council). The Atlantic States Marine Fisheries Commission (ASMFC), operating under an interstate compact, has implemented non-Federal FMP's for American Lobster and for Northern Shrimp. The ASMFC's Lobster FMP is in addition to a Federal FMP that deals with the smaller offshore lobster fishery components.

SPECIES AND STATUS

American Lobster

American lobsters are harvested with baited lobster traps (pots), although some incidental catch and bycatch of lobsters occurs in trawl fisheries targeting other species. The primary management controls are minimum and maximum size limits, maximum trap limits, release of ovigerous females

Table 4-1

Productivity in metric tons (t) and status of Northeast invertebrate fisheries resources.

Species/stock	Recent average yield (RAY)[1]	Current yield (CY)	Sustainable yield (MSY)	Stock level relative to B_{MSY}	Harvest rate	Stock status
American lobster[2]	41,303	Unknown	Unknown	Unknown		
Atlantic surfclam[3,4,5]	27,453	26,217	Unknown	Above	Not overfishing	Not overfished
Longfin inshore squid[6]	16,152	21,000	26,000	Unknown	Not overfishing	Not overfished
Northern shortfin squid[6,7]	17,351	Unknown	Unknown	Unknown	Not overfishing	Unknown
Northern shrimp	2,199	5,000	5,000	Unknown	Not overfishing	Not overfished
Ocean quahog[3,4,5]	16,720	24,189	55,238	Above	Not overfishing	Not overfished
Red deepsea crab	1,923	2,690	Unknown	Unknown	Not overfishing	Unknown
Sea scallop[3,8]	32,215	31,657	Unknown	Above	Not overfishing	Not overfished
Total	155,316					
U.S. Subtotal	126,600					

[1]2004–06 average; includes Canadian landings where available.

[2]Status determinations are made for individual stocks of American lobster: the Southern New England stock is overfishing and depleted; the Gulf of Maine and Georges Bank stocks are both not overfishing and not overfished.

[3]Yields are for shucked meat weights.

[4]RAY includes landings from both inshore (state) and offshore (U.S. EEZ) areas. CY and MSY refer only to offshore areas.

[5]Current yield (CY) is based on recent quotas.

[6]This species has a lifespan of less than one year and was not assessed during 2004–06.

[7]Does not include Canadian landings.

[8]Includes United States and Canadian portions of Georges Bank.

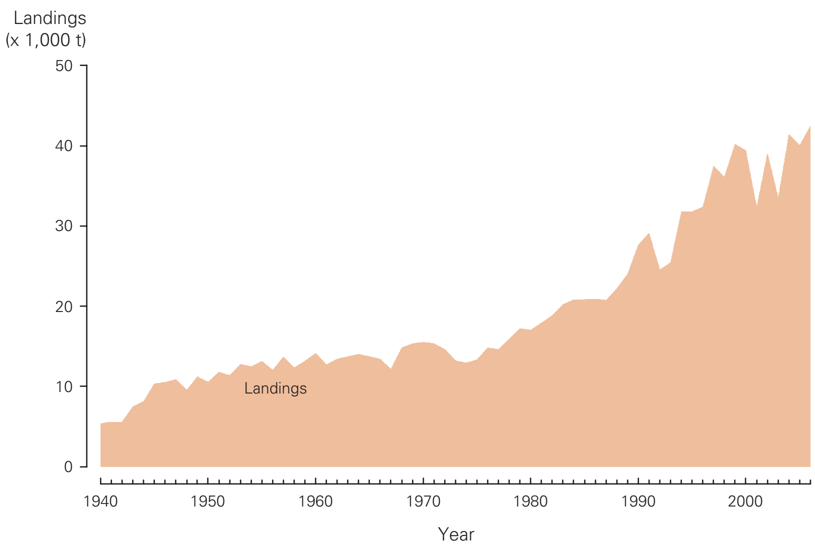

Figure 4-1

American lobster landings in metric tons (t), 1940–2006.

(egg bearing; also called eggers), and release of v-notched (tagged) females in some areas. Management of lobsters is area-specific, with fishermen often helping to develop management-area rules for their local components of the fishery.

High fishing mortality is a persistent problem in lobster fisheries along the northeast coast (ASMFC, 2006). With previous removals of relatively large individuals from the population, the lobster fishery has become increasingly dependent on small and young lobsters that reach a legal size just prior to capture. In some locations, more than 90% of the lobsters landed are new recruits to the fishery and many are not yet sexually mature. Commercial catch rates have markedly declined in nearshore areas, particularly in areas south of Cape Cod to Long Island Sound, where fishing is heaviest. Lobster abundance in the Gulf of Maine has remained high despite heavy fishing pressure, due to favorable environmental conditions for lobster reproduction and recruitment, in addition to beneficial effects of size limits and release of ovigerous and v-notched females.

American lobster landings during 2004–06 averaged 41,300 t (Table 4-1) while ex-vessel revenues averaged $406 million. Recent (2004–06) average landing levels were at or near record high levels since 1940 (Figure 4-1).

Sea Scallop

Sea scallops are harvested in U.S. waters on the Continental Shelf from Cape Hatteras north to the U.S.-Canada border on Georges Bank, and inside the Gulf of Maine. Dredges are the principal fishing gear, although otter trawls account for a small proportion of total landings (NEFSC, 2007a).

Management of the sea scallop fishery changed markedly in 1994 when regulations restricting the number of days at sea, vessel crew size, and dredge ring size began to be gradually implemented. Fishing has been prohibited in two areas of Georges Bank and in one area on Nantucket Shoals since 1994, except during highly controlled re-openings in 1999–2001 and since November 2004. These area closures were implemented primarily to protect groundfish, but have also benefited the scallop stock and fishery. In the Mid-Atlantic, there have been a number of rotational closures specifically for sea scallop management (two in 1998 and one each in 2004, 2007, and 2008). These areas are closed for 2–3 years to allow small scallops to grow to a larger size, and then reopened to limited fishing. The most successful of these rotational closures was the Elephant Trunk closure off Delaware Bay, where biomass built up to unprecedented levels during the 3-year 2004–06 closure. Landings during 2007 in the Elephant Trunk area were 7,000 t of meat, with an ex-vessel value of around $100 million. Landings are expected to continue at this level or higher during the planned 5-year controlled harvesting of this area.

The combination of effort controls and area closures have rapidly rebuilt the sea scallop fishery so that the biomass is now well above its target and landings are at record levels (Hart and Rago, 2006). The most recent sea scallop stock assessment (NEFSC, 2007a) indicated that biomass was 53% above its B_{MSY} proxy target level (Table 4-1). U.S. sea scallop landings during 2004–06 averaged 28,716 t (shucked meat weight) and were at or near record levels in all three years (Figure 4.2). Total ex-vessel value of the landings during the same period averaged $379 million per year, making it one of the most valuable fisheries in the United States and the most valuable wild scallop fishery in the world.

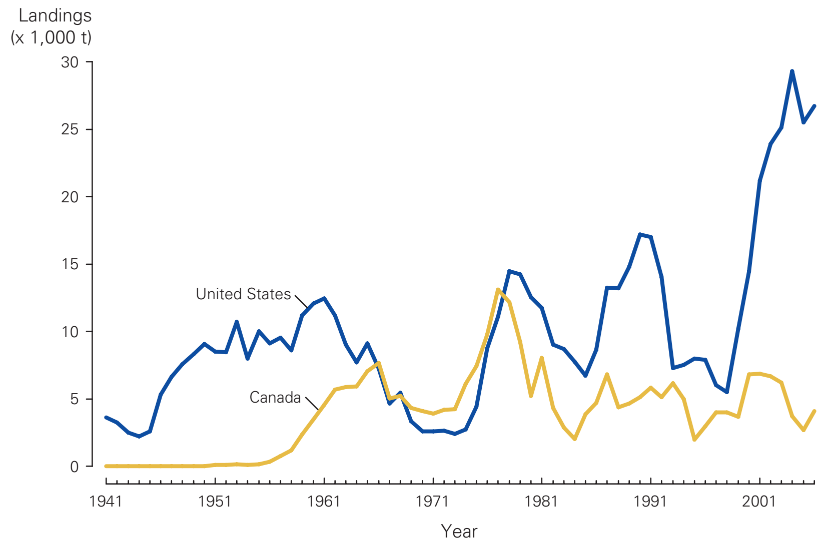

Figure 4-2
United States and Canadian landings in metric tons (t) of sea scallop, 1941–2006.

Atlantic Surfclam and Ocean Quahog

Atlantic surfclams and ocean quahogs are harvested primarily with hydraulic dredges. Most surfclam fishing occurs off New Jersey, while most fishing for quahog is off southern New England and Long Island. Fishing for both species has been prohibited on Georges Bank since late 1989 due to the possibility of paralytic shellfish poisoning from shellfish taken in that area. The primary management tool for these species is an Individual Transferable Quota (ITQ) system, enacted in 1990. This system allows individual quota shares for both species to be freely traded. The ITQ system has successfully rationalized harvesting capacity, promoted higher profitability, and helped to reduce fishing mortality (Serchuk and Murawski, 1997).

Surfclam landings increased steadily during the 1960's and early 1970's, peaking in 1974. Subsequently, poor reproduction and a surfclam die-off along the New Jersey coast in 1976 led to low stock biomass and reduced landings (NEFSC, 2007b). Large year-classes in 1976 and 1977 spawned off New Jersey and the Delmarva Peninsula, followed by consistent population-wide recruitment and reduced fishing pressure, have helped restore and maintain the surfclam stock. During 2004–06, annual landings from state and Federal waters averaged 27,453 t (shucked meat weight; Table 4-1), while annual ex-vessel revenues averaged $34.7 million per year.

Ocean quahogs inhabit relatively deep waters along the Mid-Atlantic Continental Shelf and on Georges Bank. As the surfclam resource declined in the late 1970's, a market for processed clam products developed and ocean quahog landings increased rapidly. Over the past two decades, the fisheries for ocean quahogs have moved progres-

William Millhouser, NOS

A Northern shortfin squid cruising over a sand flat.

sively northward from the Mid-Atlantic Bight to southern New England (NEFSC, 2007c). In the Gulf of Maine, where the species is found in relatively shallow nearshore waters, limited quantities of small ocean quahogs are harvested and sold as mahogany clams at relatively high prices for consumption in raw seafood restaurants (the half-shell market). Annual landings of ocean quahog during 2004–06 averaged 16,720 t (shucked meat weight; Table 4-1) with average annual ex-vessel revenues of $20.5 million.

Northern Shrimp

Northern shrimp occur at the southern extent of the species' geographical range in the Gulf of Maine. As a result, higher shrimp abundances are generally associated with lower than average water temperatures. Northern shrimp are harvested using small-mesh trawls and inshore traps. The fishery began as an inshore winter fishery during the late 1930's and expanded in the 1960's to a year-round offshore fishery with peak landings of 12,800 t in 1969 (Clark et al., 2000). The stock collapsed during the mid 1970's and the fishery was closed from mid May 1977 to February 1979. Since 1980, fishing has been restricted to the December–May period. Landings were between 3,000–5,000 t during the mid 1980's and early 1990's, increased to 9,200 t in 1996, and subsequently sharply declined. According to the most recent stock assessment (Hunter et al., 2007; NEFSC, 2007d), annual landings averaged 2,199 t during 2004–06 (Table 4-1), while annual revenues averaged $2.3 million.

Longfin Inshore Squid

The east coast U.S. stock of longfin inshore squid is distributed between the Gulf of Maine and south of Cape Hatteras, where they are harvested primarily with bottom trawls in commercial fisheries. Longfin inshore squid live less than 1 year, grow rapidly, migrate seasonally, and spawn year-round (Hatfield and Cadrin, 2002; Macy and Brodziak, 2001). Availability and abundance of this short-lived species are strongly affected by environmental factors, causing annual landings to fluctuate from year to year (Brodziak and Hendrickson, 1999; Dawe et al., 2007). Fishing patterns reflect the seasonal distributions of the stock, with offshore catches from October to March and inshore landings from April through September. The main management tools are seasonal fishing quotas that limit landings. During 1982–2003, landings averaged 15,100 t. Recent average landings (2004–06) increased slightly to 16,152 t (Table 4-1) with average annual ex-vessel revenues of $27.5 million.

Northern Shortfin Squid

The northern shortfin squid stock is distributed from Cape Hatteras to Newfoundland. Northern shortfin squid are harvested in U.S. waters between Cape Hatteras and Georges Bank, mainly by bottom trawls, but fisheries also occur in nearshore waters off Newfoundland, Canada, and historically on the Scotian Shelf. Living for less than 1 year, this species grows rapidly and undertakes seasonal migrations covering long distances (Hendrickson, 2004; Hendrickson and Holmes, 2004). Similar to longfin inshore squid, the distribution and abundance of northern shortfin squid are also influenced by oceanographic factors (Brodziak and Hendrickson, 1999; Dawe et al., 2007).

The U.S. fishery for northern shortfin squid generally occurs during June–October in offshore waters of the Mid-Atlantic Bight. Larger vessels catch and freeze squid at sea, while smaller vessels land fresh squid. A foreign fishery for shortfin squid existed during the 1970's and 1980's with a peak in total landings of 180,000 t in 1979, 90% of which were from Canadian waters. The international fishery collapsed in the early 1980's, and since 1983, U.S. domestic fisheries have accounted for most of the landings. Research surveys and fishery data indicate that the northern shortfin squid stock has been in a low-productivity regime since 1982. During 1982–2003, total landings averaged 14,721 t and U.S. landings averaged 9,348 t (Hendrickson et al., 2005). U.S. landings during 2004–06 averaged 17,351 t and were much higher than the long-term average (Table 4-1). Ex-vessel revenues averaged $11 million during the same period.

Red Deepsea Crab

Red deepsea crabs inhabit deep waters of the Continental Shelf, slope, and canyons, with most of the biomass occurring between 320 and 640 m (1,050 to 2,100 ft.). The southern New England stock is thought to be genetically distinct from the stock off the coast of Florida and in the Gulf of Mexico (Weinberg et al., 2003). Growth is thought to be slow, and individuals may reach a maximum age of about 15 years. Red deepsea crabs have been fished off the U.S. Atlantic coast since the early 1970's, primarily with baited traps. Male crabs are typically harvested when they reach about 115 mm (4½ inches) carapace width, but all female crabs must be released. Surveys completed in 2005 (Weinberg and Keith, 2003; Wahle et al., 2008) indicated that the proportion of large males in the harvested population off southern New England is lower than during the 1970's.

Developments in the deep-sea red crab fishery led to a new survey (Wahle et al., 2008), a new FMP in 2002, and an updated stock assessment completed in 2007 (NEFSC, 2006). Prior to 2006, the most recent stock assessment for red crabs was completed in the late 1970's.

During 1995–2003, U.S. landings of red crab were fairly stable and averaged 1,944 t. Recent (2004–06) landings averaged 1,923 t per year (Table 4-1) while ex-vessel revenues averaged $3.6 million.

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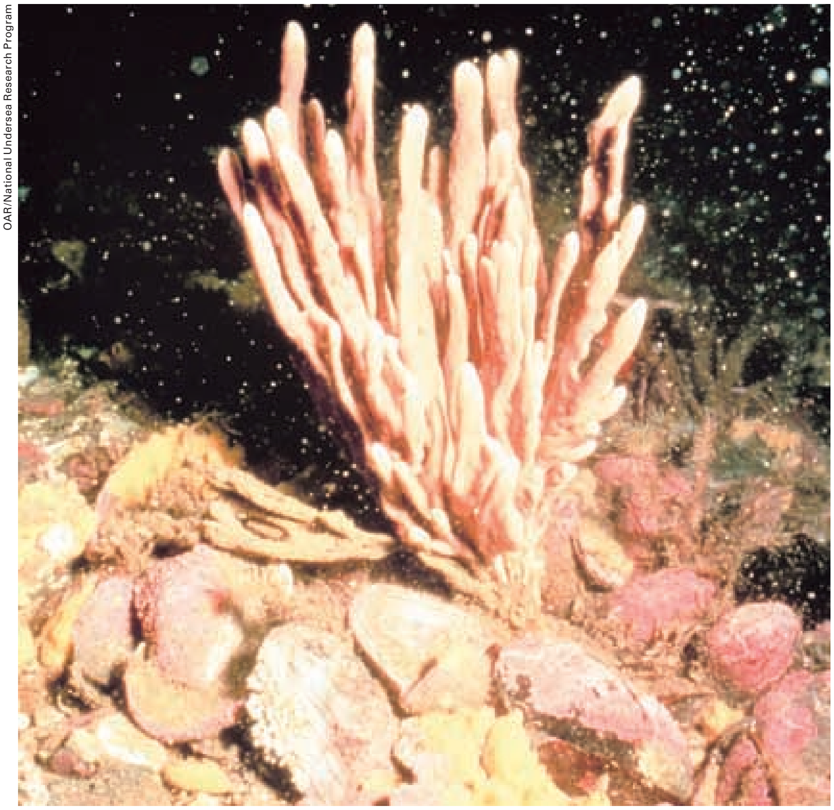

Gravel-cobble bottoms off the coast of Maine are favored scallop grounds.

ISSUES

Rotational Area Management for Sea Scallops

The key to increasing fishery yields and revenues in the sea scallop fishery and maintaining relatively high stock biomass levels is reducing harvest rates on young scallops that are still growing rapidly and shifting effort towards the larger, slow-growing individuals with the highest meat yields. Rotation between management areas (Hart, 2003) and a larger minimum ring size for commercial scallop dredges are particularly important in this regard. Under rotational management, some areas are closed to fishing to allow small scallops to grow. Larger rings (used to construct the bag which closes the dredge) allow small scallops to pass through commercial scallop dredges and increase efficiency for catching larger scallops. This approach is expected to improve yields from the fishery, while reducing total fishing effort on the stock and related environmental impacts.


William B. Folsom, NMFS

Scallop dredgers in Seaford, Virginia.

Amendment 10 to the Sea Scallop FMP, in effect since 2004, implements these approaches in the sea scallop fishery.

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Atlantic Highly Migratory Pelagic Fisheries

OAR/National Undersea Research Program

Unit

5

GUILLERMO A. DIAZ

NMFS Office of Science and Technology

Silver Spring
Maryland

Photo above:
School of yellowfin tuna in the Gulf Stream of the Atlantic Ocean.

INTRODUCTION

Oceanic pelagic fish are highly migratory species (HMS) that include swordfish, bluefin tuna, yellowfin tuna, bigeye tuna, albacore, skipjack tuna, blue and white marlin, sailfish, longbill spearfish, a variety of sharks (see Unit 6, Atlantic Shark Fisheries), and others. In the Atlantic Ocean, swordfish and bluefin tuna have long been the target of important fisheries. Since the early 1980's, yellowfin tuna and swordfish comprise the majority of the U.S. landings of tunas and tuna-like species. Landings of bigeye tuna also increased in the 1980's but represented a much lower proportion of total U.S. landings. Many recreational anglers target yellowfin tuna, bluefin tuna, blue marlin, white marlin, and sailfish in U.S. waters. Swordfish has also become a target of recreational fishermen in the past few years.

Although some HMS are not directly targeted by commercial fisheries, they are incidentally caught in some of them. For example, blue and white marlin, sailfish, and longbill spearfish are incidentally caught in longline fisheries for tuna and swordfish. However, as a conservation measure, landings of these species by commercial fishermen have been prohibited in U.S. waters since 1988.

Because these large pelagic fish migrate widely and are harvested over broad ocean areas by both U.S. and foreign fishermen, national and international management measures are necessary. In all cases, stock assessments are conducted using aggregate data and provide the basis for regulations. U.S. fleets operate in the western Atlantic

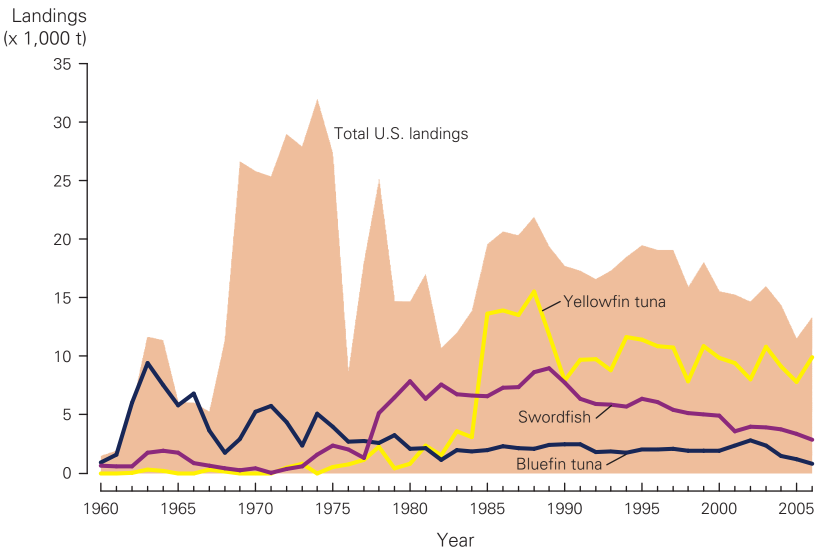

Figure 5-1

U.S. landings in metric tons (t) of Atlantic highly migratory pelagic species, 1960–2006.

Ocean, Caribbean Sea, and Gulf of Mexico and are regulated under the Magnuson-Stevens Fishery Conservation and Management Act and the Atlantic Tunas Convention Act (ATCA). Management of Atlantic tunas and swordfish in U.S. waters is based largely on recommendations by the International Commission for the Conservation of Atlantic Tunas (ICCAT) and implemented via regulatory articles under the ATCA. In the case of bluefin tuna, ICCAT has set and allocated quotas for the western stock by country since 1982 and for the eastern stock since 1994. Catch limitations were first established for North Atlantic swordfish in 1991 and South Atlantic swordfish in 1994; country-specific quotas have since been adopted for both stocks. ICCAT has additionally recommended reductions in billfish catches for all nations since 1997. Atlantic highly migratory pelagic species were formerly managed under two separate U.S. Fishery Management Plans (FMPs), the Atlantic Tunas, Sharks, and Swordfish FMP and the Atlantic Billfish FMP. In 2006, the new Consolidated Atlantic Highly Migratory Species FMP merged the management of all HMS stocks under a single plan.

SPECIES AND STATUS

Total landings of tuna and tuna-like species by U.S. fishermen increased from the early 1960's through the mid 1970's. Total U.S. landings peaked in 1975 with approximately 32,000 metric tons (t; Figure 5-1). Through 1967 the majority of the highly migratory species landings were bluefin tuna; although variable, landings of yellowfin tuna have tended to dominate since then. Swordfish landings showed an important increase from the mid 1970's until about 1990 and have been in a constant decline since then. Overall, landings by U.S. fishermen have steadily declined since 1988.

The U.S. share of current yield of the highly migratory pelagic fish stocks is about 13,300 t/year (Table 5-1; ICCAT, 2007). Since 1960, the top species by volume in the U.S. harvest has changed from bluefin tuna to swordfish to yellowfin tuna (Figure 5-1), with fishing effort shifting between these species as their abundance declined due to fishing pressure. During the 1960's, bluefin tuna represented up to 80% of the U.S. western Atlantic catch of large pelagics. However, that percentage has dropped to less than 15% since 1980, reflecting declines in the bluefin tuna population, catch restrictions, and increasing harvests of alternative species. Swordfish represented up to 20% of the U.S. catch during the 1960's, but during most of the 1970's swordfish constituted a very low percentage of U.S. landings. Swordfish landings increased toward the end of the decade and climbed to 51% in 1982, but have since dropped to about 15–20%. From the early to mid 1960's, the percentage of yellowfin tuna in the U.S. north Atlantic catch was less than 2%; levels have risen to 40–50% since 1980. The U.S. dockside ex-vessel revenue from these fisheries soared from about $30 million in the early 1980's to nearly $100 million in 1988, but has declined to roughly $60 million in recent years.

Recreational angler harvests of large pelagic fishes are estimated from dockside and telephone surveys. The average annual landed catch by recreational anglers for 2004–06 is conservatively estimated at about 7,500 t. Surveys of fishing tournaments indicate a substantial increase in recreational billfish fishing since 1972. Although the practice of tagging and releasing large pelagic fish has become common in recent years, additional data are needed to quantify the recreational fishery trends for these species in U.S. Atlantic and Gulf of Mexico waters. The value of U.S. recreational fisheries for highly migratory species has not been

Table 5-1
Productivity in metric tons (t) and status of highly migratory pelagic fisheries in U.S. waters of the Atlantic Ocean.

Species/stock	Recent average yield (RAY)[1]	Current yield (CY)[2]	Sustainable yield (MSY)	Stock level relative to B_{MSY}	Harvest rate	Stock status
Albacore (N. Atlantic)	32,400	36,077	26,800–34,100	Near	Overfishing	Overfished
Bigeye tuna (Atlantic)	74,500	64,700	68,000–99,000	Near	Not overfishing	Rebuilding
Blue marlin (Atlantic)	2,500	2,060	Unknown	Below	Overfishing	Overfished
Bluefin tuna (W. Atlantic)	1,900	1,929	3,000–3,400	Below	Overfishing	Overfished
Sailfish (W. Atlantic)	900	697	Unknown	Unknown	Overfishing	Overfished
Skipjack tuna (W. Atlantic)	26,900	25,802	Unknown	Unknown	Unknown	Unknown
Swordfish (N. Atlantic)	12,000	11,445	12,800–14,790	Near	Not overfishing	Rebuilding
White marlin (Atlantic)	400	342	Unknown	Below	Overfishing	Overfished
Yellowfin tuna (Atlantic)	109,700	103,908	~148,000	Near	Not overfishing	Appr. overfished
Other tunas (Atlantic)[3]	29,021	35,230	Unknown	Unknown		
Total	290,221	282,190				
U.S. Subtotal	18,569	13,305				

[1]2004–06 average from ICCAT Task 1 data as of 5 October 2007. Total includes landings by U.S. and foreign nationals.
[2]From ICCAT data. Based on the entire stock regardless of the harvesting nation.
[3]Harvest rate and stock status are not available for this stock.

estimated for all stocks; however, preliminary estimates indicate that they are highly valued.

The National Marine Fisheries Service (NMFS) has classified the following Atlantic HMS stocks as overfished: West Atlantic bluefin tuna, North Atlantic albacore, West Atlantic sailfish, blue marlin, and white marlin (Table 5-1). Swordfish and bigeye tuna are rebuilding following past overfishing, while Atlantic yellowfin tuna is approaching an overfished condition. The Consolidated Atlantic Highly Migratory Species FMP addresses rebuilding and/or overfishing of depleted stocks and also includes measures designed to maintain healthy stocks at the optimum yield and begin the process to update essential fish habitat. Fishing mortality rates on swordfish have been excessive since the late 1970's, prompting the development of international agreements to substantially reduce catches and the risk of further declines, beginning in 1991. U.S. harvests of swordfish since July 1991 have been consistent with ICCAT's recommendations. As a result, the last assessment of North Atlantic swordfish showed that the stock is almost rebuilt and is no longer experiencing overfishing. Western Atlantic bluefin tuna have been overharvested to the point of being severely depleted, and as a result the harvest of this species has been restricted since 1982. Stock status projections prepared during the 2006 stock assessment indicated that the 2,100 t quota established in 2007 should result in a slight increase of the spawning stock in the near future. No catch quotas are currently in place for either of the fully utilized yellowfin and bigeye tuna stocks.

ISSUES

Transboundary Stocks

Regulation of species that migrate across international boundaries is difficult. U.S. domestic regulations without international agreements are inherently limited, but international agreements can be difficult to achieve. The latter is particularly true if the primary fishing nations cannot agree on commonly shared fishing and conservation objectives, or do not abide by agreements once they are adopted. Additionally, not all nations participating in HMS fisheries belong to the international regulatory body, ICCAT. The United Nations agreement on straddling fish stocks and highly migratory fish stocks may help resolve these problems.

Bycatch and Multispecies Interactions

Bycatch of Atlantic highly migratory species causes conflicts between commercial and recreational fisheries, and reduces the impact of conservation efforts. Marlin and sailfish bycatch in tuna and swordfish fisheries is a major concern, especially when these commercial fisheries encounter concentrations of billfish that are important to

Allen Shimada, NMFS

Circle hooks on longlines arranged and ready for deployment.

Allen Shimada, NMFS

Bigeye tuna.

recreational anglers. Expansion of the U.S. longline fishery for Gulf of Mexico yellowfin tuna, and other nations' longline fishing in the tropical eastern Atlantic, have heightened concern for distressed stocks of Atlantic tunas and billfish. Bycatch of marine mammals, sea birds, and sea turtles is an important issue for the pelagic longline fishery. In 2004, the use of circle hooks in the U.S. Atlantic longline fishery became mandatory as a mitigation measure to reduce the bycatch of sea turtles. Research is currently underway to better characterize the interactions of this fleet with sea mammals and sea birds.

Domestic Management

Although the number of U.S. permits in large pelagic fisheries increased substantially during the 1990's, actual levels of effort in the longline fishery have declined in recent years. In order to reduce latent effort and prevent future expansion of the fleets, NMFS has put into place a limited-access permit system for Atlantic swordfish, shark, and tuna longline fisheries.

Since 1999, multiple areas in the Gulf of Mexico and the Atlantic Ocean have been closed to U.S. longline fishing for 1–2 months each year for the purpose of reducing bycatch of small swordfish, marlins, sea turtles, and bluefin tuna. In some of those areas, scientifically designed experimental fishing has been and is being conducted to study factors influencing bycatches.

Progress

In recent years, scientists from the United States and several other nations have made substantial progress towards improved understanding of the biological basis for managing Atlantic highly migratory fisheries. Analyses of the genetic structure of Atlantic and Mediterranean swordfish have been completed and have corroborated some of the stock structure assumptions made by ICCAT. Additionally, several years of research on the growth and reproductive biology of male and female swordfish has increased the understanding of fishing effects on both north Atlantic and Mediterranean management stock units. Genetic studies of other large pelagic species, bluefin tuna in particular, are underway. Additional studies of bluefin tuna stock structure using various tagging methods and biological markers (such as otolith micro-constituents) are in various stages of implementation. Preliminary results have corroborated the stock structure assumptions made by ICCAT. These assumptions include the existence of a western stock with spawning grounds in the Gulf of Mexico and an eastern stock that spawns in the Mediterranean Sea. There is an undetermined degree of mixing between both stocks, but fish that originated in one spawning ground always return to the same site to spawn.

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Atlantic Shark Fisheries

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Unit

6

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Photo above:
Blue shark.

INTRODUCTION

The first Fisheries Management Plan (FMP) for sharks was developed by the National Marine Fisheries Service (NMFS) for the Secretary of Commerce and implemented in 1993 (NMFS, 1993). As new information on the fisheries and on shark biology became available, four shark evaluation workshops were convened in 1994, 1996, 1998, and 2002. As a result, regulation of the fishery was moved under a new Secretarial FMP for Atlantic Tunas, Swordfish, and Sharks published in 1999 (NMFS, 1999a). This FMP was amended in 2003 (NMFS, 2003) to reflect the findings in the stock assessments for small and large coastal sharks conducted in 2002 (Cortés, 2002a; Cortés et al., 2002). Annual shark evaluation reports with updates of shark landings and catches, catch rates, and average sizes were produced in 1999, 2000, 2003, and 2005 (Cortés, 1999, 2000, 2003, 2005).

The latest assessment for large coastal sharks (LCS), completed in 2006, followed the guidelines set forth by the SouthEast Data, Assessment, and Review (SEDAR) process. Although SEDAR is a joint process for stock assessment and review by the South Atlantic, Gulf of Mexico, and Caribbean Fishery Management Councils, NMFS, the Southeast Fisheries Science Center (SEFSC), the Southeast Regional Office (SERO), and the Atlantic and Gulf States Marine Fisheries Commissions, it was felt that this process would work for the large and small coastal shark management groups as well. SEDAR is organized around three workshops: data, assessment, and review. Input data are compiled during the data workshop, population models are developed during the assessment workshop, and an independent peer review of the data and assessment models is provided during the review workshop. SEDAR documents include a data report produced by the data workshop, a stock

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Bull shark.

assessment report and summary produced by the assessment workshop, a review panel report evaluating the assessment (drafted during the review panel workshop), and collected stock assessment documents considered in the SEDAR process. In October 2006, NMFS announced the availability of the Consolidated Atlantic Highly Migratory Species (HMS) Fishery Management Plan (NMFS, 2006a). This new consolidated FMP replaced the former Tunas, Swordfish, and Sharks FMP and currently manages 39 species of sharks.

SPECIES AND STATUS

Currently, the 2006 FMP divides Atlantic shark species into four management groups: large coastal sharks, small coastal sharks, pelagic sharks, and prohibited species (Table 6-1). Following declines in the abundance of large coastal sharks, new management measures were introduced in 1997. Notably, the commercial quota for the large coastal complex was reduced from 2,570 to 1,285 metric tons (t) dressed weight (dw). A new quota for small coastal sharks was also established at 1,760 t dw. The commercial quota for pelagic sharks was reduced from 1,560 to 580 t dw. Additionally, the recreational bag limit for all Atlantic sharks was reduced to two sharks per vessel per trip, with an additional allowance of two Atlantic sharpnose sharks per person per trip. For all fisheries, possession of five species was prohibited (i.e. whale, basking, sand tiger, bigeye sand tiger, and white sharks).

Based in part on the results of the third shark evaluation workshop (SEFSC, 1998), the 1999 FMP proposed new management measures to further restrict commercial quotas and recreational bag limits. Regulations divided shark species into large coastal species, small coastal species, pelagic species, and deep water and other species, and set total allowable catches (TAC's) for large coastal, small coastal, and pelagic species. New manage-

Table 6-1
Current shark management groups under the consolidated Atlantic Highly Migratory Species FMP (NMFS, 2006).

Large Coastal Sharks	Small Coastal Sharks	Pelagic Sharks	Prohibited Sharks
Blacktip shark	Atlantic sharpnose shark	Blue shark	Atlantic angel shark
Bull shark	Blacknose shark	Oceanic whitetip shark	Basking shark
Great hammerhead	Bonnethead	Porbeagle	Bigeye sand tiger
Lemon shark	Finetooth shark	Shortfin mako	Bigeye sixgill shark
Nurse shark		Thresher shark	Bigeye thresher
Sandbar shark			Bignose shark
Scalloped hammerhead			Caribbean sharpnose shark
Silky shark			Dusky shark
Smooth hammerhead			Galapagos shark
Spinner shark			Longfin mako
Tiger shark			Narrowtooth shark
			Night shark
			Reef shark
			Sand tiger
			Sevengill shark
			Sixgill shark
			Smalltail shark
			Whale shark
			White shark

ment actions included 1) a reduction of the annual commercial quota for large coastal sharks from 1,285 to 816 t dw, apportioned between ridgeback[1] (620 t dw) and non-ridgeback (196 t dw) sharks; 2) a reduction of the annual commercial quota for small coastal sharks from 1,760 to 359 t dw (i.e. 10% higher than the 1997 landings); 3) an increase of the annual commercial quota for pelagic sharks from 580 to 853 t dw, apportioned between porbeagle (92 t dw), blue sharks (273 t dw), and other pelagic sharks (488 t dw), reducing the pelagic shark quota by any overharvest in the blue shark quota; 4) establishment of a minimum size of 137 cm fork length for ridgeback sharks; 5) a reduction of the recreational bag limit from two sharks to one shark per vessel per trip (with a minimum size of 137 cm fork length for all sharks) and an allowance of one Atlantic sharpnose shark per person per trip; 6) a prohibition on possession of 19 species (Atlantic angel, basking, bigeye sand tiger, bigeye sixgill, bigeye thresher, bignose, Caribbean sharpnose, dusky, Galapagos, longfin mako, narrowtooth, night, reef, sand tiger, sevengill, sixgill, smalltail, whale, and white sharks); 7) a requirement to count all sources of mortality, including dead discards and all landings in state waters, against the quota; and 8) a prohibition on finning of all shark species.

Due to litigation, only measures 3, 5, 6, and 8 were initially implemented. Based on stock assessments of large and small coastal sharks in 2002, NMFS classified the large coastal group as overfished, whereas the small coastal group was deemed to be fully utilized. The status of the pelagic group was listed as unknown for lack of adequate data to conduct stock assessments. Owing to its overfished status, the large coastal group has since received more intense attention than the other two management groups. As a result of the 2002 stock assessments and numerous comments received, NMFS decided that many of the management measures in

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Atlantic sharpnose shark fitted with an external acoustic transmitter. NMFS scientists use these transmitters to monitor shark movement patterns.

the 1999 FMP should be reexamined. In November 2003, NMFS released the Final Amendment I to the 1999 FMP (NMFS, 2003), which contained several management changes. Most notably, the ridgeback and non-ridgeback classification of the large coastal shark group was re-aggregated, with the commercial quotas for large coastal sharks being set at 1,017 t dw, small coastal sharks at 454 t dw, and pelagic sharks at 853 t dw, apportioned between porbeagle (92 t dw), blue sharks (273 t dw), and other pelagic sharks (488 t dw). Additional actions included 1) implementation of three fishing seasons per year instead of two; 2) a requirement that state landings after Federal closures be counted against the Federal quota; 3) adjustment to regional quotas; and 4) a time/area closure from January through July off North Carolina. The list of 19 prohibited species and minimum size of 137 cm fork length for the recreational fishery were maintained. The 2006 Consolidated HMS FMP implemented additional management measures, including 1) mandatory shark identification workshops for Federally permitted shark dealers; and 2) a requirement that the second dorsal and anal fins must remain on all sharks through landing. Both measures are designed to improve data collection at the species level.

Determining the quantity of sharks landed or discarded in terms of weight is difficult for several reasons. First, weight estimates for recreational catches are highly variable because a relatively small number of animals are measured and weighed by the biologists collecting recreational data. Second, a significant amount of the commercial catch is only reported under the general category of "sharks," and species identification either cannot be or is not reported. As a result, these landings are assigned to one of the management groups analytically for

[1] A number of species in the large coastal shark management unit are characterized by a mid-dorsal ridge that is easily identified even after the fish has been gutted and finned. This mid-dorsal ridge is useful as diagnostic characteristic for management and enforcement purposes. Ridgeback sharks include sandbar, dusky, silky, night, and bignose sharks. Non-ridgeback sharks include blacktip, spinner, bull, tiger, nurse, lemon, narrowtooth, and hammerhead sharks.

Table 6-2

Productivity in numbers or metric tons (t) and status of Atlantic shark fisheries resources.

Species/stock	Recent average yield (RAY)[1]	Current yield (CY)[2]	Sustainable yield (MSY)[3]	Stock level relative to B_{MSY}	Harvest rate	Stock status
Large coastal sharks[4]	273	1,017	Unknown	Unknown	Unknown	Unknown
Blacktip shark (Gulf of Mexico)	127	NA	12,100	Above	Not overfishing	Not overfished
Blacktip shark (Atlantic)	31	NA	Unknown	Unknown	Unknown	Unknown
Sandbar shark	60	NA	202	Below	Overfishing	Overfished
Small coastal sharks[5]	998	454	2,623	Above	Not overfishing	Not overfished
Atlantic sharpnose shark	442	NA	1,270	Above	Not overfishing	Not overfished
Blacknose shark	84	NA	89	Below	Overfishing	Overfished
Bonnethead	310	NA	569	Above	Not overfishing	Not overfished
Finetooth shark	14	NA	96	Above	Not overfishing	Not overfished
Pelagic sharks[6]	26	853	Unknown	Unknown	Unknown	Unknown
Blue shark[7]	3	273	Unknown	Above	Unknown	Unknown
Shortfin mako[7]	12	488	Unknown	Unknown	Unknown	Unknown
Prohibited shark species[8]	Unknown	0	Unknown	Unknown		
Dusky shark	19	0	≤23	Below	Overfishing	Overfished
Total[9]	1,297	2,324	Unknown			

[1]2002–04 average for large coastal sharks (LCS); 2003–05 average for small coastal sharks (SCS); 2004–06 average for pelagic sharks; 2001–03 average for dusky sharks. Expressed in thousands of fish, except for dusky sharks, which are in tons dressed weight (t dw). Shark totals are not included in the summary tables of the National Overview.

[2]Total allowable catches for sharks include quotas and discards. Dead discards and state landings after Federal closures are subtracted from quotas when adjusting the commercial quota for sharks to account adequately for all sources of fishing mortality. Expressed as t dw.

[3]MSY values are in t dw for LCS and dusky sharks; in thousands of fish for SCS.

[4]Separate stock assessments were conducted for sandbar and blacktip sharks (Gulf of Mexico and Atlantic), but the management unit is large coastal sharks and there are no individual quotas set for these species.

[5]Separate stock assessments were conducted for Atlantic sharpnose, bonnethead, blacknose, and finetooth sharks, but the management unit is small coastal sharks and there are no individual quotas set for these species.

[6]CY is apportioned between porbeagle (92 t dw), blue sharks (273 t dw), and other pelagic sharks (488 t dw).

[7]Separate stock assessments were conducted by ICCAT for blue shark and shortfin mako in the North Atlantic Ocean. Values reported refer to the U.S. portion.

[8]Species that cannot be kept commercially or recreationally.

[9]Total value for RAY does not include any of the prohibited shark species.

statistical purposes. Third, discard estimates are typically reported as numbers of fish. Because of these uncertainties, another set of estimated mean weights per fish for recreational catches or another set of assumptions regarding the allocation of the unidentified commercial shark landings is likely to produce different total weights for the recent average yield (RAY). To help minimize some of the effects of these factors, the landings and catch data used in the large coastal shark stock assessments are typically compiled in numbers of animals instead of weight (Table 6-2).

Large Coastal Sharks

The U.S. Atlantic shark fishery is primarily a southeastern fishery extending from Virginia to Texas, although sharks are also landed in the states north of Virginia. Figure 6-1 shows the numbers that were reported landed and discarded for sharks in the large coastal management group from 1981 to 2004. Commercial landings collected under the NMFS cooperative statistics program include the period of 1981–2004. Landings are typically reported in dressed weight, and an average weight is used to convert to numbers. Data for average weights are more reliable for 1994–2004 because they were based on an observer program of the directed shark bottom longline fishery. Similarly, commercial landings estimates are more reliable starting in 1995 because of improved species-specific reporting. Unreported commercial landings from 1986 to 1991 are also included. Recreational catches in numbers also span the period of 1981–2004 and include estimates from the NMFS Marine Recreational Fishery Statistics Survey (MRFSS), headboat survey, and the Texas Parks and Wildlife recreational creel survey. Discards include estimates from the pelagic longline fishery for 1981–2004, the shark bottom longline fishery for 1993–2004, and the menhaden fishery in the Gulf of Mexico for 1994–2004.

Sandbar and blacktip sharks are the two most important species in the large coastal shark (LCS) fishery (Figure 6-1). An assessment of these two species was conducted at the 1998 and 2002 Shark Evaluation Workshops (SEFSC, 1998) and at the 2006 LCS SEDAR (NMFS, 2006b). At the LCS SEDAR it was determined that blacktip sharks in the Gulf of Mexico and the western Atlantic Ocean comprise two separate stocks, based on genetic evidence. As such, two assessments were conducted for that species: blacktip sharks—Gulf of Mexico and blacktip sharks—western Atlantic Ocean. The catch series available for sandbar and blacktip sharks spanned the period from 1981 to 2004, including commercial landings, recreational catches, catches from artisanal fisheries in Mexico, and unreported commercial landings (for 1986–1991). Discards included estimates from the menhaden fishery for 1981—2004.

The report of the Second Shark Evaluation workshop (SEFSC, 1996) concluded that catch rates of many shark species and species groups declined by about 50–75% from the early 1970's to the mid 1980's, but that the rapid rate of decline in catch rates that characterized the stocks in the early 1980's had slowed significantly in the 1990's. Partly based on results from the 1996 workshop, a 50% reduction in catches of large coastal species (i.e. relative to 1995) was targeted. This reduction was to be achieved by a 50% reduction in the commercial quota for the large coastal management group and a reduction of the recreational bag limit to two fish per boat per day (from the previously established recreational bag limit of four fish). During the third Shark Evaluation Workshop (SEFSC, 1998), preliminary data for 1997 were presented and reviewed, and the indications were that commercial catches, in numbers of animals, were reduced from 1995 by more than 50%, but recreational catches were reduced by only 12%. The most recent catch rate data analyzed at that time continued to show inconsistent trends, many of which were not statistically significant. These findings were not totally unexpected given that the expected rates of change in shark abundance are small and the measures of stock abundance used are uncertain, meaning that longer time series are needed to detect significant changes in stock size following implementation of the most recent management measures.

Biomass dynamic model analyses that utilized catch, catch rate, and demographic data were integrated within a Bayesian statistical estimation approach during the Third Shark Evaluation workshop (SEFSC, 1998). The main findings of these analyses were that 1) for the large coastal

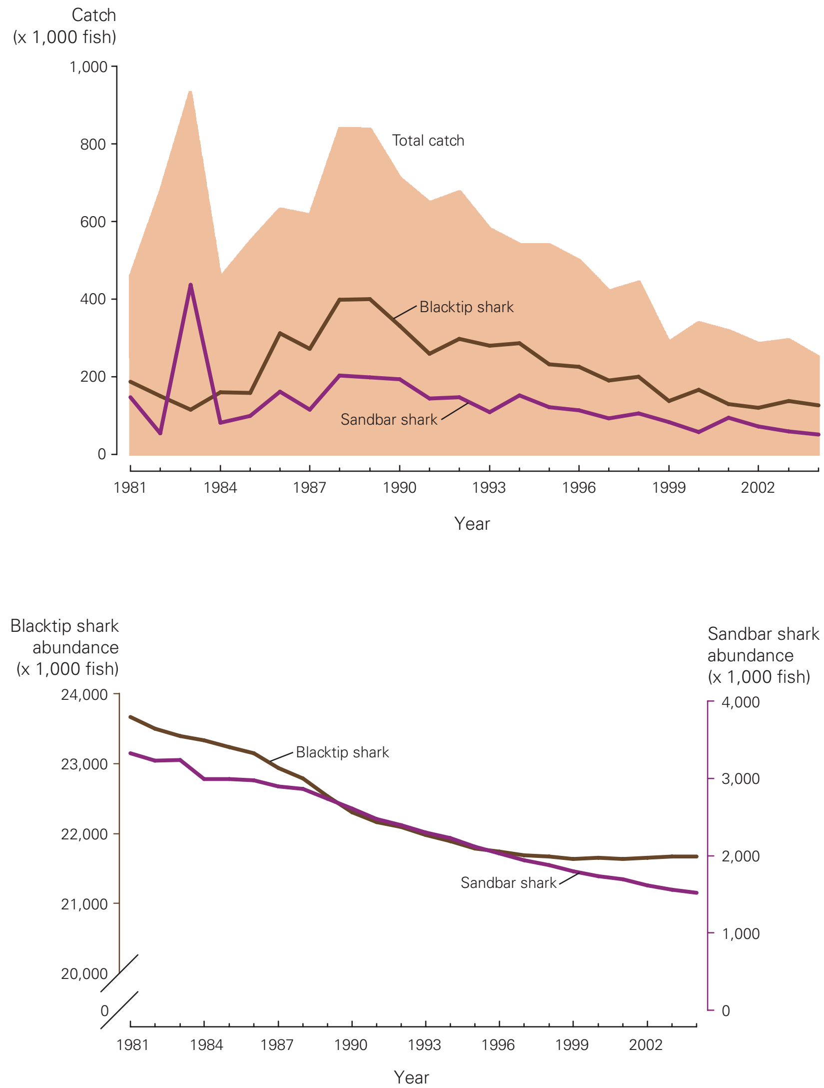
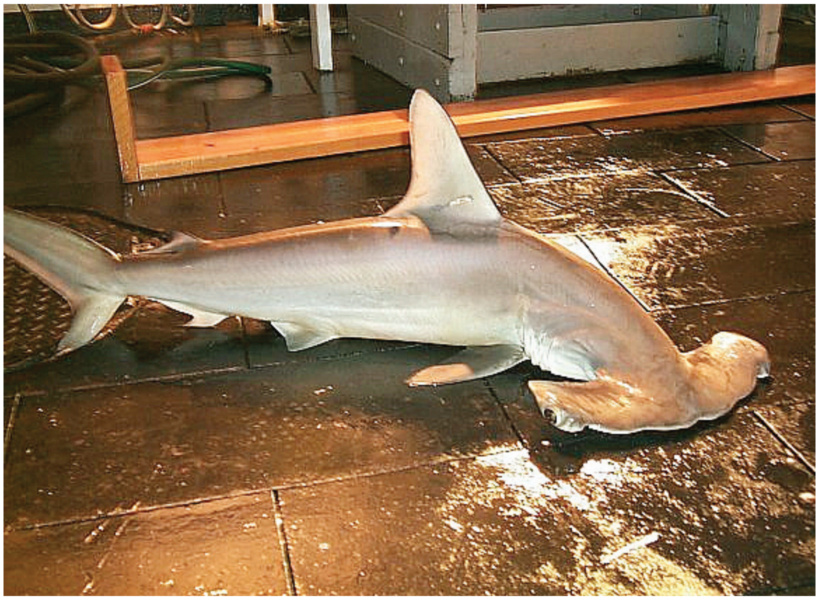


Figure 6-1

Catches (above) of large coastal sharks and estimated stock abundance (below) of blacktip shark (Gulf of Mexico stock) and sandbar shark, 1981–2004.



Hammerhead shark on the deck of a NOAA Fishery Survey Vessel.

complex, the 1998 stock size was estimated to be between 30 and 36% of the stock size producing maximum sustainable yield (MSY); 2) for sandbar shark, the 1998 stock size was between 58 and 70% of MSY levels; and 3) for blacktip shark, the 1998 stock size was between 44 and 50% of MSY levels. A sensitivity analysis undertaken following peer review (Cortés, 2002a) showed that results for blacktip shark were particularly sensitive to some of the estimation techniques used. The 2002 stock assessment (Cortés et al., 2002) conducted for the LCS complex showed that the status of the resource had improved since 1998, but continued to show that overfishing was likely to be occurring and the resource was likely to be overfished. It also indicated that on average a reduction in catch of at least 50% of the 2000 catch level was likely required for the biomass to reach MSY in 10 years.

Multiple models and estimation techniques were used to assess the status of sandbar and blacktip sharks during the 2002 assessment (Cortés et al., 2002). Results indicated on average that the status of sandbar sharks had also improved since 1998 and that 2002 biomass could be near or somewhat above MSY, but overfishing could still be occurring. Most results for blacktip shark indicated that the stock was rebuilt and that 2002 removal levels were sustainable.

For the 2006 assessment, three large coastal shark groupings were assessed: 1) LCS complex including all 22 species originally in the management group (1993 FMP); 2) LCS excluding all prohibited species (11 species; current LCS management group); and 3) LCS excluding all prohibited species as well as sandbar and blacktip sharks (nine species). For all assessments prior to 2006, the large coastal aggregate included the species of prohibited sharks that were formally considered part of the LCS management group.

The Review Panel for the 2006 LCS SEDAR determined that, overall, the data utilized in the assessment of the LCS complex were the best available to the analysts at the time, and the assessment of the status of the complex was the best possible given the data available (NMFS, 2006b). However, the assessment performed inadequately at representing the status of the LCS complex (in any of the formulations: 22, 11, or 9 species) because of the potential for conflicting or mismatching information from various species components in the catch and abundance index data. Therefore, it was unclear to the Panel what exactly the results of the assessment represented, making it impossible to support use of the results for management of the complex. Further, the Panel stressed that results of previous assessments that used the same approach and similar data (perhaps of lesser quality) would attract the same or even stronger negative criticisms. They concluded that continued assessment of the LCS complex with the current approach and data was unlikely to produce effective management advice and was not recommended (although for continuity, output from such an approach should be made available when the complex is next subject to review). Instead, research, data analysis, and model development to permit species-specific assessments for the main components (except sandbar and blacktip, which are already assessed separately) of the complex (both permitted and prohibited species) was deemed a priority.

For sandbar sharks, the SEDAR Review Panel determined that the population model and resulting population estimates were the best possible given the data available (NMFS, 2006b). The change in stock status in the 2006 assessment from the more optimistic status in 2002 appears to be mainly attributable to revisions to the life history parameters in the 2006 assessment, along with changes in the input data due to standardization of many of the relative abundance indices. The population was assessed to be less productive than was assumed in 2002. The Panel was confident that the 2006 assessment provided a more reliable estimate of stock status than the 2002 and earlier assessments did. Stock status was determined from the results of a range of model fits reflecting the Panel's uncertainty about life history parameters. All results indicated that the stock was overfished and that overfishing was occurring. The target year to rebuild the stock was estimated to be 2070.

Blacktip sharks in the Gulf of Mexico were determined not to be overfished, nor was overfishing occurring. The Panel accepted the stock status, but did not accept the absolute estimates of stock abundance. The three abundance indices believed to be most representative of the stock were consistent with each other, suggesting that stock abundance has been increasing over a period of declining catch during the past 10 years. Based on life history characteristics, blacktip sharks are a relatively productive shark species, and a combination of these characteristics and recent increases in the most representative abundance indices suggests that the blacktip stock is relatively healthy. However, there was no scientific basis for advising an increase in catches.

For blacktip sharks in the western Atlantic Ocean, the Panel concluded that the data used for the analyses were treated appropriately (NMFS, 2006b). However, it was unclear whether catch estimates prior to 1991 adequately represented historical removals. Moreover, it was impossible to judge the extent to which each of the standardized catch-rate series reflected real trends in the abundance of the stock. Therefore, given the widely differing results arising from the different models, the status of the stock of Atlantic blacktip shark was deemed to be uncertain, and no reliable estimates of abundance, biomass, or exploitation rates were advanced. Further, in the absence of reliable estimates of abundance, biomass, and exploitation rates, no reliable estimates of stock status were suggested. In summary, given that current status was unknown, no reliable population projections were possible, so no probable values for future population condition and status were provided. However, there was clearly no scientific basis for advising a change in catch levels.

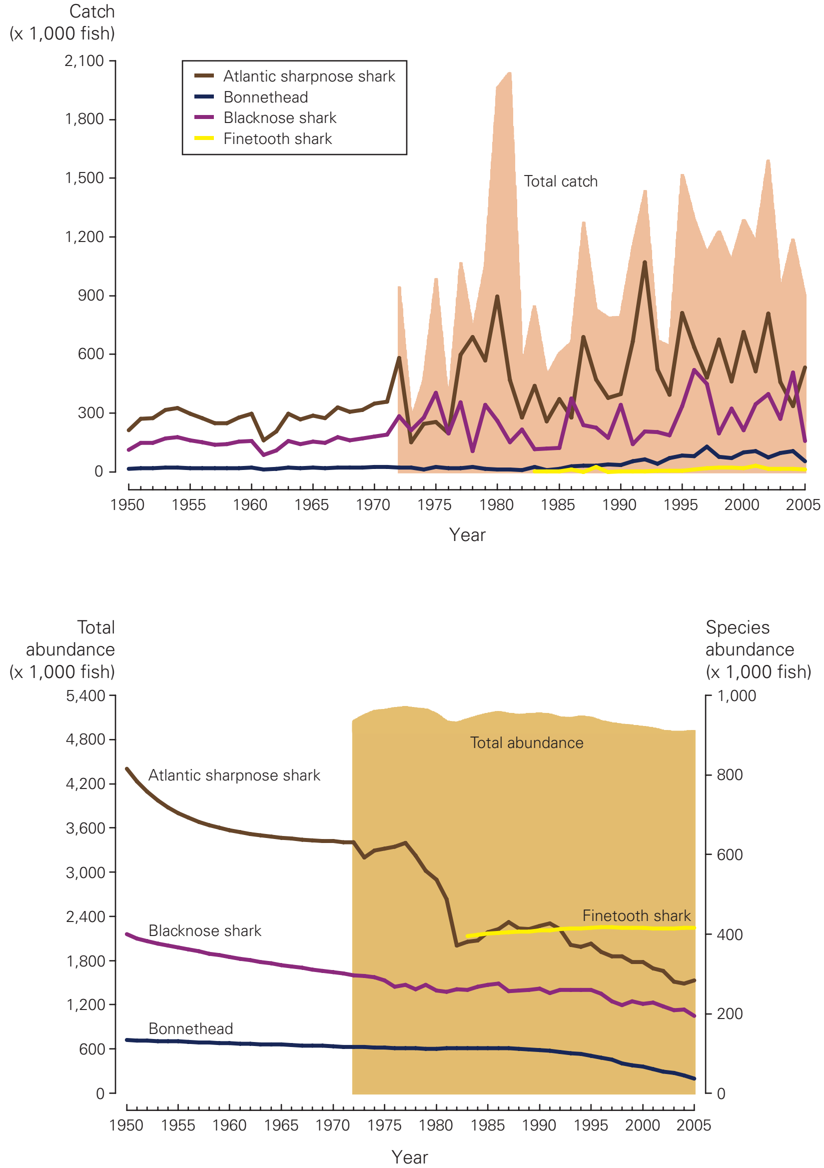


Figure 6-2

Catches (above) and estimated stock abundance (below) of small coastal sharks (1972–2005), Atlantic sharpnose, bonnethead, and blacknose sharks (1950–2005), and finetooth shark (1983–2005).

Small Coastal Sharks

Of the four species (Atlantic sharpnose, bonnethead, blacknose, and finetooth sharks) of small coastal sharks (SCS) in the complex, Atlantic sharpnose and bonnethead sharks account for approximately 94% of the catch (Figure 6-2). Landings represent only a small fraction of all catches because small coastal sharks are also caught as bycatch and discarded in a variety of fisheries, notably shrimp trawl fisheries. Bycatch in the shrimp trawl fishery operating in the Gulf of Mexico and U.S. South Atlantic was estimated based on observer data and

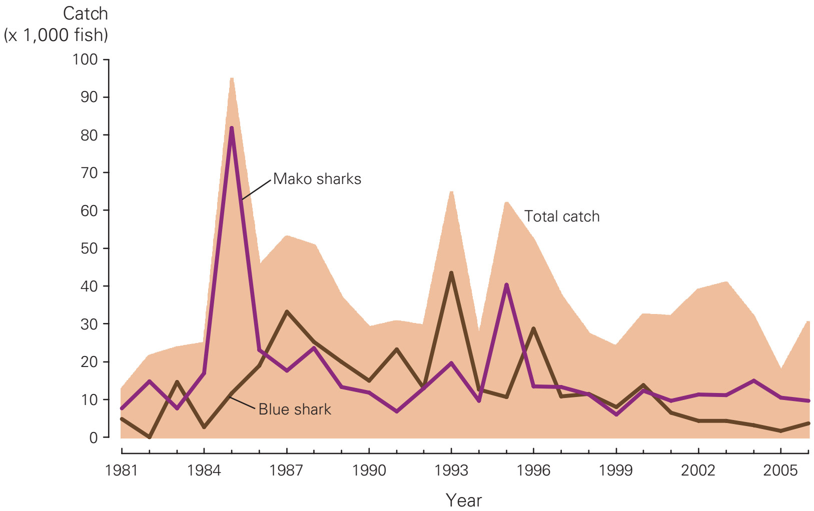


Figure 6-3
Landings in metric tons (t) of pelagic sharks, 1981–2004.

total effort for 1972–2005 for the small coastal shark aggregate, and for 1950–2005 for Atlantic sharpnose, bonnethead, and blacknose sharks, and accounts for the majority of the catches.

The latest stock assessments for the small coastal shark complex, and Atlantic sharpnose, bonnethead, blacknose, and finetooth sharks individually were conducted by the 2007 SCS SEDAR using surplus-production and age-structured approaches and Bayesian estimation techniques (NMFS, 2007). The Review Panel for the 2007 SCS SEDAR concluded that while the assessment of the status of the complex was considered adequate based on the available data, given that species-specific assessments were also conducted, any conclusions should be based on the results of the individual species assessments. Only Bayesian biomass dynamic models could be used to evaluate the status of finetooth sharks. Results, which incorporated uncertainty about life history parameters, catches, and indices of relative abundance, indicated that the stock was not overfished nor was overfishing occurring, in contrast to the results of the 2002 SCS assessment (Cortés, 2002b), which found overfishing was occurring. Because of the general level of uncertainty in the data, the Review Panel suggested cautious management of this resource.

Both biomass dynamic and age-structured models were used for the other three species. For blacknose sharks, the assessment indicated that the stock was overfished and overfishing was occurring both in 2005 and in the preceding 2001–04 period. However, due to uncertainty in life history parameters, catches, and indices of relative abundance, the Review Panel cautioned that stock status could change substantially in an unpredictable direction in future assessments. In contrast, the assessments for Atlantic sharpnose and bonnethead sharks determined that the stocks were not overfished nor was overfishing occurring. However, for Atlantic sharpnose sharks, F was near F_{MSY} and for bonnethead sharks, fishing mortality rates in recent years had fluctuated above and below F_{MSY}.

Pelagic Sharks

For the pelagic group, the available catch series spans from 1981 to 2006 (Figure 6-3). Commercial landings include the period of 1982–2006, recreational catches include 1981–2006, and dead discard estimates from the pelagic longline fishery are available for 1987–2006. Due to the highly migratory nature of pelagic sharks, these species are harvested or caught as bycatch in the North Atlantic by fishermen from several nations. An assessment of blue sharks and shortfin makos was conducted by the International Commission for the Conservation of Atlantic Tunas (ICCAT) Sub-Committee on Bycatch in June 2004 using surplus production, age-structured, and catch-free stock assessment models. Results indicated that blue shark biomass in the North and South Atlantic is above B_{MSY}, while shortfin mako biomass may be below B_{MSY} in the North Atlantic but is above B_{MSY} in the South Atlantic. The conclusions drawn from this assessment were considered to be very preliminary due to limitations on the quantity and quality of available data, and recommendations were made to increase research and monitoring efforts for sharks and other species caught as bycatch in tuna fisheries. The next ICCAT assessment for shortfin mako and blue shark is scheduled for late 2008.

Prohibited Species

Dusky sharks off the U.S. East Coast were classified as a prohibited species by NMFS in 1999, but had not been individually assessed. In 1997, they were also designated by NMFS as a candidate species for listing under the Endangered Species Act (ESA), and in 2004 were listed by the International

Union for the Conservation of Nature (IUCN) Red List of Threatened Species as vulnerable in the northwest Atlantic and Gulf of Mexico.

A stock assessment of dusky sharks was completed in 2006 (Cortés et al., 2006). The multiple indicators used in this assessment all provided a consistent picture of heavy fishing impact and high vulnerability to exploitation of dusky sharks in the northwestern Atlantic Ocean and Gulf of Mexico. Decreasing temporal trends in mean size of catch and catch rates, in tandem with decreasing biomass and increasing fishing mortality rates derived from all the stock assessment methodologies used, indicated that the stock considered has been very heavily exploited. Results obtained with multiple stock assessment methods, which included surplus production, age-structured, and age-structured catch-free modeling approaches, indicated depletions in 2003 ranging from 62 to 93% of virgin biomass, with most models estimating depletions of over 80%. In all, the various stock assessment methodologies used to estimate stock status were all consistent in showing large depletions with respect to virgin (unexploited) levels. Despite some recent signs of recovery, the dusky shark stock in the U.S. Atlantic and Gulf of Mexico has been severely depleted with respect to virgin levels.

ISSUES

Scientific Information and Adequacy of Assessments

The lack of extensive time series for species-specific catch and effort data continues to be a problem that hampers shark stock assessments (NMFS, 1999b). Without reliable species-specific data and stock assessments, management measures will necessarily continue to be based on species aggregates. Several of these important data deficiencies have been recognized in the past (SEFSC, 1998; Cortés et al., 2002; NMFS, 2006b). To continue to improve shark stock assessments, it is critical to 1) continue to improve species- and size-specific catch (landed and discarded animals caught both in U.S. and non-U.S. fisheries) and effort data, and 2) improve fishery-independent measures of shark abundance and productivity. Additionally, it has been recognized that every effort should be made to assess the status of shark species separately because individual species respond differently to exploitation based on their innate capacity to rebound and fishing history (NMFS, 2006b). Thus, management of coastal shark species aggregates can result in excessive regulation on some species and excessive risk of overfishing on others.

Florida Keys National Marine Sanctuary

Nurse shark resting beneath a coral ledge.

Management Concerns

Although the collection of species-specific data is preferable from a scientific standpoint, reliable species identification continues to pose problems in the practical management of the fisheries, and may only be remedied through observer programs, extensive public outreach, and educational programs. The new mandatory shark identification workshops described in the latest FMP will assist in this process (NMFS, 2006a). The magnitude of recreational catch estimates has surpassed that of commercial landings in several years since 1996. It also appears that the minimum size limit imposed on the recreational sector has been largely ineffective, and a reduced bag limit per trip is not achieved. Significant reductions in mortality from the recreational sector could be realized if these regulations were followed. The issue of incidental catches and discarding of dead sharks in commercial fisheries is also contentious from a management perspective. Amendment 1 to the 1999 FMP incorporated a number of measures to mitigate bycatch in commercial shark fisheries, including gear restrictions and adoption of Vessel Monitoring Systems[2] (VMS) in some cases (NMFS, 2003). A time/area closure aimed at protecting sandbar and dusky shark nursery and pupping areas off North Carolina from January to July was also implemented. Pending work includes individual assessments of species classified as prohibited, especially night and sand tiger sharks, which were recently designated as Species of Concern[3] by NMFS.

Progress

Considerable progress has been made since the first Atlantic shark FMP implemented in 1993. Since that time (when 98% of commercial shark landings were simply reported as "sharks"), mandatory commercial permitting and reporting has significantly reduced the proportion of catch reported as unclassified. Beginning in 1995, a quota monitoring program on permitted shark dealer reports from the Southeast Region has improved the quality of commercial landings data because it supports a more diverse species list. NMFS also funds two observer programs that provide extensive data on species and size composition, catch disposition, distribution of fishing effort, and bycatch in directed shark fisheries. The shark drift gillnet observer program has been in effect since 1993, and the shark bottom longline observer program since 1994. A third observer program providing valuable information on sharks caught as bycatch in pelagic longline fisheries targeting tunas and tuna-like species began in 1992.

A number of improvements have supported more informative and comprehensive assessments of shark stocks. There has been an increase in the number and duration of fishery-independent surveys, and some fishery-dependent time series of relative abundance have become available and have been analyzed through General Linear Modelling (GLM) techniques. Nursery area and tagging studies in the Atlantic and Gulf of Mexico have been expanded and incorporated into stock assessments to some degree. Population and demographic modeling on several species has also contributed substantially to new stock assessments.

Progress has also been made in domestic management. NMFS' HMS Management Division is responsible for developing management measures consistent with the requirements of the Magnuson-Stevens Fishery Conservation and Management Act. To that end, an HMS Advisory Panel was formed to help prepare the 1999 FMP for Atlantic Tunas, Swordfish, and Sharks, which amended the 1993 FMP. The 1999 FMP and its amendment (NMFS, 2003) established a rebuilding program for the overfished large coastal shark complex, attempted to prevent further overfishing of sandbar and finetooth sharks, continued to monitor the status of some stocks that were deemed to be rebuilt and healthy (blacktip and all small coastal sharks except the finetooth shark), and limited access to the commercial shark fishery. The 2006 FMP was finalized before the results of the 2006 LCS SEDAR were complete; an amendment to incorporate the 2006 LCS results is under development.

Internationally, the United States continues to play a key role in several shark management forums. The United States participated in the United Nations Food and Agriculture Organization's Consultation on Shark Conservation and Management. This consultation culminated in the adoption of a National Plan of Action in 2001 to guide national, regional, and international science and management under the precautionary approach. The United States also participates actively in ICCAT as a member of the Shark Working Group of the Sub-Committee on Bycatch, providing data for stock assessments. These efforts contributed to the 2004 stock assessments of blue shark and shortfin mako. In 2001, NMFS implemented the Shark Finning Prohibition Act of 2000 (Public Law 106-557), which effectively bans the practice of finning (landing or possessing shark fins without carcasses) in U.S. territorial waters. Additionally, the United States has been collaborating with Mexico in catch rate analysis of sharks commonly harvested by both countries in the Gulf of Mexico, and a research survey to assess Mexican shark resources in the Gulf

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[2]A device that continuously beams a boat's location, direction, and speed to a global satellite network that relays the information, alerting NMFS and the Coast Guard when a boat enters a closed area or when it is fishing out of season.

[3]Species of Concern are species that NMFS has identified as having significant uncertainty regarding status and threats, but insufficient information is available to indicate a need to list the species under the Endangered Species Act.

of Mexico. These bilateral activities are conducted under the auspices of the MEXUS-Gulf Cooperative Program.

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Atlantic and Gulf of Mexico Coastal Pelagic Fisheries

Allen Shimada, NMFS

Unit 7

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Photo above:
Retrieving a dolphinfish hooked on a recreational squid jig.

INTRODUCTION

Coastal pelagic species of the U.S. Atlantic Ocean and Gulf of Mexico include king mackerel, Spanish mackerel, dolphinfish, cobia, and cero. The mackerels typically occur in tropical, subtropical, and temperate waters at depths from 20 to 150 feet. King mackerel are distributed throughout the western Atlantic from New England south to Brazil, while Spanish mackerel are generally found north of the Yucatan peninsula in Mexico. Cobia and dolphinfish are broadly distributed in tropical to warm-temperate waters of the Atlantic, Pacific and Indian Oceans. In the western North Atlantic, cobia range from Nova Scotia south to Argentina, including the Caribbean Sea. Dolphinfish share a similar distribution from New England south to Brazil. During autumn and winter months, cobia migrate southward and offshore, seeking warmer waters. In early spring, the population moves northward and inshore along the U.S. Atlantic coast.

Coastal pelagic species share a suite of typical adaptations. They are generally fast-swimming predatory fishes that school, feed voraciously, grow rapidly, mature early, and spawn over an extended period of several months.

Most coastal pelagic species are highly valued and sought-after gamefish. During 1984–2006, recreational fishermen landed between 7,200 and 19,000 metric tons (t) of coastal pelagics each year (Figure 7-1). Annually, king and Spanish mackerel accounted for 36–61% of all coastal pelagic recreational harvests. In addition to king and Spanish mackerel, dolphinfish and cobia contributed significantly to the total recreational yield of coastal pelagics.

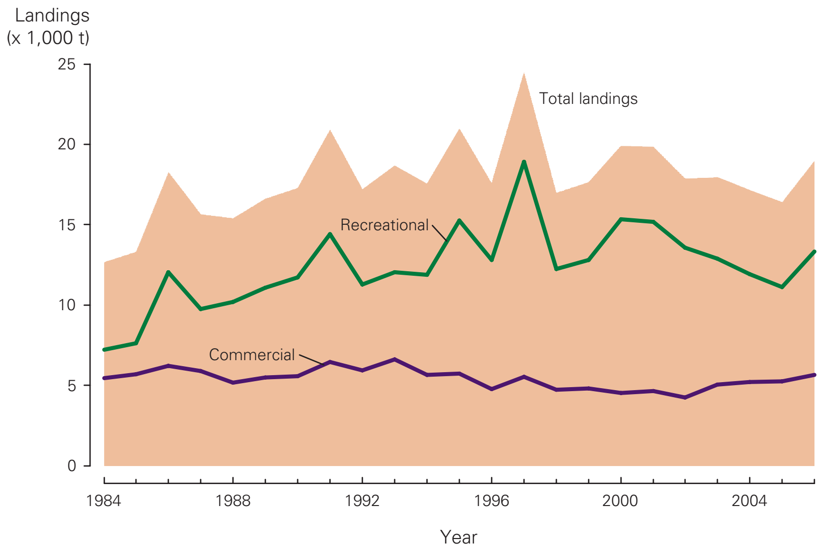

Figure 7-1
Total landings in metric tons (t) by fisheries sector of coastal pelagic stocks, 1984–2006.

Commercial landings of coastal pelagic species oscillated between 4,200 and 6,600 t per year during 1984–2006 (Figure 7-1). Landings were primarily of king and Spanish mackerels (80% on average). Cobia are caught incidentally on some commercial trips targeting mackerels, but these landings are restricted to two fish per trip. Cero are of minor commercial importance since they are typically non-schooling and are difficult to target in commercially relevant densities.

Coastal pelagic species under the Coastal Migratory Pelagic Resources Fishery Management Plan (FMP) are co-managed by the South Atlantic Fishery Management Council (SAFMC) and the Gulf of Mexico Fishery Management Council (GMFMC). Management regulations have included annual total allowable catches (TAC's), minimum size restrictions, and creel limits. For king and Spanish mackerel, the Councils recognize two separate migratory groups: the Gulf of Mexico group managed by the GMFMC, and the Atlantic group managed by the SAFMC. The management process begins with SouthEast Data, Assessment, and Review (SEDAR) assessments that recommend Acceptable Biological Catches (ABC's) for each migratory group. The Councils then choose annual TAC's, with separate commercial and recreational allocations. The TAC set for the Gulf migratory group is further divided into separate sub-regions within the Gulf (e.g. eastern and western). Quota management of coastal pelagic species began in 1985. Presently, both commercial and charter boat operators must hold current Federal fishing permits for king mackerel, Spanish mackerel, and other coastal pelagic species. In addition to quota limits, commercial catches must comply with minimum size restrictions; daily landing limits and/or trip limits in Florida and North Carolina may also apply. Since 1998, NMFS requires mandatory reporting through logbooks for all commercial king mackerel fishing trips.

SPECIES AND STATUS

Some species in the coastal pelagics group are currently being fished near or at the maximum sustainable yield (MSY) production levels (Table 7-1). The Gulf king mackerel stock was considered

Table 7-1
Productivity in metric tons (t) and status of coastal pelagic fishes in the U.S. Atlantic Ocean and Gulf of Mexico.

Species/stock	Recent average yield (RAY)[1]	Current yield (CY)	Sustainable yield (MSY)	Stock level relative to B_{MSY}	Harvest rate	Stock status
Cobia	1,097	972	659 (Gulf)	Unknown	Not overfishing	Not overfished
Dolphinfish	5,451	5,770	Unknown	Unknown	Not overfishing	Not overfished
King mackerel						
Atlantic group	2,415	2,676	2,308	Near	Not overfishing	Not overfished
Gulf group[2]	4,434	5,301	5,183	Below	Not overfishing	Rebuilding
Spanish mackerel						
Atlantic group	2,313	2,250	Unknown	Unknown	Not overfishing	Not overfished
Gulf group	1,772	1,990	Unknown	Unknown	Not overfishing	Not overfished
Total	17,482	18,959				

[1]2004–06 average. Includes recreational landings.
[2]Stock status is classified as rebuilding because in the most recent stock assessment (2004), the stock abundance was above the overfished threshold but still had not reached the target biomass level of MSY.

overfished until recently because of prior overexploitation and has been under a rebuilding program since 1985. According to the most recent stock assessment in 2004, MSY was estimated at 5,183 t for the Gulf king mackerel stock and 2,308 t for the Atlantic king mackerel stock. Current yields (2006) were above the MSY estimates, 5,301 t in the Gulf and 2.676 t in the Atlantic.

The king mackerel stocks of the Gulf of Mexico and Atlantic migratory groups are managed using 1) a maximum fishing mortality threshold (MFMT) of $F_{30\%}$SPR[1] and 2) a minimum spawning stock threshold (MSST) of 80% of B_{MSY}. By definition, overfishing is occurring if the current median estimated harvesting rate (F) is above MFMT, and the stock is considered overfished if the current biomass is below the MSST levels. According to the 2004 assessment, the king and Spanish mackerel stocks are not experiencing overfishing. The Councils have also defined target (MSY) and optimal yield (OY) levels for these stocks. In the case of Atlantic king mackerel, OY is defined as the yield at $F_{40\%}$SPR, while a value of yield at 85% F_{MSY} is used for Gulf king mackerel.

Spanish Mackerel

Both U.S. and Mexican fishermen have commercially exploited Spanish mackerel since the 1850's. Initially, the U.S. fishery was located off the northeastern United States, but over time, it shifted southward to the U.S. South Atlantic and Gulf of Mexico. By 2006, over 70% of the commercial catch was landed off Florida. During the early years, most Spanish mackerel were harvested using hook-and-line gear. Later, gillnets became the dominant gear, and accounted for the majority of the landings. However, in 1996 gillnets were banned in Florida state waters which substantially reduced the total commercial catch of Spanish and king mackerel, particularly on the West Florida coast where state waters extend up to 9 n.mi. offshore.

Spanish mackerel are highly valued recreational gamefish throughout their range. Since the 1990's, the proportion of Spanish mackerel landed by recreational fishermen has increased in the Gulf of Mexico. Currently, about 30% of the landings of the Atlantic stock and 70% of the landings of the Gulf stock are taken by recreational anglers (Figure 7-2).

Atlantic Spanish mackerel are considered to be at or near their full maximum fishery potential. The 2003 stock assessment suggested that the stock was not overfished. However, fishing mortality on Spanish mackerel from the Atlantic shrimp fishery is believed to be greater than had been assumed. Similar uncertainty exists for other coastal pelagic species caught incidentally by the shrimp fishery,

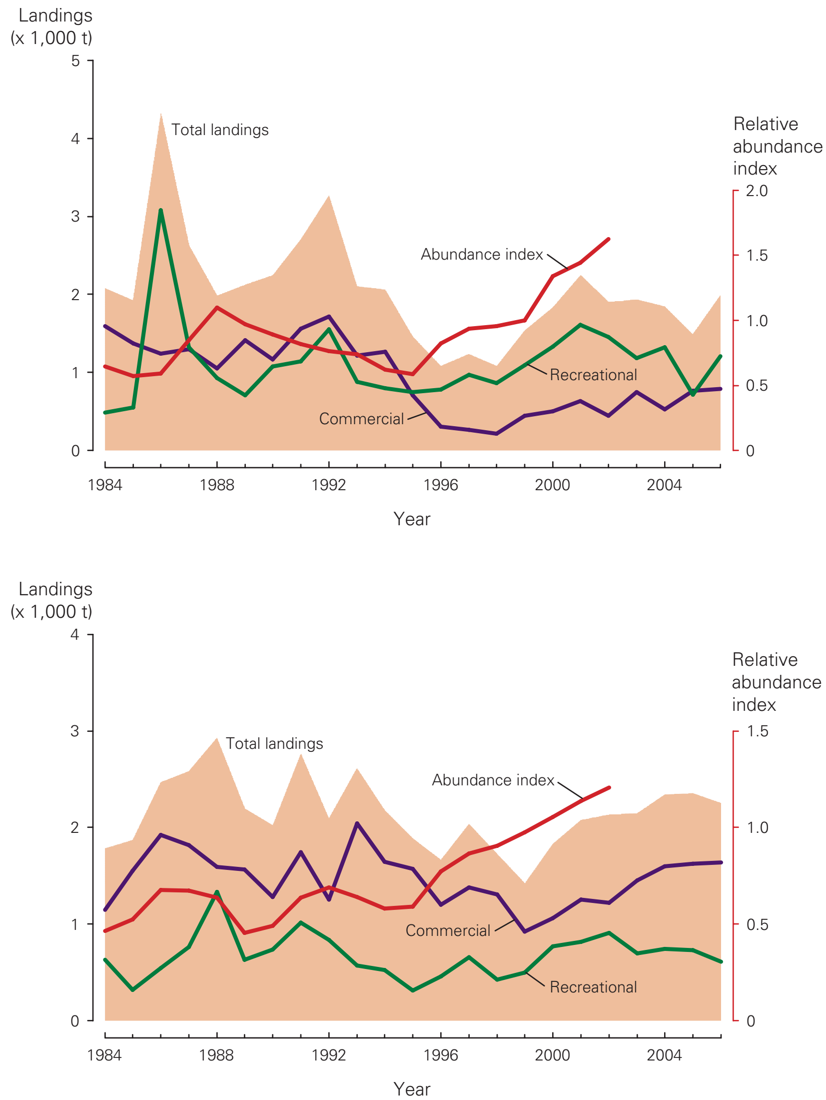

Figure 7-2
Landings in metric tons (t) and relative spawning stock size of Spanish mackerel, 1984–2006. Top, Gulf of Mexico group; bottom, South Atlantic group.

[1]The spawning potential ratio (SPR) is the amount of reproductive output produced by an average recruit in a fished stock, divided by the reproductive output produced by an average recruit in an unfished stock. $F_{30\%}$ is the fishing mortality rate expected to produce 30% SPR.

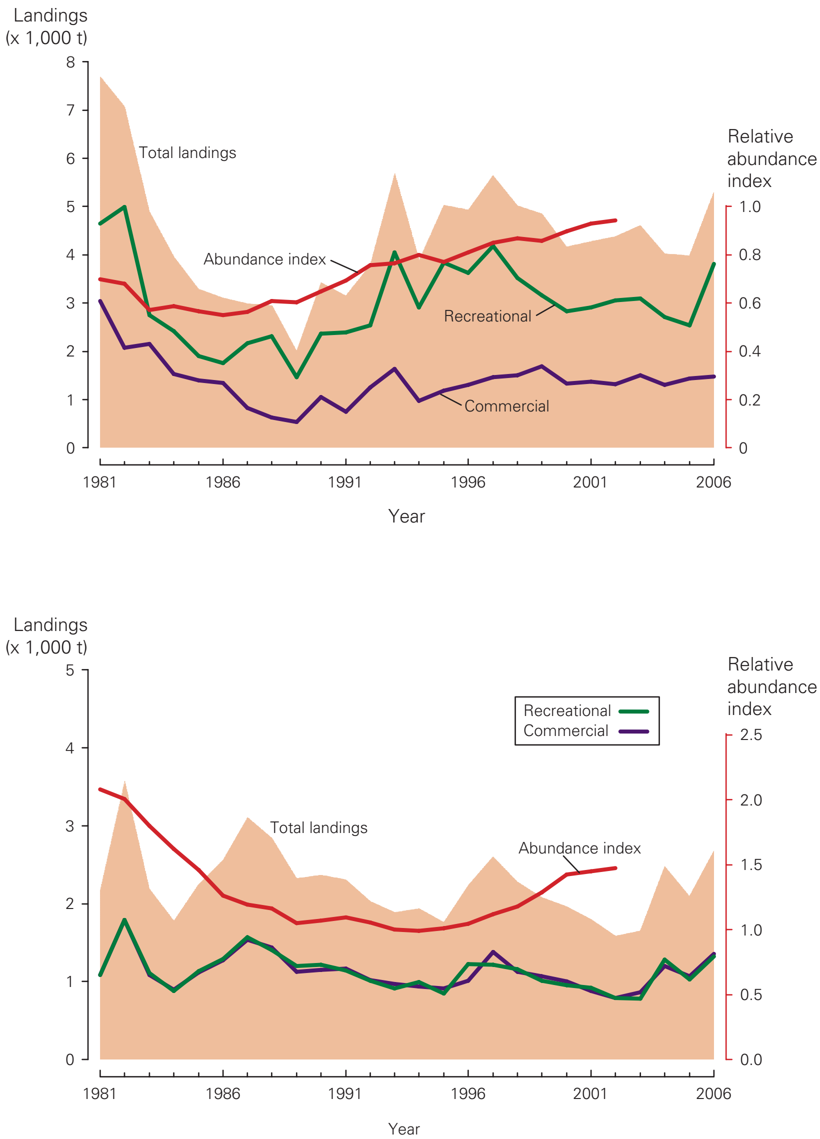

Figure 7-3

Landings in metric tons (t) and relative spawning stock size of king mackerel, 1981–2007 (data for 2007 are not final). Top, Gulf of Mexico group; bottom, South Atlantic group.

and additional information is needed to better quantify this source of mortality. A new assessment of the Atlantic stock of Spanish mackerel is underway and will be completed in 2008.

Gulf Spanish mackerel successfully recovered from an overfished status in 1995, following management regulations that began in 1987. The 2003 stock assessment of Gulf Spanish mackerel indicated that current fishing mortality on this stock is less than MFMT ($F_{30\%}$SPR), although there is also high uncertainty regarding the mortality associated with the Gulf shrimp fishery.

King Mackerel

The U.S. commercial fishery for king mackerel began in the 1880's off Chesapeake Bay and has since moved southward. There are four major production areas: 1) off North Carolina, 2) the Florida east coast (Cape Canaveral to Palm Beach), 3) the Florida Keys, and 4) off Grand Isle, Louisiana. The Louisiana fishery began in the early 1980's; this area harbors larger and older king mackerel (mainly females). Unrestricted high fishing mortality on these fishes from the late 1970's through the early 1980's quickly reduced the overall Gulf stock. Landings reached a peak of 7,600 t in 1981 in the Gulf, and 3,600 t in 1982 in the Atlantic (Figure 7-3). Since then, Gulf landings decreased to a minimum of 2,000 t in 1989, then recovered during the 1990's to about 4,500 t. In the Atlantic, landings decreased to a minimum of 1,600 t in 2002, then recovered to 2,600 t by 2006. King mackerel landings have been under a Federal quota management system since 1985.

Historically, the commercial king mackerel fisheries have utilized gillnets, troll lines, handlines, purse seines, otter trawls, and pound nets. In 1989, purse seines and drift gillnets were prohibited, and in 1996, all gillnets were prohibited in Florida state waters. Commercial yields remained unregulated until the mid 1980's. Recreational fisheries for king mackerel have been very popular in the Gulf and South Atlantic, with several tournaments targeting king mackerel since the 1960's. In fact, since 1981 recreational landings have consistently been greater than commercial landings. Recreational landings experienced large reductions during the 1980's, likely as a consequence of the expansion of the commercial runaround gillnets fishery during the 1970's and a driftnet fishery that operated off southeast Florida during the late 1980's. By 2006, recreational landings accounted for 70% of the total landings of king mackerel in the Gulf.

The Gulf king mackerel stock is believed to have a large MSY, but the stock was severely depleted until recent years (Figure 7-3, upper graph). According to the last stock assessment (2004), average annual production in the early 2000's was estimated at approximately 62% of the MSY level. It is believed that the major stock reductions during the late 1980's and early 1990's were due to excessive harvests in the late 1970's and early 1980's. Results from the 2004 stock assessment indicated that the Gulf stock had recovered and that overfishing was not occurring. However, these results should be viewed with caution. During the most recent years, recruitment was estimated to be higher than average, particularly for the 1999 and 2001 year-classes. As these year-classes move out of the fishery, future stock biomass levels could decline.

The Atlantic king mackerel stock is thought to be at or near its MSY. Catches have oscillated between 1,500 and 3,000 t since 1981 (Figure 7-3, lower graph); however, annual TAC's have not been reached in most recent years. Commercial and recreational landings show a similar degree of annual variability. Bycatch of Atlantic king mackerel in shrimp fisheries is assumed to be low, but it is recognized that the actual level has not been determined with either accuracy or precision. The results of the 2004 stock assessment of Atlantic king mackerel indicated that current harvest rates were below the MFMT, thus overfishing was not occurring. Spawning stock biomass was above the spawning biomass at MSY in 2003, indicating that the population was not overfished at that time. The next assessment of king mackerel stocks is scheduled to be finished by the end of 2008 (SEDAR 16).

Cobia

Cobia is primarily targeted by recreational anglers; commercial landings are on average 13% of the total annual landings (Figure 7-4). Current management regulations for cobia include minimum size, individual bag limits, and commercial trip limits (2 cobia per trip). For management and assessment purposes, it is assumed that two separate stock units of cobia exist: one in the Gulf of Mexico and another in the U.S. Atlantic. During 1981–2006, annual yields of Atlantic cobia have ranged from 13 to 700 t. Gulf cobia yields are generally larger, ranging from 300 to 1,110 t annually since 1981. Fishing mortality is assumed to be low for the Atlantic group, while in the Gulf, cobia are believed to be more heavily exploited.

The data needed to assess the population dynamics and stock status of cobia are scarce and limited. Therefore, the status of cobia stocks remains uncertain. The 1993–94 assessment estimated that the spawning stock biomass per recruit (SBR)[2] for Gulf cobia was between 20% and 45% of the maximum possible SBR, while, for the Atlantic group, SBR was estimated to be above 30% with low fishing mortality rates. The last stock assessment for Gulf cobia (2001) indicated that the population had increased since the 1980's, and that the Gulf stock was not overfished. The sustainable yield for Gulf cobia was set at 659 t.

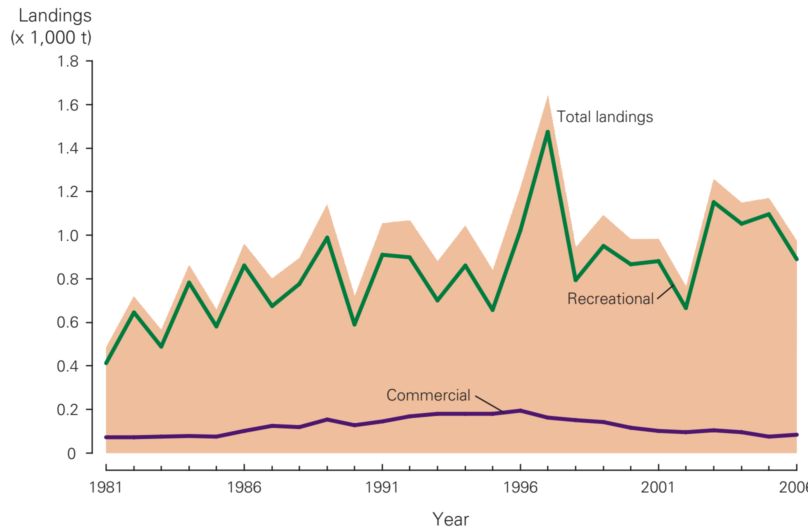

Figure 7-4
Landings in metric tons (t) of cobia, 1981–2006.

More information on biology and fisheries data are needed to assess the population structure and stock status of cobia in the Gulf and the Atlantic. This can be accomplished by increasing biological sampling of fish landed by the recreational and commercial fisheries, updating available reproductive information, and estimating the bycatch of cobia in other fisheries. In addition, more precise estimates of the natural mortality rate would improve assessment estimates of stock levels and maximum sustainable yield.

Dolphinfish

Dolphinfish are primarily landed by recreational anglers in the southeastern United States.

[2]SBR is the expected lifetime contribution to the spawning stock biomass for the average recruit, calculated by assuming that fishing mortality, natural mortality, and growth are constant over the lifespan of a year-class.

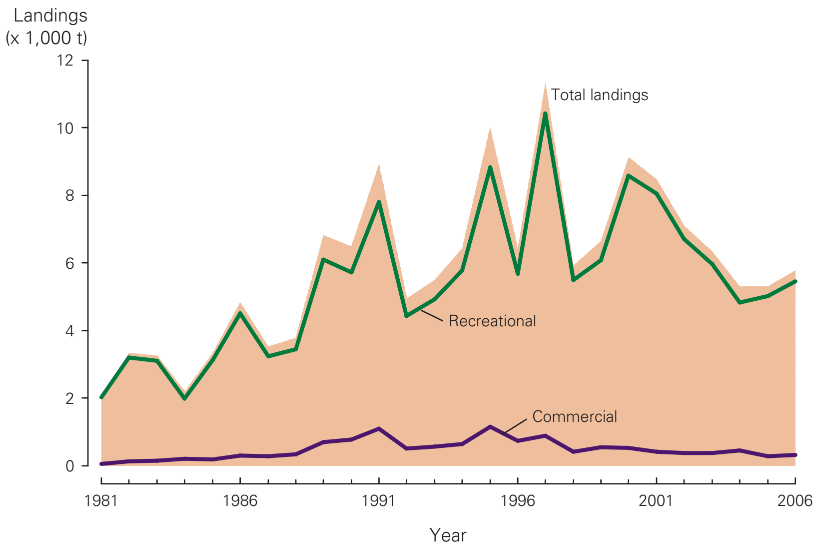

Figure 7-5

Landings in metric tons (t) of dolphinfish, 1981–2006.

During 1998–2006, recreational anglers landed, on average, 6,240 t (94%) while commercial fishermen landed 415 t (6%) of dolphinfish. Total landings increased from 2,100 t in 1981 to a peak of 11,300 t in 1997; by 2006 landings decreased to 5,800 t (Figure 7-5). The available information supports the hypothesis of a single stock across the Gulf of Mexico and the U.S. South Atlantic. Current stock status is difficult to quantify because comprehensive information for the total U.S. stock is limited. Stock assessment results in 2000 suggested some increase in stock size relative to previous estimates. Uncertainties in stock structure, the need to corroborate abundance trends, and the lack of mortality rates in recent years make it difficult to estimate the true current status of U.S. dolphinfish stocks. Research efforts should be focused on these areas. Also, because of the transnational migratory movements of this species, international cooperation between scientists is needed to further refine information on stock status.

Fishermen with their catch of king and Spanish mackerel from a charter boat trip out of Watson Island near Miami, Florida.

ISSUES

Stock Separation and Mixing Rates of King Mackerel

The stocks of Atlantic and Gulf king mackerel overlap during the winter months in the southeast Florida and Florida Keys region. Recent studies suggest that there is considerable mixing, but the proportion of effective emigration/immigration between stocks, and the contribution of each stock to regional landings during the mixing period, are still uncertain. Additional sampling and research are needed to better quantify the stock composition of king mackerel landed in the mixing region.

Transboundary Stocks

Effective management of migratory coastal pelagic species will continue to require the coordination of Federal and state regulatory agencies. Furthermore, king mackerel (and to some degree Spanish mackerel) in the western Gulf of Mexico migrate between Mexico and U.S. territorial waters. Assessing the magnitude of mixing between these transboundary stocks merits increased research efforts.

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Atlantic, Gulf of Mexico, and Caribbean Reef Fisheries

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Unit 8

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INTRODUCTION

Reef fishes include a variety of structure-associated species that reside on coral reefs, artificial structures, or other hard-bottom areas, and also tilefishes that live in muddy bottom and Continental Shelf areas. Reef fishes occur from Cape Hatteras, North Carolina, through the Gulf of Mexico and Caribbean Sea in depths ranging from ~2 m to more than 200 m. Reef fish fisheries are extremely diverse, vary greatly by location and species, and are utilized by commercial, artisanal, and recreational fisheries for food, commerce, sport, and trophies. These fisheries operate from charter boats, head boats, private boats, and the shore, while using gears such as fish traps, hook and line, longlines, spears, trammel nets, bang sticks, and barrier nets.

Reef fish fisheries are associated closely with fisheries for other reef animals, including spiny lobster, conch, stone crab, corals, and live rock and ornamental aquarium species (see Unit 11, Southeast and Caribbean Invertebrate Fisheries). Nonconsumptive uses of reef resources (e.g. ecotourism, sport diving, education, and scientific research) also are economically important and may conflict with traditional commercial and recreational fisheries. Although reef fishes have been caught for generations, dependable landings data for most areas did not begin to accrue until the late 1970's, when recreational fishing surveys were initiated. Fishery data collection remains difficult because there are diverse users and landings are made at many ports. Fishing pressure has increased over time along with growing human populations, greater demands for fishery products, and technological improvements

Photo above:
Bluestriped grunts peek out from the shelter of a coral reef.

Charles Gardner

Measuring a gray (mangrove) snapper during a NMFS Marine Recreational Fisheries Statistics Survey (MRFSS) in Florida.

(e.g. more efficient and less expensive gear, electronic fish finders, and navigational aids).

SPECIES AND STATUS

Although figures vary for individual species, reef fishes overall produce significant landings and values (Figures 8-1, 8-2, and 8-3). Recent average commercial and recreational catches (2004–06) for the U.S. Atlantic, Caribbean, and Gulf of Mexico have been about 24,253 metric tons (t) annually (Table 8-1), with dockside ex-vessel commercial revenue of $68,124,000. In the U.S. South Atlantic and Gulf of Mexico, sport anglers make more than 20,000,000 angler-trips per year.

Many reef fishes are vulnerable to overfishing due to life-history characteristics such as slow growth, late maturity, ease of capture, large body size, and other factors. Many stocks with known status are currently considered overfished (Table 8-1). In most cases, the current and maximum sustainable yields are unknown, though for many species they are probably higher than current recent average yields would indicate due to overfishing (Table 8-1).

The South Atlantic Fishery Management Council (SAFMC), the Gulf of Mexico Fishery Management Council (GMFMC), and the Caribbean Fishery Management Council (CFMC) manage reef fish fisheries in the Southeast Region occurring within the U.S. Exclusive Economic Zone (EEZ; seaward of territorial waters out to 200 miles from shore). These three Councils have developed Fishery Management Plans (FMP) for reef fish fisheries that include a combined total of 117 reef fishes (excluding fish species collected for the marine aquarium trade). The territorial waters are managed by the eight coastal states of the region, the U.S. Virgin Islands, and the Commonwealth of Puerto Rico.

In the Gulf of Mexico, the Reef Fish Resources of the Gulf of Mexico FMP and its amendments contain numerous management measures for the 42 reef fish species within the management unit. These measures include the prohibition of fish traps, roller trawls, and powerheads on spearguns within designated stressed areas; minimum size and bag limits on many reef fishes; and data reporting requirements. For example, during 2008 there was a two-fish recreational daily bag limit for red snapper with a 1,111 t annual quota, and a com-

Table 8-1

Productivity in metric tons (t) and status of Atlantic, Gulf of Mexico, and Caribbean reef fish fisheries resources.

Species/stock	Recent average yield (RAY)[1]	Current yield (CY)[2]	Sustainable yield (MSY)[2]	Stock level relative to B_{MSY}	Harvest rate	Stock status
South Atlantic						
Black sea bass	770	719	1,730	Below	Overfishing	Overfished
Gag	491	727	Unknown	Unknown	Overfishing	Appr. overfished
Goliath grouper[3,4]	0	0	Unknown	Below		
Nassau grouper[3]	0	0	Unknown	Below	Not overfishing	Unknown
Red porgy	47	Unknown	450	Below	Not overfishing	Overfished
Red snapper	146	Unknown	Unknown	Unknown	Overfishing	Unknown
Snowy grouper	130	124	142	Below	Overfishing	Overfished
Tilefish	215	134	153	Near	Overfishing	Not overfished
Vermilion snapper	571	Unknown	Unknown	Unknown	Overfishing	Unknown
Wreckfish	71	Unknown	Unknown	Unknown	Not overfishing	Unknown
Amberjacks[5]	382	Unknown	Unknown	Unknown		
Grunts[5]	226	Unknown	Unknown	Unknown		
Other groupers[5,6,7]	489	Unknown	Unknown	Below		
Other porgies[5]	989	Unknown	Unknown	Unknown		
Other sea basses[5]	2	Unknown	Unknown	Unknown		
Other snappers[5]	606	Unknown	Unknown	Unknown		
Other species[5]	1,007	Unknown	Unknown	Unknown		
Subtotal, South Atlantic	6,142	6,420	7,691			
Caribbean						
Nassau grouper[3]	0	Unknown	Unknown	Below	Overfishing	Overfished
Grunts	70	Unknown	Unknown	Unknown	Unknown	Unknown
Other groupers[5,6,7]	69	Unknown	Unknown	Unknown		
Snappers[5,6]	363	Unknown	Unknown	Unknown		
Other species[5,6]	432	Unknown	Unknown	Unknown		
Subtotal, Caribbean	934	934	934			
Gulf of Mexico						
Goliath grouper[3]	0	0	Unknown	Unknown		
Nassau grouper[3]	0	0	Unknown	Unknown	Not overfishing	Undefined
Red grouper	3,769	Unknown	Unknown	Unknown	Not overfishing	Not overfished
Red snapper	3,657	2,722	15,000	Below	Overfishing	Overfished
Vermilion snapper	1,069	Unknown	Unknown	Unknown	Not overfishing	Not overfished
Gray triggerfish	285	Unknown	Unknown	Unknown	Overfishing	Undefined
Amberjacks[5,6,7]	1,403	Unknown	Unknown	Unknown		
Shallow groupers[5]	2,940	Unknown	Unknown	Unknown		
Other groupers[5]	695	Unknown	Unknown	Unknown		
Other snappers[5]	2,144	Unknown	Unknown	Unknown		
Other species[5]	1,215	Unknown	Unknown	Unknown		
Subtotal, Gulf of Mexico	17,177	16,242	28,520			
Total	24,253	23,416	37,145			

[1]2004–06 average.

[2]CY is overestimated, and MSY is probably greatly underestimated; although potential production estimates are not available for most species groups, many are probably overfished.

[3]A total fishing prohibition has been imposed on these species in all Federal waters, state waters of the South Atlantic and Gulf of Mexico, and territorial waters of the U.S. Virgin Islands.

[4]Status determinations for goliath grouper are for the South Atlantic and Gulf of Mexico combined; the stock is not overfishing and stock status is unknown.

[5]Harvest rate and stock status are not available for this stock.

[6]This multispecies stock grouping contains at least one species that individually is considered to be overfishing.

[7]This multispecies stock grouping contains at least one species that individually is considered to be overfished.

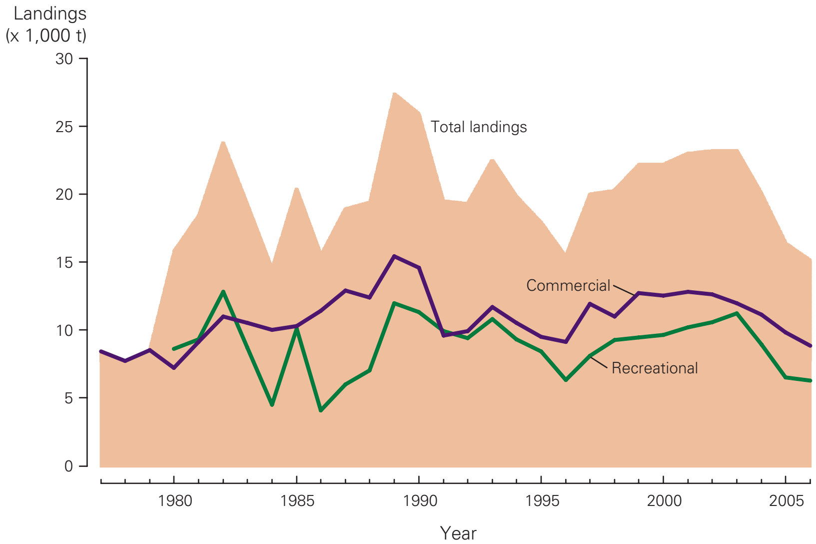


Figure 8-1
Gulf of Mexico reef fish landings in metric tons (t), 1977–2006.

mercial annual quota of 1,157 t. For grouper, a five-fish recreational daily bag limit (one fish for red grouper) and 3,992 t shallow-water and 463 t deepwater commercial quotas were established. Other FMP regulations include a ban on the harvest of goliath and Nassau groupers, a framework procedure for establishing total allowable catches and allowing the target date for rebuilding to be changed depending on scientific information, and a revised target year of 2032 for rebuilding the red snapper stock. In 1992, a moratorium on issuing new commercial reef fish permits was established. Marine protected areas (MPA's) closed to fishing have been established in three areas near the Dry Tortugas (off south Florida) and in two areas off west-central Florida (the Madison-Swanson and Steamboat Lumps Marine Reserves).

In the southern U.S. Atlantic, the Snapper–Grouper Fishery of the South Atlantic Region FMP emphasizes minimum size limits, bag limits, and commercial fishing quotas. A total of 73 reef fishes are included in the snapper–grouper complex. Because of its mixed-species nature, this fishery is challenging to manage. Through the original FMP and subsequent amendments, the Council has addressed overcapacity, implemented measures to rebuild overfished species, and is moving forward with the use of MPA's as a management tool for deepwater species. Various gears are restricted, including a prohibition of roller trawls and fish traps (except sea bass traps). Strict management measures, including prohibition of harvest in some cases, have been implemented to rebuild overfished species in the snapper–grouper complex. For example, both goliath grouper (since 1990) and Nassau grouper (since 1992) are protected from harvest, and strict limits have been implemented for speckled hind and warsaw grouper. Additional restrictions on commercial and recreational fishing have been enacted for designated special management zones.

In the U.S. Caribbean, the Reef Fish Fishery of Puerto Rico and the U.S. Virgin Islands FMP establishes regulations to rebuild declining reef fish stocks in the EEZ and reduce conflicts among users. In this fishery management unit there are 79 reef fish species harvested for human consumption, plus an additional 60 species collected for the aquarium trade only. Regulatory management measures include those that define criteria for the construction of fish traps and requirements for owner identification and the marking of gear and boats; prohibit hauling or tampering with another person's traps without the owner's written consent; prohibit the use of poisons, drugs, other chemicals, and explosives for the taking of reef fish; and establish minimum size and bag limits for multiple species of reef fish. Many species of reef fish in

Florida Keys National Marine Sanctuary

Yellowtail snapper in front of a sea fan.

William B. Folsom, NMFS

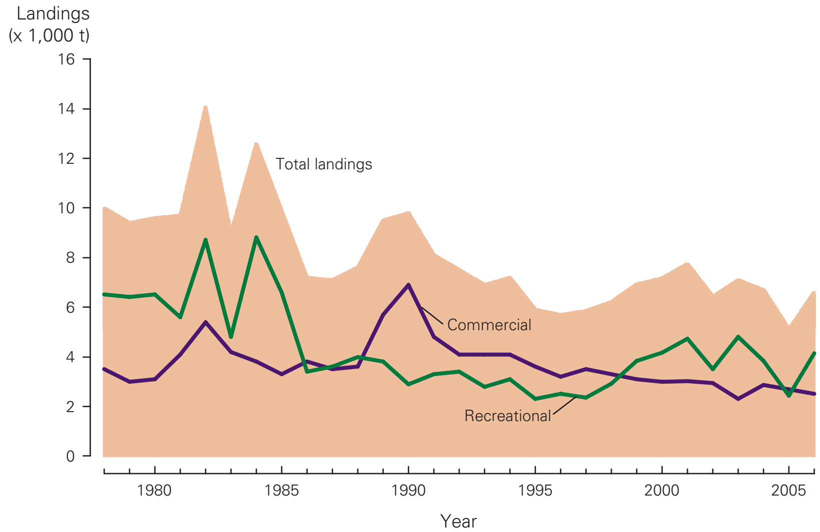


Figure 8-2
South Atlantic reef fish landings in metric tons (t), 1978–2006.

Puerto Rico and the U.S. Virgin Islands are believed to be overexploited, largely due to trap fishing and bycatch associated with this fishery.

ISSUES

Fishing Impacts, Trophic Interactions, and Bycatch

Fishing may have direct and indirect effects on reef fish ecosystem structure and production. Removals of apex predators from the reef complex may result in shifts of species composition (i.e. trophic and ecological cascades), increased variability in population dynamics of targeted species, and potential evolutionary effects on targeted species. Bycatch (non-targeted catch) increases mortality rates for non-targeted species. For example, juvenile red snapper are caught in nearshore shrimp trawls in the Gulf of Mexico region, resulting in increased red snapper mortality and, subsequently, decreased numbers of adults available for harvest by commercial and recreational fisheries. For species caught and released alive, post-release mortality may affect stock production levels.

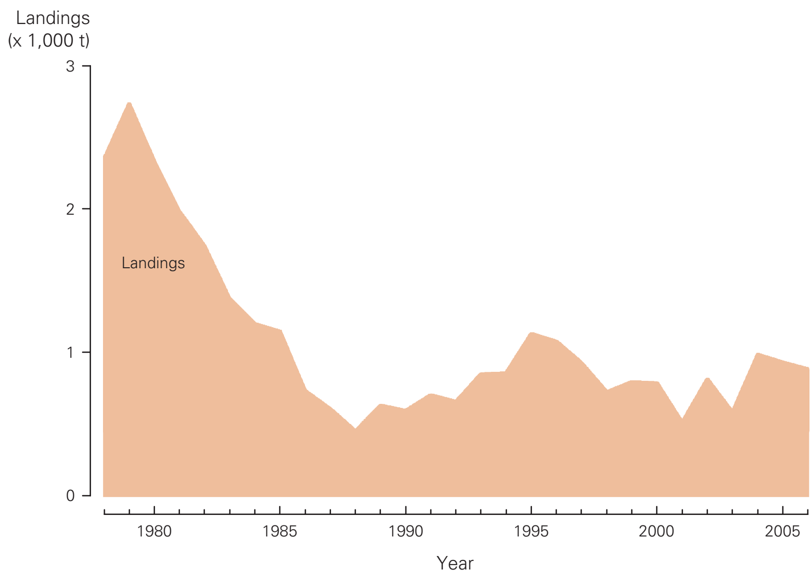
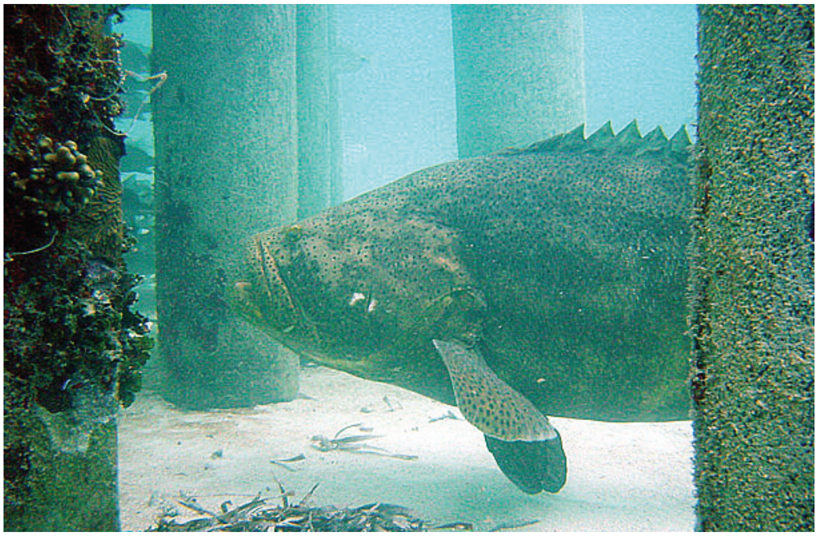


Figure 8-3
Caribbean reef fish landings in metric tons (t), 1978–2006.

Scientific Information and Adequacy of Stock Assessments

There are a number of important issues that need to be addressed to improve scientific advice for management. For all species, additional or improved fishery-dependent and fishery-independent data would improve the accuracy of statistical models used in stock assessments. For many species,

Photo, above left:
A catch of snapper from the small-boat fishing fleet in Municio de Rincon, Puerto Rico.



SEFSC

A large goliath grouper swims between pier pilings. Fishing on this species is prohibited in the EEZ and state/territorial waters except off Puerto Rico to allow the species to recover from past overfishing.

insufficient data exist to perform stock assessments. Additional life history and biological data are also needed for many species. Additionally, information on species interactions (e.g. predator–prey dynamics) will be necessary to guide multispecies assessments and facilitate the movement toward ecosystem management.

Allocation

A wide range of stakeholders utilizes reef fish resources, and conflicts may arise between commercial and recreational fishers and other users such as ecotourists. Balancing the competing interests of these user groups is an important management issue.

Progress

Stock rebuilding plans are in effect for all reef fish species classified as overfished or experiencing overfishing. Some overfished reef fishes (e.g. goliath grouper) are undergoing apparent significant increases in abundance. Increased awareness and public interest in conservation of marine resources have led to the establishment of a number of marine protected areas in which harvest of all marine organisms is prohibited.

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Southeast Drum and Croaker Fisheries

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INTRODUCTION

Important recreational and commercial species in the family Sciaenidae (drums and croakers) include the Atlantic croaker, spot, red drum, black drum, kingfishes (whiting), weakfish (grey seatrout), spotted seatrout, and other seatrouts. These species are all bottom-dwelling carnivores that feed on benthic invertebrates and small fishes. Sciaenids have constituted an important fishery resource since the late 1800's, although significant increases in commercial landings did not occur until the 1950's, when the pet food industry began harvesting them in the northern Gulf of Mexico. The recreational harvest of Sciaenids in the Gulf of Mexico and Atlantic Ocean has generally been similar to commercial landings in weight (Figure 9-1). Some stocks occur primarily within state jurisdiction (generally 0–3 n.mi.) and are managed by state authorities and the interstate fishing commissions; other stocks are managed jointly by the interstate fishing commissions and the regional fishery management councils. Most recreational fishing occurs within state waters and is managed primarily by the coastal states. Regulations heavily favoring recreational use of Sciaenids have been established in some states, including the declaration of some species (red drum and spotted seatrout) as game fish species, prohibiting commercial fishing. The recent average annual yield of Sciaenids in the Southeast Region is estimated at almost 41,000 metric tons (t; Table 9-1).

Large numbers of Sciaenids are caught and killed as an incidental catch in Southeast shrimp fisheries. The small mesh used in shrimp trawls can catch nontarget species such as sea turtles, red

Photo above:
Juvenile Atlantic croaker, spot, other Sciaenids, and other species in the bycatch from a shrimp trawl.

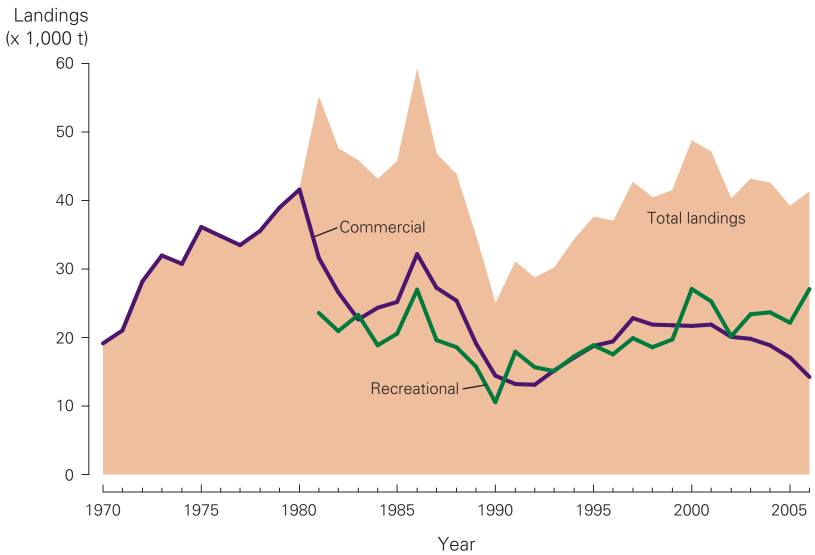


Figure 9-1

Southeast Sciaenid landings in metric tons (t), 1970–2006.

snappers, croakers, seatrouts, and other species. Sciaenids constitute the bulk of the finfish bycatch biomass. Much of this bycatch is juveniles, and mortality resulting from incidental take may slow the recovery of overfished stocks or otherwise prevent full use of the recruited adult population.

SPECIES AND STATUS

Commercial landings of drums and croakers in the northern Gulf of Mexico rose sharply in 1956 to over 32,000 t, more than 20,000 t above that of 1953. The catch consisted mainly of Atlantic croaker and sand and silver seatrouts, which made up about 76%. This increase for the most part resulted from a developing demand for Sciaenids as raw material in the production of canned pet foods.

Atlantic Croaker

As one of the most abundant fishes along the U.S. Atlantic coast, Atlantic croaker are popular in both commercial and recreational fisheries. Although they are found in coastal waters from the Gulf of Maine south to Argentina, croaker fisheries occur mainly off Maryland through North Carolina. The annual recruitment for Atlantic croaker is highly variable and can fluctuate with environmental conditions. Because of this, commercial landings tend to be cyclical and range between approximately 1,100 and 15,500 t annually. Landings have been near the high end of the cycle since 1996; the commercial catch in 2006 was 9,460 t. The available time series of recreational

Table 9-1

Productivity in metric tons (t) and status of southeast drum and croaker fisheries resources.

Species/stock	Recent average yield (RAY)[1]	Current yield (CY)[2]	Sustainable yield (MSY)[2]	Stock level relative to B_{MSY}	Harvest rate	Stock status
Atlantic croaker[3]	15,224	Unknown	50,000	Below		
Black drum[4]	4,079	Unknown	Unknown	Unknown		
Kingfishes (whiting)[4]	2,039	Unknown	Unknown	Unknown		
Red drum[5]						
Atlantic	709	Unknown	Unknown	Below	Overfishing	Unknown
Gulf of Mexico	5,869	Unknown	7,900	Below	Not overfishing	Undefined
Seatrouts[6]	9,002	Unknown	Unknown	Variable		
Spot	4,072	Unknown	Unknown	Unknown	Unknown	Unknown
Total	40,994					

[1]2004–06 average.

[2]MSY is probably underestimated and CY overestimated; although potential production estimates are not available for some species groups, it is expected that they may be overfished.

[3]Status determinations are made for two separate stocks of Atlantic croaker: the Mid-Atlantic stock is not overfishing and not overfished; the harvest rate and stock status of the South Atlantic stock are both unknown.

[4]Harvest rate and stock status are not available for this stock.

[5]Gulf of Mexico red drum were last assessed in 1999 and Atlantic red drum were last assessed in 2000.

[6]Status determinations are not available for this stock grouping. The most recent assessment of weakfish (grey seatrout) in 2002 showed that the stock had recovered and was no longer overfished. However, the population abundance is believed to have declined precipitously in recent years and is now classified as unknown. The status of other species in this group is unknown as well.

landings goes back only as far as 1981, but shows a similar trend (steadily increasing since the early 1990's, with current levels at about 4,000 t). The recent average yield (2004–06; commercial and recreational landings) of Atlantic croaker is 15,224 t (Table 9-1). Although the stock status is unknown, the current stock biomass is estimated to be below the level required to produce the maximum sustainable yield (MSY).

The Atlantic States Marine Fisheries Commission (ASMFC) approved the Fishery Management Plan (FMP) for Atlantic croaker in 1987. This plan addressed the lack of data available for stock assessments, as well as the serious issue of bycatch of Atlantic croaker in other fisheries (particularly in the shrimp trawl fishery). In 1994, ASMFC determined that the FMP lacked the clearly defined recommendations necessary to meet its goals. Amendment 1 was prepared in response and later approved in November 2005. In addition to revising the management goals and objectives, the amendment also establishes biological reference points and provides for the development of separate management measures for the Mid-Atlantic and South Atlantic stock components.

Spot

The recent average yield (2004–06) of spot is 4,072 t (Table 9-1), divided evenly between commercial landings and recreational catches. The commercial fishery peaked at 6,600 t in 1952, and landings have generally fluctuated between 2,000 and 5,000 t since. Annual fluctuations in landings are normal because spot are a short-lived species, the catch is composed mainly of a single year-class, and stock abundance is largely determined by environmental conditions. No formal coast-wide spot assessment has ever been conducted, and its stock status is currently unknown.

The ASMFC and the South Atlantic Fishery Management Council (SAFMC) cooperatively manage spot. In 1987, the FMP for Spot addressed the lack of biological and fisheries data necessary for management of the resource. Currently, management is primarily through minimum size limits administered by the Atlantic coastal states. Progress has also been made in reducing the impact of spot bycatch in the shrimp trawl fishery.

Charles Gardner

A young angler displays her red drum catch in Florida.

Red Drum

Red drum are one of the most popular recreational fish species in the Southeast Region. Recreational anglers catch red drum mainly in nearshore (state) waters; most of this nearshore catch is composed of juveniles. Since the 1980's, recreational landings have accounted for approximately 90% of the total catch (ASMFC, n.d.). State management actions have heavily favored recreational use of the red drum resource; North Carolina and Virginia are currently the only states that allow commercial fishing for red drum.

Commercial landings of red drum increased rapidly in the mid 1980's, when public popularity and market demand suddenly grew for a new seafood preparation called blackened redfish. To supply this demand, a red drum purse-seine fishery primarily targeting the offshore adult spawning stock evolved in the Gulf of Mexico. As the offshore purse-seine fishery developed it became clear that the schooling adults were extremely vulnerable to overexploitation, thus jeopardizing recruitment in subsequent years.

Fishery analyses showed that maintaining the maximum sustainable yield depended in large part on limiting the harvest of adult red drum from offshore waters, as well as limiting the take of smaller individuals in inshore waters by both recreational and commercial fishermen (Goodyear, 1996; Porch, 2000). These conservation measures were

Tom McIlwain

Catch of red drum from a recreational charter boat in Mississippi.

established by FMP's developed and implemented first in the Gulf of Mexico and later in the U.S. Atlantic. The FMP for the Red Drum Fishery of the Gulf of Mexico (administered by the Gulf of Mexico Fishery Management Council [GMFMC]), was followed by the Atlantic Coast Red Drum FMP (administered by the SAFMC). Both ban red drum fishing within Federal jurisdiction of the U.S. Exclusive Economic Zone (EEZ; generally 3–200 n.mi. off the shore) until the adult population has sufficiently increased in abundance. Because state management actions have preserved inshore harvests, they have in effect barred the development of another adult red drum fishery in Federal waters.

The ASMFC and SAFMC are responsible for jointly managing the red drum fishery resource on the Atlantic coast, where the recent average yield (2004–06) is 709 t. The stock status of red drum on the Atlantic coast is unknown, and the stock level is below the MSY level (Vaughan and Carmichael, 2000), although significant population increases have been seen over the past decade. Major concerns remain over poor recruitment to the spawning stock due to heavy fishing pressure on juveniles in state waters. Because data on the adult population are very limited, scientists are not able to accurately assess its status and the state fishery is managed to ensure that a certain percentage of juvenile females survive to reproduce (referred to as spawning potential ratio or SPR). Amendment 2 to the Atlantic Coast Red Drum FMP was approved in June 2002 and established several measures, including bag and size limits for recreational fisheries. The Amendment also requires management actions to achieve and maintain a SPR of at least 40%. A new stock assessment is scheduled for 2009 to check the effect of the management measures implemented in Amendment 2.

The GMFMC and various state agencies are responsible for managing red drum in the Gulf of Mexico. The recent average yield (2004–06) of red drum is 5,869 t, a level substantially higher than landings on the Atlantic coast (Table 9-1). The status of the Gulf stock is undefined, although the stock level is thought to be below the level necessary to produce MSY. The absence of an offshore fishery, size limits, bag limits, and increased catch-and-release by conservation-oriented anglers are all expected to help rebuild the red drum spawning stock and reduce overall mortality in the Gulf of Mexico. Current statistics indicate that such conservation measures are having this desired effect in some areas.

Black Drum

Black drum are found mainly within state waters in the Southeast Region and are managed primarily by the Gulf States Marine Fisheries Commission (GSMFC). The species was generally considered undesirable and was underutilized until the late 1970's and early 1980's, when demand grew because black drum could be substituted for red drum in restaurants as blackened fish. The demand for black drum has dropped since 1988 and it is currently a relatively low-value species (GSMFC 2005). The recent average annual yield of black drum is 4,079 t (Table 9-1).

Weakfish

Weakfish (grey seatrout) have supported coastal fisheries since the 1800's. They are found along the entire U.S. Atlantic coast, but are most common from New York through North Carolina. Tremendous growth in commercial fisheries began in the early 1970's and continued until 1980, when annual landings reached a peak of 16,000 t. Since then, commercial landings have steadily declined to 482 t in 2006. Recreational catches of weakfish have exhibited a similar decline and are currently about equal to the commercial catch (417 t). The ASMFC is the primary management authority for weakfish. In 1996, Amendment 3 to the Weakfish

FMP was approved and a subsequent assessment indicated that the measures imposed led to significant declines in fishing mortality and increases in recruitment and the spawning stock biomass. These developments moved the stock status from overfished to recovered. In November 2002, Amendment 4 was approved and established assessment benchmarks for fishing mortality (*F*) and spawning stock biomass (SSB), further improving management of weakfish. However, some important concerns regarding weakfish stock assessments were identified during an external peer review in 2006 and the stock status is currently unknown; a new peer-reviewed assessment is scheduled for 2009.

Spotted Seatrout

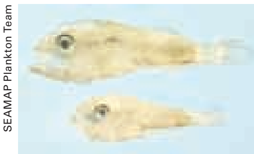
Abundant from Chesapeake Bay southward, spotted seatrout are a highly popular and sought-after gamefish. In the Gulf of Mexico, landings are almost exclusively in state waters and management is coordinated through the GSMFC. Some states have declared spotted seatrout a gamefish (banning all commercial fishing), while other states still allow limited commercial harvests. On the Atlantic Coast, management actions are administered jointly by the ASMFC and SAFMC. Declines in spotted seatrout abundance have been seen in South Atlantic waters in recent years; such declines are the combined result of habitat loss due to increased coastal development and heavy fishing pressures. Recreational landings have been substantially larger than commercial landings for the past 20 years and have increased since 1996 (ASMFC, n.d.). However, the number of spotted seatrout released annually by conservation-oriented anglers has also increased since 1998. Although the collection of data on catch and effort has improved since the Spotted Seatrout FMP was approved by the ASMFC in 1984, more accurate data is still needed to support a coast-wide stock assessment.

ISSUES

Bycatch

Bycatch of Sciaenids in other fisheries, particularly in the southeast shrimp fishery, has a significant impact on their status. Large numbers of small Atlantic croaker, spot, and seatrout are caught and discarded dead from shrimp trawls. It is estimated that as many as 500 million spot, 1 billion seatrout, and 7.5 billion Atlantic croaker are discarded annually. These species constitute the bulk of the finfish bycatch (Atlantic croaker alone make up about 10%), which averaged about 175,000 t per year during the 1980's. The National Marine Fisheries Service continues to actively work with the fishing industry to develop and test gear designs that will reduce bycatch levels without being prohibitively expensive to the fishing industry. Cooperative efforts have developed bycatch reduction devices for shrimp trawls, which can reduce the amount of bycatch by as much as 50 to 75%. Use of these types of gear modifications have become more popular as the cost has fallen and the devices have become easier to use. Shrimp management regulations currently require the use of bycatch reduction devices, and shrimpers throughout the South Atlantic use them. Widespread use of such devices has contributed to the rebound of some overfished stocks, such as weakfish.

SEAMAP Plankton Team



Two red drum larvae collected by researchers at the Southeast Fisheries Science Center.

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Southeast Menhaden Fisheries

Allen Shimada, NMFS

Unit 10

DOUGLAS S. VAUGHAN
JOSEPH W. SMITH

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Photo above: Menhaden boats heading out for a day of fishing in Moss Point, Mississippi.

INTRODUCTION

Menhaden are a herring-like fish found in coastal and estuarine waters of the U.S. Atlantic and Gulf of Mexico. They form large schools at the surface, which are located by aircraft and harvested by purse seines to produce fishmeal, fish oil, and fish solubles[1] (a reduction fishery). An active bait-fish fishery along the Atlantic coast, primarily located in Virginia and New Jersey, harvests about 15–20% of the amount landed by the industrial fishery. These fisheries are managed by individual coastal states, with interstate coordination handled through the Atlantic States Marine Fisheries Commission (ASMFC) and the Gulf States Marine Fisheries Commission (GSMFC). Menhaden are prey for many fishes, marine mammals, and sea birds, and form an important component of coastal ecosystems.

In the Atlantic area, the menhaden resource is near fully utilized, with a maximum sustainable yield of 264,000 metric tons (t) per year and a recent average annual yield (2004–06) for the reduction and bait fisheries of 196,000 t (Table 10-1). In the Gulf of Mexico, the menhaden resource is near fully utilized, with a maximum sustainable yield of 645,000 t and a recent average yield for the reduction fishery of 456,000 t.

SPECIES AND STATUS

Atlantic Menhaden

Atlantic menhaden range from West Palm Beach, Florida, north to Nova Scotia, Canada. As coastal waters warm in April and May, large surface

[1]Fish solubles are the heavier components of the liquid that is pressed from cooked fish while making fishmeal; the lighter portion of the liquid is fish oil. The solubles are boiled down to a thick solution that is sold as fish emulsion and used in pet food as flavoring, in animal feed as added protein, and in fertilizer.

Table 10-1
Productivity in metric tons (t) and status of southeast menhaden fishery resources.

Species/Stock	Recent average yield (RAY)[1]	Current yield (CY)[1]	Sustainable yield (MSY)[2]	Stock level relative to B_{MSY}[3]	Harvest rate	Stock status
Atlantic menhaden	196,000	196,000	264,000	Above	Not overfishing	Not overfished
Gulf menhaden[4]	456,000	456,000	645,000	Unknown		
Total	652,000	652,000	909,000			

[1]2004–06 average; includes reduction fishery landings only for gulf menhaden, and both reduction and bait landings for Atlantic menhaden.
[2]MSY is based on the yield per recruit at *F*-threshold times median recruitment.
[3]Stock level criteria are based on terminal population fecundity relative to target fecundity.
[4]Harvest rate and stock status are not available for this stock. Benchmarks for gulf menhaden have been developed similar to Atlantic menhaden (Vaughan et al., 2007); these benchmarks have been recommended but not yet adopted by the GSMFC. Status relative to the proposed benchmarks is not overfishing and not overfished.

schools form along the coasts of Florida, Georgia, and the Carolinas. The schools move slowly northward, stratifying by age and size during summer, with the older and larger fish generally moving farther north. The southward migration begins in early fall with surface schools disappearing in late December or early January off the Carolinas. Atlantic menhaden may live up to 10 years, but most fish caught are age 3 or younger.

Menhaden reduction landings rose during the 1940's and early 1950's, peaking at 712,100 t in 1956 (Figure 10-1). Landings remained high during the late 1950's and early 1960's, dropped precipitously during the mid 1960's and remained low, bottoming out at 161,600 t in 1969. Through the 1970's and 1980's, landings improved, but not to the levels of the late 1950's. Landings peaked again in 1983 at 418,600 t. Landings during 1990–98 averaged about 311,000 t annually. Beginning in 1998 the industry underwent considerable consolidation until only two factories (one in Reedville, VA, and one in Beaufort, NC) and 12 vessels were active on the Atlantic coast in 2000. Correspondingly, reduction landings in 2002 and 2003 declined to 174,000 t and 166,100 t, respectively. After the 2004 fishing season, the factory in Beaufort closed; since 2005 the factory in Reedville, VA, with 10 vessels, has been the only reduction facility active on the Atlantic coast. Reduction landings in 2007 amounted to 174,500 t. The commercial ex-vessel revenue of Atlantic menhaden for 2004–06 averaged $27.3 million per year.

Joseph W. Smith, NMFS

Menhaden catch is concentrated or "hardened" in the bunt of the purse seine and pumped aboard the carrier vessel through a large hose.

The decline in stock biomass in the 1960's resulted from poor recruitment during a period of initially high spawning stock. This decline drove fishing effort southward to Virginia and North Carolina, and more recently concentrated effort in Chesapeake Bay (Smith, 1999). During the 1990's, spawning stock biomass increased following good-to-excellent survival of recruits during the 1970's and 1980's. While spawning stock biomass recently peaked in 1997 at about 130,800 t, recruitment of age-1 fish has declined over the last decade to recent lows. Recruitment of age-0 Atlantic menhaden appears to have improved during odd years from 1999 to 2005, with the 2005 year-class contributing substantially to the reduction catch as age-1 and age-2 fish during 2006 and 2007, respectively. Moreover, adult Atlantic menhaden have been abundant in the coastal waters of southern New England during the summers of 2005–07, suggesting that the stock is expanding once again toward the northern half of its range.

Concern over recent poor recruitment (especially from Chesapeake Bay) and heightened interest in the ecological role of menhaden led to development of an Amendment to the Fishery Management Plan (FMP) for Atlantic Menhaden (ASMFC, 2001). The Amendment provided managers with two benchmark variables: fishing mortality (F), and spawning stock biomass (SSB). Exceeding pre-specified levels of these benchmark variables determines the need for specific management actions. In 2003, the stock assessment for Atlantic menhaden underwent a peer review process, SouthEast Data Assessment and Review, or SEDAR (ASMFC, 2004). In early 2004, the Atlantic Menhaden Plan Development Team recommended changing the second management benchmark to address population fecundity; later that year the ASMFC adopted an Addendum to the FMP.

Gulf of Mexico Menhaden

Gulf menhaden are found from Mexico's Yucatán Peninsula to Tampa Bay, Florida. They form large surface schools that appear in nearshore Gulf waters from April to November. Although no extensive coastwide migrations are known, some evidence suggests that older fish move toward the Mississippi River delta. Gulf menhaden may live to age 5, but most of those landed are ages 1 and 2. In 2007, active gulf menhaden reduction plants were located in Moss Point, Mississippi, and in Empire, Intracoastal City, and Cameron, Louisiana.

Historically, landings rose after World War II to a peak of 982,800 t in 1984 (Figure 10-1). Landings were generally high during the mid 1980's (greater than 800,000 t for 1982–87), but they declined steeply from 894,200 t to 421,400 t between 1987 and 1992. During this period (1987–92), the number of processing plants declined from 8 to 6 and the number of active vessels fell from 75 to 51. Landings in 1994 of 761,600 t were the greatest during the 1990's. Since 2000, only 4 processing plants operated on the Gulf, with about 40 vessels. Landings during 2004–06 averaged 456,000 t annually. Landings in 2007 amounted to 453,800 t. In 2005, Hurricanes Katrina and Rita did considerable damage to the four gulf menhaden reduction factories; two closed after the storms for the remainder of the fishing season, and faced major difficulties re-opening in 2006. The commercial ex-vessel revenue of Gulf menhaden for 2004–06 averaged $39.7 million/year.

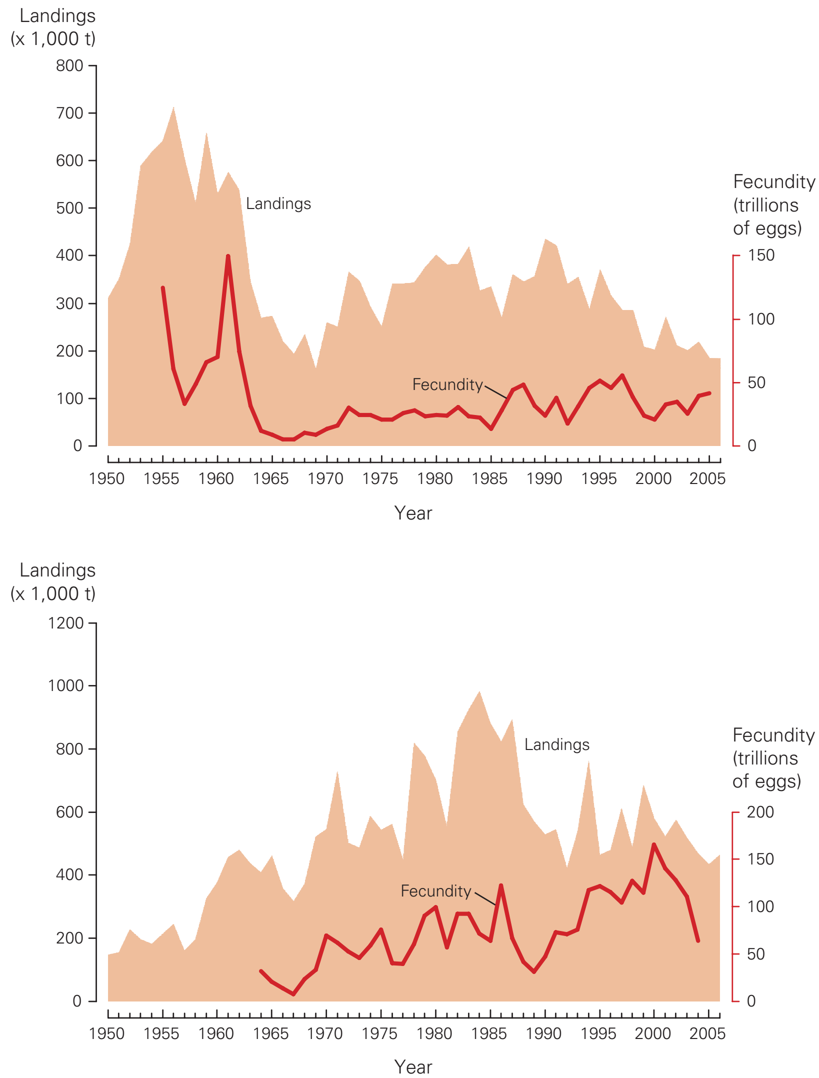


Figure 10-1

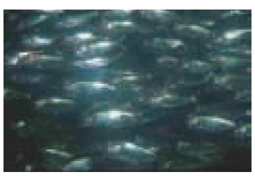
Landings in metric tons (t) and fecundity of menhaden, 1950–2006. Top, Atlantic (includes both reduction and bait fishery landings); bottom, Gulf of Mexico (includes only reduction landings).

Because Gulf menhaden have a short life cycle and a high natural mortality, growth overfishing has not been a management concern. Management is coordinated through the GSMFC, and consists of an approximate 28-week fishing season (mid April through 1 November) and closure of inside waters across the northern Gulf of Mexico. The Gulf Menhaden FMP was revised and adopted in 2002 (GSMFC, 2002). An updated stock assessment for Gulf menhaden (using data through 2004) has recently been completed (Vaughan et al., 2007). Suggested benchmarks for management of the fishery are similar to those for Atlantic menhaden (*F* and population fecundity).

ISSUES

Management Concerns

The primary concern for the Atlantic menhaden stock is a decline in recruitment noted since 1989 (1988 year-class) to low levels through 2003. This is considered in context with relatively high population fecundity during this period. Poor recruitment through the 1990's, with high spawning, suggests an underlying environmental problem (e.g. predation, water quality, etc.), rather than overfishing. Additionally, the need for multispecies management has been raised. In August 2006, ASMFC approved Addendum III of the Atlantic menhaden FMP, which capped annual removals of menhaden for reduction from Chesapeake Bay at 109,020 t for 5 years (2006–10) with provisions for catch overages and underages. Additionally, Addendum III encourages research on the status of menhaden within the Bay and assessment of localized depletion of the resource.


Wm. Hettler, NMFS

Above: Menhaden swim through the water column with their mouths agape, filtering out plankton for food.

Gulf menhaden landings have declined greatly since the mid 1980's; however, estimates of static spawning potential ratio remain high (about 60%).

Transboundary Stocks and Fishery Management Jurisdictions

Because this resource migrates long distances, interstate coordination of fishery management is required for Atlantic menhaden along the U.S. Atlantic Coast and for Gulf menhaden along the northern Gulf of Mexico through the interstate marine fisheries commissions. During the late 1980's and early 1990's, fish landed at processing plants in New Brunswick and Nova Scotia, Canada, were caught off Maine by U.S. vessels and transported to Canada for processing.

Bycatch and Multispecies Interactions

Two Saltonstall-Kennedy studies, funded in 1992 to investigate bycatch in the Atlantic and Gulf menhaden purse-seine fisheries, showed very low bycatch incidence (<0.1% of other species). However, the importance of menhaden as prey for other species has been an issue of much concern. The ASMFC recently created a Multispecies Technical Committee, and a subcommittee is currently updating the multispecies virtual population analysis (MSVPA) that passed Stock Assessment Review Committee (SARC) peer review in December 2005. This model focuses on the effect of three predators (striped bass, bluefish, and weakfish) on Atlantic menhaden. The eventual goal of this work is to manage forage and predator fish species at a multispecies level.

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Southeast and Caribbean Invertebrate Fisheries

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Unit 11

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INTRODUCTION

Important recreational and commercial marine invertebrates in the southeastern United States include shrimp, spiny lobster, stone crab, and conch. Some fisheries, as for coral, are almost nonexistent. Others, like the Penaeid[1] shrimp fishery, are both extensive and extremely valuable. The Southeast Region's shrimp fisheries are one of the most valuable U.S. fisheries, based on ex-vessel revenue. Other fisheries, such as those for spiny lobster and stone crab, have only moderate value on a national basis but are important locally or regionally. Because of the diversity in species, fisheries, geographic locations, yields, values, and other factors, each species group in the marine invertebrates unit must be examined separately for proper perspective.

[1]Family of prawns.

SPECIES AND STATUS

Shrimp Species

Penaeid shrimp have been fished commercially since the late 1800's. The first fishery used long seines in shallow waters, until the otter trawl (introduced in 1915) extended shrimping to deeper waters. At first, most vessels towed one large trawl, sometimes 120 feet wide at the mouth. Soon, a single-trawl arrangement on both sides of the vessel (with each trawl about 40–75 feet wide at the mouth) was found more effective. Some shrimpers began using a twin-trawl system that tows four

Photo above: Caribbean spiny lobster, Florida Keys.

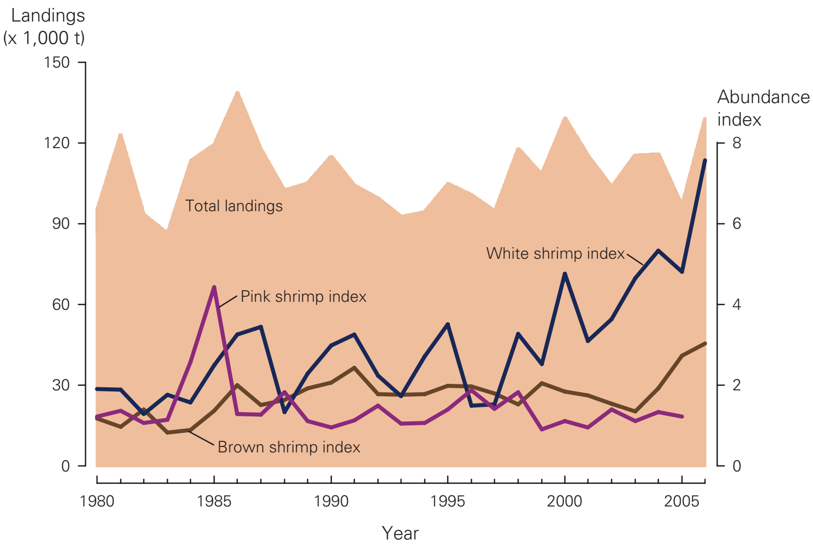


Figure 11-1

Shrimp landings in metric tons (t) and abundance index from the U.S. Gulf of Mexico, 1980–2006. The abundance index is calculated by dividing the current level of reproductive shrimp by the overfishing level.

trawls, each about 40 feet wide at the mouth. The twin-trawl system is now a very common gear on commercial offshore shrimpers.

Brown, white, and pink shrimp account for over 99% of the total Gulf of Mexico shrimp catch. In 2006 alone, these three important species produced 128,644 metric tons (t) valued at $388,278,286 in ex-vessel revenue (Figure 11-1). They are typically found in all U.S. Gulf waters shallower than 120 m. Most of the offshore brown shrimp catch is taken at 40–80 m depths; white shrimp are caught in 20 m or less; and pink shrimp in 40–60 m. Brown shrimp are most abundant off the Texas–Louisiana coast, whereas the greatest concentration of pink shrimp is off southwestern Florida. Current, recent, and maximum sustainable yields for these species are given in Table 11-1.

Brown and white shrimp catches in the Gulf increased significantly from the late 1950's to around 1990, but catch levels during most of the 1990's were below these maximum values. However, catch levels in 2000 were extremely good for both species, with near-record levels reported. Catches in 2001–04 were again below these record catch levels, but still well above average for both species. Catch levels in 2006 were excellent for both species, with white shrimp reaching an all-time high at approximately 59,500 t. Pink shrimp catches remained stable until about 1985 and then declined to an all time low in 1990. During the mid 1990's, catches increased above average levels, but have again shown a moderate declining trend in recent years (Hart and Nance, 2007). The number of young shrimp of each species entering the fisheries has generally reflected the level of catch. All commercial shrimps are harvested at maximum levels. Until very recently the fishery was believed to have more boats and gear than needed (i.e. reducing fishing effort would not significantly reduce the shrimp catch; Nance, 2007a). Reducing bycatch of the shrimp industry, however, would help protect finfish resources.

Recruitment overfishing has not been evident in the Gulf of Mexico for any shrimp stocks (Klima et al., 1990; Nance, 1993, 2007b). The number of young brown shrimp produced per parent increased significantly until about 1991 and has remained near or slightly below that level during most years. White and pink shrimp have not shown any general trend. Although pink shrimp stocks rebounded from the low values experienced in the early 1990's, they have started to decline again in recent years. The brown shrimp increase appears related to marsh habitat alterations. Coastal sinking and a sea-level rise in the northwestern Gulf of Mexico inundates intertidal marshes longer, allowing shrimp to feed for longer periods within the marsh area. Both factors have also expanded estuarine areas, created more marsh edges, and pro-

William B. Folsom, NMFS

Photo on right:
Shrimp boats, Bayou la Batre, Alabama.

Table 11-1

Productivity in metric tons (t) and status of Southeast and Caribbean invertebrate fisheries resources.

Species/stock	Recent average yield (RAY)[1]	Current yield (CY)	Sustainable yield (MSY)	Stock level relative to B_{MSY}	Harvest rate	Stock status
Brown shrimp[2]						
Gulf of Mexico	53,557	Unknown	57,809	Near	Not overfishing	Not overfished
South Atlantic	2,160	Unknown	3,341	Near	Not overfishing	Not overfished
Pink shrimp[2]						
Gulf of Mexico	6,563	Unknown	7,392	Near	Not overfishing	Not overfished
South Atlantic	551	Unknown	786	Near	Not overfishing	Overfished
Rock shrimp						
Gulf of Mexico	715	Unknown	1,070	Unknown	Undefined	Undefined
South Atlantic	1,474	Unknown	1,561	Unknown	Not overfishing	Not overfished
Royal red shrimp	227	Unknown	305	Unknown	Not overfishing	Unknown
Seabob shrimp	1,149	Unknown	2,927	Unknown	Undefined	Undefined
White shrimp[2]						
Gulf of Mexico	51,995	Unknown	42,614	Near	Not overfishing	Not overfished
South Atlantic	5,995	Unknown	6,290	Near	Not overfishing	Not overfished
Coral[3]	0	0	Unknown	Unknown		
Queen conch[4]	110	Unknown	Unknown	Below	Overfishing	Overfished
Caribbean spiny lobster						
Caribbean	123	Unknown	Unknown	Unknown	Unknown	Unknown
Southeast United States[5]	1,988	Unknown	2,742	Near	Not overfishing	Unknown
Golden deepsea crab	177	Unknown	Unknown	Unknown	Unknown	Unknown
Stone crab[6]	1,177	Unknown	1,465	Near	Not overfishing	Undefined
Total	127,961	Unknown	128,712			

[1]2004–06 average.

[2]MSY for brown, pink, and white shrimp is based upon last observed 10-year average annual yield (1997–2006).

[3]Coral harvest prohibited except for a small take allowed for use in aquarium and pharmaceutical industries. Harvest rate and stock status are not available for this stock.

[4]Landings from Puerto Rico and the U.S. Virgin Islands. Fishing for this species is prohibited in Florida.

[5]Yields based on commercial catches; recreational catch is unknown but may be significant.

[6]Yields are in tons of claws; declawed crabs are released and regenerate new claws.

vided more protection from predators. As a result, the nursery function of those marshes has been greatly magnified, and brown shrimp production has expanded. However, continued subsidence will lead to marsh deterioration and an ultimate loss of supporting wetlands, and current high fishery yields may not be indefinitely sustainable. Parent stock indices for the three major Gulf species are shown in Figure 11-1.

Regulations in the Gulf of Mexico Shrimp Fishery Management Plan (FMP) restrict shrimping by closing two shrimping grounds. There is a seasonal closure of fishing grounds off Texas for brown shrimp and a closure off Florida for pink shrimp. Size limits also exist for white shrimp caught in Federal waters and landed in Louisiana. These regulations strive to improve the monetary value of the shrimp fishery (Hart and Nance, 2007; Nance, 2008).

The shrimp fishery in the South Atlantic is much smaller than the Gulf of Mexico fishery. White shrimp landings are about 12% of the Gulf yield, while brown and pink shrimp are around 4% and 8% of the Gulf yield, respectively (Table 11-1). In the South Atlantic, white shrimp stocks are centered off the Georgia and South Carolina coasts and brown shrimp are centered off the North and South Carolina coasts. The Atlantic fishery is currently managed under a Federal FMP implemented in November 1993. The FMP provides for compatible state and Federal closures if needed to protect overwintering shrimp stocks. Subsequent amendments added rock shrimp and royal red shrimp to the management unit of the FMP, and defined overfishing definitions for all species.

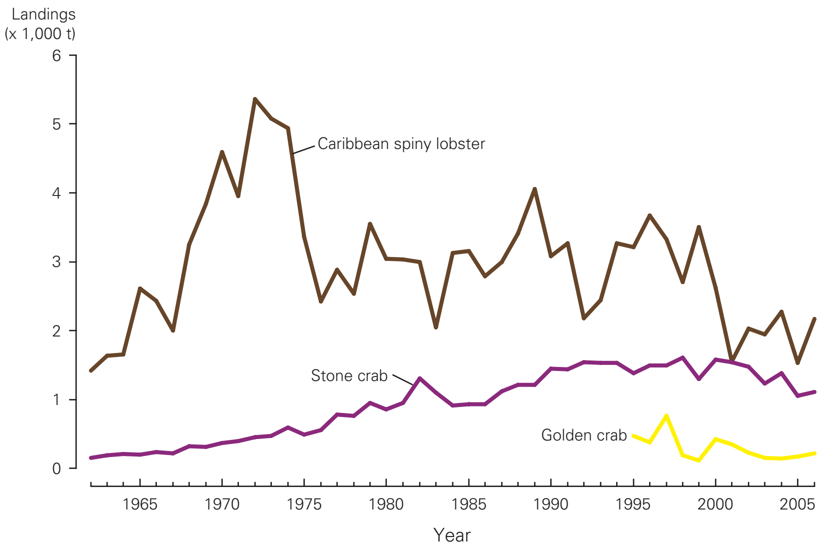
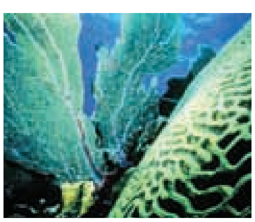


Figure 11-2

Landings in metric tons (t) of stone crab (claw weight), golden crab, and Caribbean spiny lobster, 1962–2006.

Caribbean Spiny Lobster

Annual landings of Caribbean spiny lobster in Florida historically have fluctuated, but remained fairly stable since 1980 with an average catch of about 2,790 t (Figure 11-2). Recent high landings were experienced in 1996 when the 3,568 t catch was worth approximately $30 million ex-vessel. The fishery is considered overcapitalized, and a trap reduction program was instituted in 1993. This program, not to exceed 10% per year, is oriented toward maintaining or maximizing the sustainable Caribbean spiny lobster harvest from the fishery. The program has successfully reduced the number of traps from 900,000 in 1992 to slightly fewer than 500,000 in 2005 (SEDAR, 2005). A continuing problem in the commercial fishery is the use of live undersized lobsters as attractants in lobster traps. Due to a high mortality rate for these live bait animals, about 30–50% of the potential yield is lost. The recreational fishery for Caribbean spiny lobster in the southeastern U.S. is not well quantified in terms of effort and landings; however, it is a popular recreational species, and the recreational catch may be significant.



Florida Keys Nat. Marine Sanctuary

Close-up of a sea fan (left) and brain coral (right). Corals provide important habitat for many species of fish.

Caribbean spiny lobster along the southeastern coast of the United States are managed under a joint FMP coordinated with regulations by the State of Florida. Current regulations specify a 3-inch minimum carapace length, a closed season from 1 April to 5 August to protect spawning adults, mandatory release of egg-bearing females, closure of some nursery areas, recreational bag limits, a 2-day sport season, and a trap reduction program which began in 1993 (Harper and Muller, 2001).

The fishery for Caribbean spiny lobster in the U.S. Caribbean is much smaller than the Florida fishery (Table 11-1). Annual Caribbean spiny lobster landings for Puerto Rico have averaged 104 t since 1990, varying from 68 t in 1993 to a high of 149 t in 1999. U.S. Virgin Islands landings for 1980–2006 were fairly stable, averaging 28 t. In the U.S. Caribbean, Caribbean spiny lobster are caught primarily by fish traps, lobster traps, and divers. The Caribbean Fishery Management Council's Spiny Lobster FMP includes the Federal waters of Puerto Rico and the U.S. Virgin Islands. The Federal plan is based on a 3.5-inch minimum carapace length and protection of egg-bearing female lobsters (Bolden, 2001).

Caribbean spiny lobster larvae may drift at sea for up to 9 months, and thus identification of their source or parent stock is almost impossible. The origin of Caribbean spiny lobster stocks in U.S. waters, including the Florida stock, remains unknown. To improve management, there is a practical need to increase knowledge of lobster origin and subsequent movements into fisheries.

Conch

The conch fishery targets the queen conch but also takes other species. Most conchs are taken by divers, and the resource can be easily depleted. Conchs are currently protected in state and Federal waters off Florida, but a fishery still exists in some areas of the U.S. Caribbean. An FMP was implemented in 1996 for the Federal waters off Puerto Rico and the U.S. Virgin Islands by the Caribbean Fishery Management Council.

Corals

Corals are managed as two groups, hard[2] and soft[3]. Because they are generally slow growing and

[2]Coral colonies are cemented together by the calcium carbonate secreted by individual coral polyps. The calcium carbonate skeletons form reefs.

[3]Corals that do not produce substantial calcium carbonate skeletons and do not build reefs.

provide critical habitat for many fishes, hard corals are protected except for very small collections taken by permit for research and educational purposes. Regulations are based on the fact that the value of coral as natural habitat is far more important than their commercial use. Soft corals include gorgonians and sea fans. Some gorgonians are taken (about 50,000 colonies annually) for the aquarium and pharmaceutical trade. Growth potential for most species is considered limited. Sea fans are completely protected except for research and educational use by permit.

Stone Crab

Stone crabs are caught mainly off southern Florida, though some are landed farther north along Florida's west coast. The Gulf of Mexico Stone Crab FMP, approved in September 1979, generally extended Florida's regulations into the U.S. Exclusive Economic Zone (EEZ). These regulations are based on a minimum claw size of 2.75 inches, biodegradable trap panels, protection of egg-bearing females, and closed seasons. Minimum size regulations assure that crabs have reproduced at least once before being caught.

Annual catches of stone crab (claw weight) averaged 1,419 t on the Gulf of Mexico and Atlantic coasts 1990–2006, with a record 1,604 t landed during 1998 (Figure 11-2). Recent annual ex-vessel revenue averaged $24,400,000. The number of stone crab traps fished seasonally increased from 295,000 in 1979–80 to a record 1,568,000 during 2001–02 (Muller et al., 2006). While total landings have increased since 1980, it is clear that these landings are the result of increased fishing effort (number of traps fished), especially during the early months of the stone crab season.

Golden Deepsea Crab

The deepwater commercial fishery for golden deepsea crab was established in the mid 1990's following the prohibition of fish traps in the snapper–grouper fishery of the U.S. South Atlantic Ocean. The Golden Crab FMP was developed cooperatively with fishermen and included measures to protect the stock. These measures included a limited entry program that prohibited large vessels entering the fishery from outside the area, and established fishing zones and other protective measures for the crabs. Annual catches have averaged 300 t from 1995 through 2006, with a record 759 t landed in 1997 (Figure 11-2).

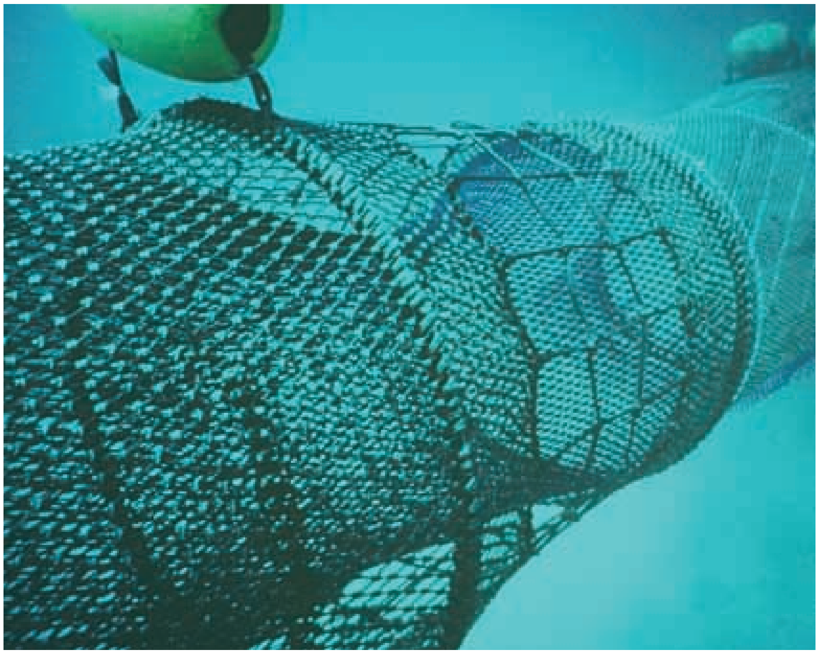
ISSUES

Habitat Concerns

Habitat concerns impact many of the southeast and Caribbean invertebrate fishery resources. Estuarine and marsh loss removes critical habitat used by young shrimp (Zimmerman et al., 2000; Minello et al., 2003). Additional studies are needed to further assess the impacts of human-induced changes in habitat availability, environmental conditions, predator abundance, and pollution in nursery areas. Caribbean spiny lobsters in Florida depend on reef habitat and shallow-water algal flats for feeding and reproduction, but these habitat requirements may conflict with expanding coastal development. The productivity of stone crabs in Florida Bay is related to water quality and flow through the Everglades. Specific water requirements need to be identified and maintained through comprehensive Everglades

Heather Dine

Conch in a healthy sea grass bed, Florida Keys National Marine Sanctuary.



NOAA

A shrimp trawl outfitted with a combination bycatch reduction/turtle excluder device deployed in the water. Fish escape by swimming forward and out of the large holes in the net, while shrimp are retained by being swept into the bag at the end of the net. The oval metal ring and bars (right side of photo) deflect turtles, and force any turtle that has become stuck in the net toward a trap door that will open, allowing the turtle to swim free.

water management. A unified program to integrate and study the combined effects of environmental alterations, fishing technology improvements, regulations, habitat restoration, and economic factors on shrimp, lobster, and crab production is needed, particularly in the reef habitats of south Florida. Steps also need to be taken to mitigate or restore lost estuarine habitats.

Transboundary Stocks and Fishery Management Jurisdiction

Spiny lobster stocks in Florida could be of Caribbean origin, being swept into the region by currents of the Gulf Stream. Another hypothesis is that they could comprise a number of different spawning stocks. The actual sources of all Florida and Caribbean lobster stocks (both U.S. and foreign) need to be identified and international management established to prevent overharvesting.

Bycatch and Multispecies Interactions

Shrimp fisheries use small-mesh trawl nets and can catch nontarget species, including commercially fished species such as red snappers, croakers, and seatrouts, and also protected resources such as sea turtles. Juvenile finfish are a major component of the bycatch and this may be a major source of mortality for them. Some fish caught by shrimpers are currently at low stock levels (see Unit 8, Atlantic, Gulf of Mexico, and Caribbean Reef Fisheries and Unit 9, Southeast Drum and Croaker Fisheries); this bycatch may prevent or slow recovery if not mitigated. All sea turtle species are listed as endangered or threatened under the Endangered Species Act, and shrimp vessels have been required to use turtle excluder devices in their nets since 1988 to avoid capturing sea turtles.

Other Management Concerns

In Florida, increasing numbers of recreational Caribbean spiny lobster fishermen have been a cause of concern for fishery managers and have sparked conflicts between the commercial and recreational sectors. Also, a recently discovered, highly lethal virus infecting juvenile spiny lobster has the potential to negatively impact recruitment of this important fishery species.

Until very recently, the shrimp fisheries were overcapitalized, with more fishing effort being expended than was needed to sustainably harvest the resource (Nance et al., 2006). This trend in fishing effort may have been modified by the lower-than-average ex-vessel prices for shrimp and higher-than-average fuel prices over the past few years. Additionally, the harvesting of small shrimp is sacrificing yield and value of the catch by cutting short future population growth (Caillouet et al., 2008).

Progress

The National Marine Fisheries Service and the fishing industry are working together to continue development of bycatch-reduction gear to address the problems of finfish bycatch in shrimp fisheries of the Gulf of Mexico and South Atlantic. A gear conflict between stone crab trappers and shrimp trawlers off southwestern Florida has mostly been resolved in the 200-mile EEZ with a line separating the fishing areas and seasonal area closures. This approach requires continued monitoring to gauge its success and prevent renewal of conflicts.

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Pacific Coast Salmon

David Csepp

Unit 12

ROBERT G. KOPE

NMFS Northwest Fisheries Science Center

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Photo above:
Male coho salmon showing spawning coloration and physical condition.

INTRODUCTION

Pacific salmon support important commercial and recreational fisheries in Washington, Oregon, and California. Salmon are a vital part of the culture and heritage of the Pacific Northwest, having been harvested by Native Americans for millennia and by European settlers since their arrival on the Pacific Coast of North America.

Pacific salmon include five species: Chinook, coho, sockeye, pink, and chum salmon. All are anadromous: they spawn in fresh water and migrate to the ocean where they may undergo extensive migrations. At maturity, they return to their home stream to spawn and complete their life cycle. Coho salmon and most southern U.S. runs of Chinook salmon tend to stay over the Continental Shelf during their ocean residency, where they are vulnerable to fisheries as immature fish. Sockeye, pink, and chum salmon migrate farther offshore and rear in the Gulf of Alaska and central North Pacific Ocean. These species are only vulnerable to shore-based fisheries as mature fish on their spawning migrations.

Chinook and coho salmon are harvested recreationally and commercially in the Pacific Ocean, Puget Sound, and in freshwater rivers on their spawning migrations. All recreational fisheries use hook-and-line gear, whereas commercial fisheries use a variety of gear depending on location. In the Pacific Ocean all harvest is by trolling; in Puget Sound, gillnets and purse seines are used in addition to trolling; in fresh water and estuaries, gillnets are the primary gear used. Pink, chum, and sockeye salmon are not as important to recreational fisheries as Chinook and coho salmon, and are uncommon in recreational catches outside of Puget Sound. While there are intense recreational fisheries directed at these species in a few locations, the majority of harvest is by commercial gillnet and purse seine fisheries in Puget Sound and gillnet fisheries in estuaries. All species are also harvested for subsistence and ceremonial purposes by Native American tribes.

Table 12-1
Productivity in metric tons (t) and status of Pacific Coast salmon fisheries resources. Harvest rate and stock status information for Pacific Coast salmon are available for individual runs, but cannot be calculated for coastwide stocks. For more information on the status of individual salmon runs, see the *Status of U.S. Fisheries Reports* available online at http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm.

Species/stock	Recent average yield (RAY)[1]	Current yield (CY)[2]	Sustainable yield (MSY)[2]	Stock level relative to B_{MSY}[3]
Chinook salmon	8,919	11,460	11,460	Near
Chum salmon	6,170	4,636	4,636	Near
Coho salmon	3,127	5,300	5,300	Near
Pink salmon	1,846	7,270	7,270	Near
Sockeye salmon	1,048	4,646	4,646	Near
Total	21,110	33,312	33,312	

[1]2004–06 average, except for pink salmon which is for the years 2001, 2003, and 2005. Recreational harvests were converted from numbers of fish to approximate weights using average weights of salmon caught in commercial fisheries from 1999–2006: Chinook = 6.00 kg; chum = 3.79 kg; coho = 3.04 kg; pink = 1.75 kg; sockeye = 2.32 kg.
[2]Potential yields include doubling of production for some stocks.
[3]*B* is biomass. B_{MSY} represents the stock size that can withstand maximum sustainable yield without collapsing.

During 2004–06, the annual commercial salmon catch averaged 16,300 metric tons (t) and provided revenues averaging approximately $40 million at dockside. Recreational catches are more difficult to value since the recreational experience associated with the catch cannot be easily measured. If recreationally caught fish are valued at a conservative $20 per fish, the 2004–06 average catch of 800,000 fish would have been worth about $16 million annually. Total recent average annual landings (2004–06) were more than 21,000 t (Table 12-1).

The abundance of individual stocks of Pacific salmon and the mixture of stocks contributing to fisheries fluctuate considerably. Consequently, annual landings fluctuate as well. For all species, there is excess fishing capacity and overcapitalization of the fishing fleets. Although harvest rates in recent years have been held near or below levels that would produce the maximum sustainable yield, recent environmental conditions have resulted in poor ocean survival of Chinook and coho salmon stocks in general and some individual stocks of the other species. This has led to sharp declines in abundance of most southern stocks over the past 5 years and has led to the closure of all 2008 ocean salmon fisheries off the coasts of Oregon and California, except for a small recreational coho fishery off the coast of Oregon which only allows retention of marked hatchery fish.

Management Situation

The management of this resource is complex, involving many stocks originating from various rivers and jurisdictions. The Pacific Fishery Management Council (PFMC), in cooperation with the states and tribal fishery agencies, manages ocean fisheries for Chinook and coho salmon under a framework fishery management plan (FMP). Within Puget Sound and the Columbia River, the states and tribes manage fisheries for these two species. The Pacific Salmon Commission (PSC), the State of Washington, and tribal fishery agencies primarily manage fisheries for pink, chum, and sockeye salmon.

Fisheries are managed using a variety of regulations. Ocean fisheries are managed mainly through


William Heard, AFSC

Photo to right:
School of juvenile pink salmon in a healthy river.

gear restrictions, minimum size limits, and time and area closures, although harvest quotas have been in place for individual fisheries in recent years. The PSC uses harvest quotas (updated on the basis of in-season abundance forecasts) and cumulative impact quotas for weak stocks to regulate some commercial fisheries in the Strait of Juan de Fuca and north Puget Sound.

Pacific salmon depend on freshwater habitat for spawning and rearing of juveniles. Because the quality of freshwater habitat is largely a function of land management practices, salmon production is heavily influenced by entities not directly involved in the management of fisheries. Salmon management involves the cooperation of the U.S. Forest Service, Bureau of Land Management, U.S. Fish and Wildlife Service, Bureau of Reclamation, Army Corps of Engineers, Environmental Protection Agency, Bonneville Power Administration, state resource agencies, Indian tribes, municipal utility districts, agricultural water districts, private timber companies, and landowners.

Following coast-wide status reviews for all species of salmon and anadromous trout, numerous evolutionarily significant units (ESU's) of all species except pink salmon have been listed as threatened or endangered under the U.S. Endangered Species Act (ESA). As a result, most freshwater habitat supporting anadromous salmonids now includes listed species. The need to reduce impacts on listed stocks has constrained allowable harvest rates on healthy stocks in recent years. In order to access hatchery-produced salmon, most hatchery-produced coho salmon are currently being marked by removal of the adipose fin to distinguish them from wild salmon. In most hook-and-line fisheries allowing retention of coho salmon, all unmarked fish must be released. Similar mass marking of hatchery-produced Chinook salmon has begun in many hatcheries, and limited mark-selective fisheries have been implemented for this species as well.

SPECIES STATUS

Chinook Salmon

The main production areas for Chinook salmon are rivers and hatcheries in Puget Sound in Washington, the Umpqua and Rogue Rivers in Oregon, the Klamath and Sacramento Rivers in California, and the Columbia River. Stocks are named for the season in which they migrate from the ocean to freshwater to spawn, and include spring, summer, fall, and winter runs. Chinook salmon production tends to fluctuate considerably (Figure 12-1) depending on hatchery production, freshwater habitat conditions, and ocean productivity. The proportion of Chinook salmon production originating from hatcheries has been increasing. In recent years, freshwater habitat loss and degradation have been exacerbated by drought in many areas in the west, in addition to generally unfavorable ocean conditions for Chinook salmon from the late 1970's through the late 1990's. This resulted in historically low abundance for a number of stocks and reduced commercial and recreational catches in many areas.

Currently, the upper Columbia River spring-run and the Sacramento River winter-run ESU's are listed as endangered under the ESA and seven additional ESU's are listed as threatened. Concern over the depressed status of stocks and biological opinions requiring reduced impacts on listed ESU's led to increasingly restrictive ocean fishing seasons through most of the 1990's. Improvements in marine survival beginning around 1999 allowed for brief modest increases in harvests and improvements in spawner abundance for most Chinook salmon stocks. However, since 2004 most populations originating south of the Columbia River have declined sharply.

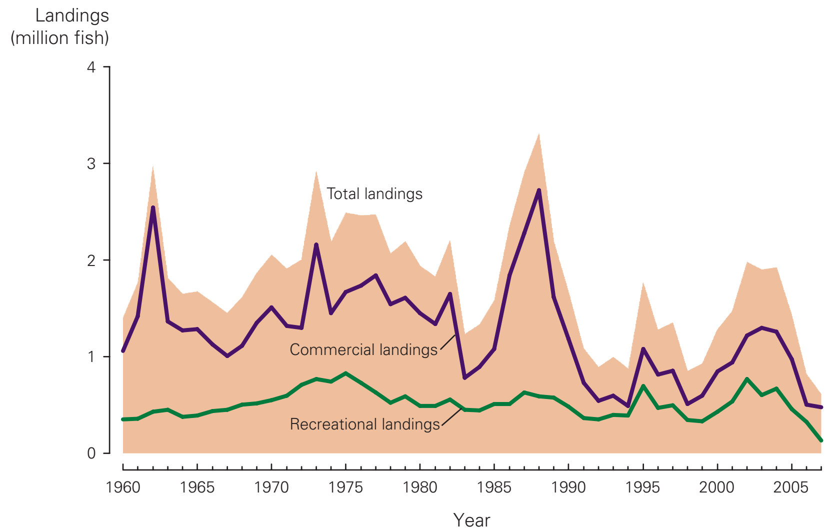

Figure 12-1
Chinook salmon landings in individual fish, 1960–2007.

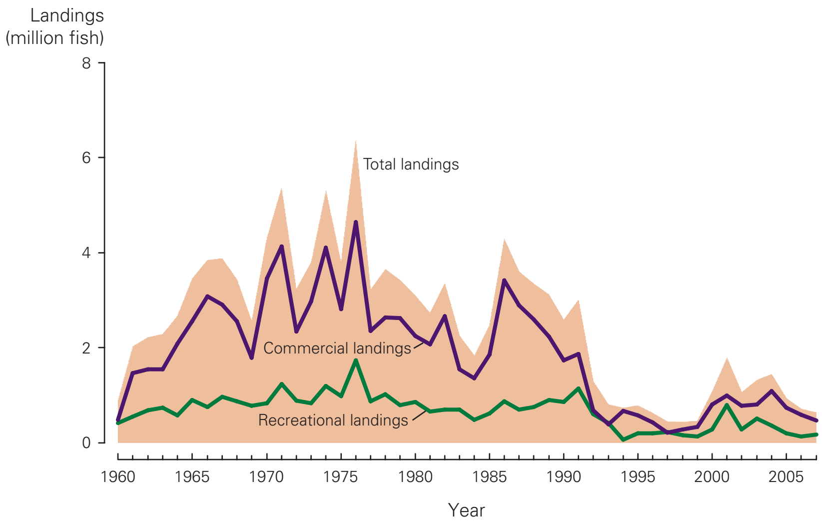

Figure 12-2

Coho salmon landings in individual fish, 1960–2007.

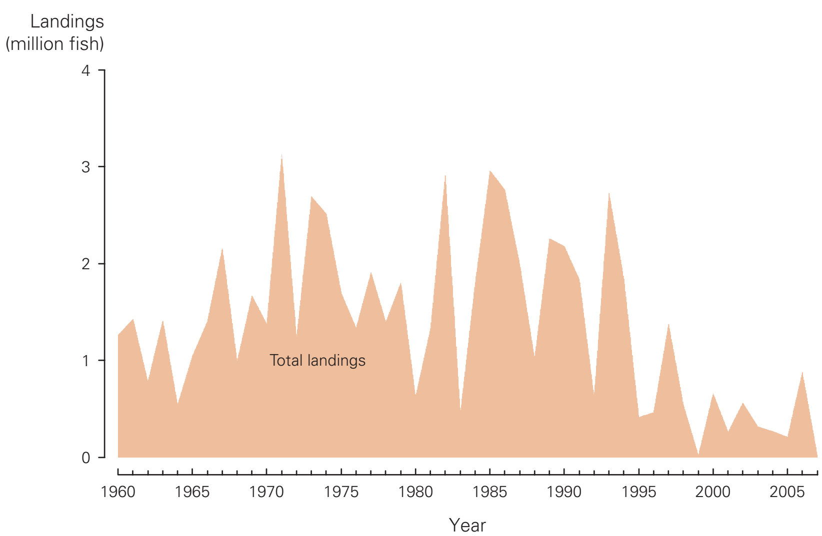

Figure 12-3

Sockeye salmon landings in individual fish, 1960–2007.

Coho Salmon

Coho salmon are produced primarily in rivers and hatcheries in the Puget Sound area in Washington, hatcheries on the Columbia River, and coastal rivers and hatcheries in Oregon and California. Hatcheries play a larger role in the production of coho salmon than they do for Chinook salmon; in some areas, hatcheries account for more than 80% of the abundance available to fisheries. Landings reductions during the 1990's resulted from record low abundances of several stocks of coho salmon, including Oregon coast natural and Columbia River hatchery stocks (Figure 12-2). To protect the spawning escapement of these stocks and to provide fish for the legally mandated tribal allocation, severe restrictions have been placed on ocean fisheries since 1993. Since then, natural populations of coho salmon in the United States have also benefited from reductions in Canadian coho-directed fisheries to protect depressed Canadian stocks and the implementation of mark-selective regulations in most U.S. ocean fisheries, under which only hatchery-marked coho may be retained and unmarked natural coho must be released.

Currently, three coho salmon ESU's are Federally listed as threatened: northern California-southern Oregon in 1997; Lower Columbia River in 2005; and Oregon Coast ESU, which was originally listed in 1998 but had the listing overturned by a Federal district court in 2001 and was re-listed in 2008. Additionally, the central California ESU, formerly listed as threatened, was upgraded to endangered in 2005.

Sockeye, Pink, and Chum Salmon

Pink and chum salmon originate primarily from the tributaries of Puget Sound, Washington. Chum salmon are also produced, in limited numbers, in the Columbia River and coastal streams as far south as the central Oregon coast. Sockeye salmon originate primarily from river systems connected to lakes. They are produced in a few rivers in the Puget Sound area, in limited numbers in a few coastal rivers on the Olympic Peninsula, and in the upper Columbia and Snake River basins. The majority of these species are caught commercially in the Puget Sound region of Washington. Much of the sockeye and pink salmon harvested in Puget Sound originates from the Fraser River in Canada. Chum salmon in Puget Sound have been doing very well, and recent abundance has been near record levels. Sockeye runs in the Fraser River have been erratic in the past decade. There have been large changes in survival and run timing for several runs, and some run components are under consideration for listing under Canada's Species at Risk Act. Pink salmon in Puget Sound rebounded from a record low return in 1999 to near record high abundance in recent years. However, commercial fisheries have been constrained by a combination of low price and incidental impacts on sockeye and listed Chinook populations. Historical landings of the species are shown in Figures 12-3, 12-4, and 12-5 for sockeye, chum, and pink salmon, respectively.

Recreational Fisheries

Pacific salmon support valuable recreational fisheries in salt water, fresh water, and estuaries. Recreational landings of Chinook salmon have averaged about 480,000 fish annually for the period 2004–06. During the same period, recreational landings of coho salmon have averaged about 230,000 salmon from hatchery and natural production combined. These landings reflect a substantial decline in abundance since 2004.

Recreational landings for sockeye and chum salmon have averaged 25,000 and 10,000 fish annually over the 2004–06 period. In years when pink salmon are available, they normally account for the bulk of recreational landings for these species, but there are only significant runs in odd-numbered years. Recreational landings of pink salmon from the 2001, 2003, and 2005 runs averaged nearly 214,000 fish. While recreational landings of Chinook and coho are comparable to commercial landings, recreational landings of pink, chum, and sockeye account for a much lower proportion of the total catch. The reason for this lies partly in the life histories and migration patterns of the individual species. Sockeye, pink, and chum salmon migrate far offshore into the central North Pacific Ocean and the Gulf of Alaska. Thus they are only available to recreational fisheries briefly during their spawning migration. In addition, pink and chum salmon spawn and die shortly after entering fresh water as adults. By the time they reach terminal areas where recreational fisheries are located, they have undergone physiological changes in preparation for spawning, reducing the quality of their flesh and making them less highly prized relative to Chinook, coho, and sockeye salmon. While the recreational fisheries for sockeye, pink, and chum salmon are substantially smaller than recreational fisheries for Chinook and coho salmon, they are still important.

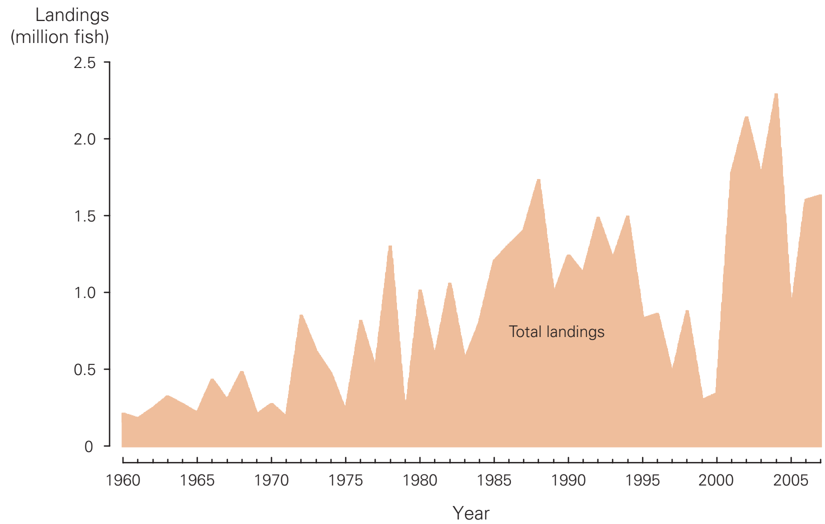

Figure 12-4
Chum salmon landings in individual fish, 1960–2007.

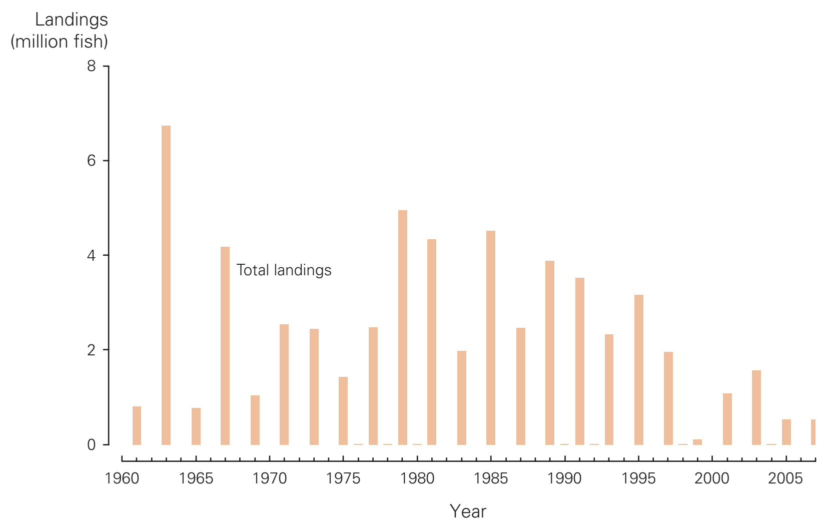

Figure 12-5
Pink salmon landings in individual fish, 1960–2007.

Commercial Fisheries

For 2004–06, the combined Chinook salmon harvest from natural and hatchery production averaged about 910,000 fish. In the same period, the commercial catch of coho salmon averaged about 799,000 salmon. Both species experienced brief rebounds from very low abundance levels in the 1990's. However, since 2003, stocks originating south of the Columbia River have declined sharply,

Spawning salmon in a Washington State fish hatchery.

culminating in the 2008 closure of all commercial salmon fisheries in California and most of the Oregon coast.

Landings of sockeye, pink, and chum salmon demonstrate a very different pattern from those of Chinook and coho salmon. Recent average annual catches of these species were roughly 427,000 sockeye salmon (2004–06), 1.57 million chum salmon (2004–06), and 843,000 pink salmon (2001, 2003, and 2005). Recent trends in landings have generally been stable or increasing, but marked downturns in landings were seen in the late 1990's. Landings of chum salmon have rebounded since then, while landings of pink salmon and sockeye salmon have not. The reasons for these differences are unique for each species.

While landings of chum salmon are mainly made up of stocks from the Puget Sound region, a large proportion of the pink salmon and nearly all of the sockeye salmon landed in Washington State are from stocks originating in the Fraser River system in British Columbia. Pink and chum salmon stocks both increased in abundance around 2000, and while chum landings reflect this rebound, pink salmon landings do not. After rebounding from a record low return in 1999, near record runs of pink salmon in 2001 and 2003 were only lightly harvested because of depressed prices, and incidental impacts on depressed sockeye runs and ESA-listed Chinook runs in Puget Sound. In the case of sockeye salmon, Fraser River runs were strong through the mid 1990's, but ocean conditions have caused a large proportion of the fish to migrate north of Vancouver Island where they were unavailable to U.S. fisheries. Renegotiation of the Pacific Salmon Treaty with Canada also sharply reduced the U.S. share of the catch. In addition, since 1996 the late-run of sockeye salmon has been entering the river earlier than it did historically. The timing of the late-run has advanced as much as 6 weeks, and this early river entry has been associated with high pre-spawning mortality. This unexplained behavior, as well as declines in abundance and shifts in the timing of other run components, has alarmed fishery managers and prompted severe restrictions on harvest in sockeye fisheries.

ISSUES AND PROGRESS

Balancing Competing Uses

The decline in Chinook and coho salmon abundance has forced severe reductions and closures of ocean fisheries in recent years. These reductions, in some cases, follow earlier legally mandated reductions to allocate salmon to interior-water fisheries for harvest by Native American tribes. Ocean salmon fisheries cannot redirect their effort to take advantage of abundant sockeye, pink, and chum salmon stocks because the ocean distribution of these species keeps them outside the range of coastal fisheries. With the prospect of continued restrictions to protect threatened and endangered species and depressed prices, the future viability of these commercial fisheries is uncertain.

Hatchery Versus Wild Salmon

The use of hatcheries to mitigate habitat loss and enhance fisheries, especially for Chinook and coho salmon, has raised concerns about the interactions of hatchery and natural fish. While hatchery fish can supplement natural production, they can also compete with naturally produced fish. In areas where fisheries are managed on the basis of hatchery production, harvest rates may be higher than the natural stocks can sustain. In addition, some hatchery fish fail to return to the hatchery, spawning in natural areas with wild fish. Some hatchery brood stocks are of non-local origin, and the insertion of non-local genes into natural populations can compromise the genetic integrity of the native stocks and decrease their productivity. Even when hatchery stocks are of local origin, multiple generations of hatchery rearing appear to reduce the fitness of fish to compete and survive in the wild.

Market Competition

One problem faced by commercial salmon fisheries in the Pacific Northwest has been declining prices driven by market competition from record landings of Alaskan salmon and steadily increasing aquaculture production. For example, in 2002 the average ex-vessel price paid for dressed Chinook salmon in California was $1.55/lb, while the 1979 price was $2.53/lb. Prices for other species have declined even more, with pink salmon selling for as little as $0.05/lb in Puget Sound in 2003. Since then, prices have rebounded somewhat, as niche markets for local ocean-caught fish have developed, and catches have declined.

Marine Mammal Interactions

Since the passage of the Marine Mammal Protection Act in 1972, populations of pinnipeds (seals and sea lions) have increased to historic levels. As pinniped populations have increased, so have their interactions with salmon populations and with fisheries. Aggregations of seals and sea lions have appeared at river mouths and dams where migrating salmon are concentrated and more vulnerable to predation. In addition to preying on migrating salmon, some pinnipeds have also specialized in removing salmon from recreational and commercial fishing gear. This has resulted in damage to fishing gear, injuries to pinnipeds, and an increase in the incidental mortality associated with recreational and commercial salmon fishing, but the magnitude of the increase is unknown.

In 2005, Southern Resident killer whales were listed under the Federal ESA as an endangered species. While transient killer whales feed on other marine mammals, the resident killer whales feed primarily on fish. Genetic analysis of observed feeding events and stool samples indicate that Chinook salmon are their preferred prey. The listing of these killer whales and recent declines in Chinook abundance have focused further scrutiny on the ecological impacts of salmon fisheries.

Transboundary Stocks and Jurisdiction

Because salmon migrate long distances, they are subject to interception by fisheries far from their region of origin. Issues of allocation have never been easy to resolve and have been addressed in a variety of forums. Much of the annual process of managing ocean salmon fisheries by the PFMC is concerned with the allocation of fish between different user groups: ocean and interior-water fisheries, commercial and recreational fisheries, and tribal and non-tribal fisheries. The PSC oversees the allocation of salmon between the United States and Canada. In 1994, a breakdown of the United States–Canada negotiations led to aggressive harvesting that compounded forecasting errors and nearly destroyed one of the most productive runs of sockeye salmon from the Fraser River in British Columbia. In 1999 the PSC reached an agreement that established an abundance-based management regime for Chinook salmon, replacing the fixed quotas in major southeast Alaska and British Columbia fisheries with a quota system that changes in response to the aggregate abundance of Chinook salmon available to each fishery. A similar abundance-based management regime for coho salmon was agreed upon in 2002.

David Csepp

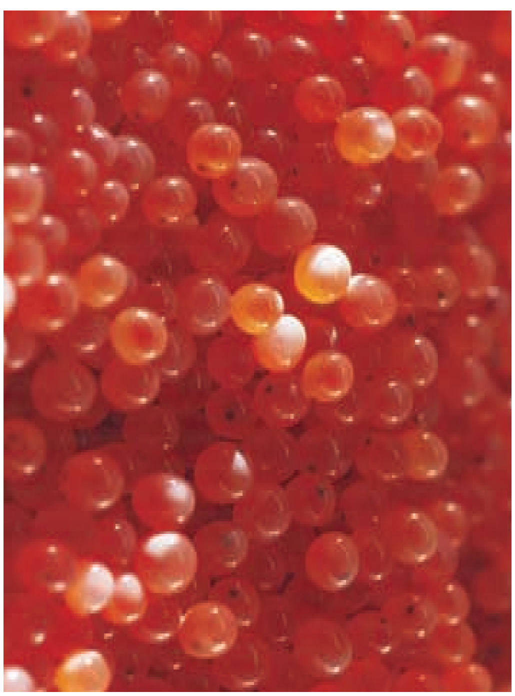

Photo to left:
Fertilized salmon eggs.

Ecosystem Considerations

Coho salmon abundance reached a peak in 1976, and suffered a dramatic decline through the late 1990's. Chinook salmon abundance has also generally declined since the mid 1970's, although there was a brief increase in the late 1980's. These declines affected both hatchery and natural stocks, and appeared to indicate a period of declining ocean survival. These declines were also coincident with a change in the oceanographic regime off the West Coast that occurred around 1978. Since then, the coastal waters off California, Oregon, and Washington, where many Chinook and coho salmon stocks mature, have been warmer and less productive than they were in the period from roughly 1950 to 1978. The decline in ocean productivity off the Pacific Coast appears to be linked to increased productivity in the Gulf of Alaska. Sockeye, pink, and chum salmon, which migrate farther offshore than Chinook and coho salmon, were relatively stable or increasing during the same period that Chinook and coho salmon declined.

More recently, conditions for Chinook and coho salmon briefly improved. In 1999, water temperatures were lower than normal off the coasts of California, Oregon, and Washington. In 2000, the marine plankton assemblages in the Pacific Northwest shifted from species characteristic of temperate regions to species more characteristic of subarctic regions, and bait fish became abundant. However, by 2005 most indicators of ocean productivity in within the California Current system pointed toward poor conditions for survival of Chinook and coho salmon. Indicators have remained unfavorable since then, and Chinook and coho populations south of the Columbia River have continued to decline.

Because Pacific salmon depend on freshwater habitat for spawning and juvenile rearing, they are particularly vulnerable to habitat degradation. Dam construction, logging, agriculture, grazing, urbanization, and pollution have degraded freshwater habitat throughout their range. Water extraction and flow manipulation for hydropower, irrigation, flood control, and municipal needs directly compete with salmon for the fresh water on which they depend. As the human population in the western United States continues to increase, so will the pressures on salmon habitat. The fact that we still have salmon in harvestable quantities is a tribute to the resilience of these fish.

FOR FURTHER READING

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ODFW and WDFW. 2002. Status report. Columbia River fish runs and fisheries 1938–2000. Oregon Department of Fish and Wildlife, Portland, OR, and Washington Department of Fish and Wildlife, Olympia, WA, 324 p.

PFMC. 2008. Review of 2007 ocean salmon fisheries. Pacific Fishery Management Council, Portland, OR, 326 p.

Alaska Salmon

William Heard, AFSC

Photo above:
Pink salmon spawning in an Alaska river.

Unit 13

WILLIAM R. HEARD

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Auke Bay
Alaska

INTRODUCTION

Pacific salmon have played an important and pivotal role in the history of Alaska. Salmon, along with mining, timber, and furs, were the keystone natural resources that led to the settling and development of the 49th state by non-native peoples. Even now, the abundant salmon resources of this region continue to shape much of the contemporary lives of residents and visitors to Alaska. Alaska native peoples and their heritage have a long, colorful bond with salmon as an economic, cultural, and subsistence necessity. This heritage incorporated some of the most highly developed aboriginal fishing complexes anywhere (Cooley, 1961; Betts and Wolf, 1992).

Today many Alaskans still depend heavily on salmon for recreation, food, and industry. Commercial harvesting and processing, along with rapidly growing tourism-based guided sport fishing for salmon, provides the state with its largest private sector employment. Subsistence use by rural Alaskans is still an important part of the overall salmon story, accounting for around 1 million fish per year (ADFG, 2005; NPAFC, 2005).

Alaska commercial salmon harvests generally have increased over the last 3 decades (Figure 13-1). After reaching record low catch levels in the 1970's, most populations rebounded and fisheries in recent years have been at or near all-time peak levels in many regions of the state (Burger and Wertheimer, 1995; Baker et al., 1996; Wertheimer, 1997; Byerly et al., 1999; McGee, 2004;). The record-high commercial landings of 218 million salmon in 1995 were 17% higher than the previous record of 196 million salmon in 1994. Throughout the mid to late 1990's, recreational and subsistence fishermen harvested between 2 and 3 million salmon annually (Howe et al., 2001; ADFG, 2005; NPAFC, 2005).

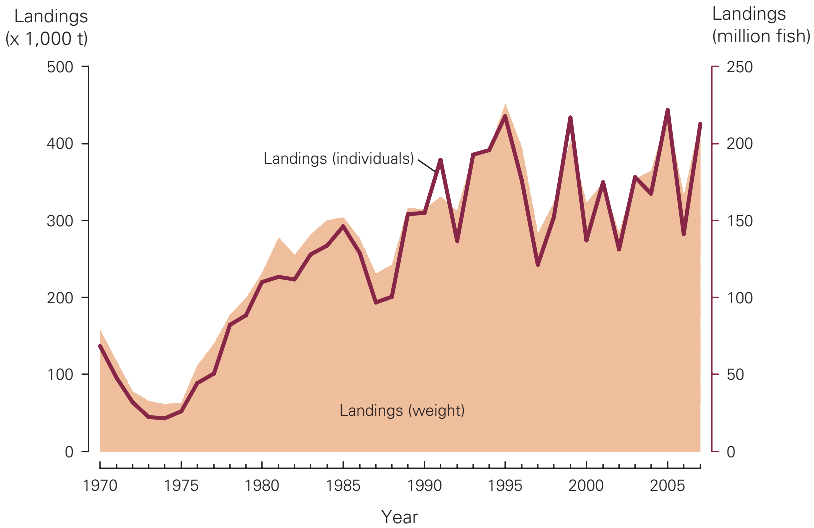

Figure 13-1
Commercial landings of Alaska salmon (all species) in metric tons (t) and individual fish, 1970–2007.

A number of factors have contributed to the current high abundance of Alaska salmon. These include 1) pristine habitats with minimal impacts from extensive development; 2) generally favorable oceanic conditions that allow high survival of juveniles; 3) improved fisheries management by state and Federal agencies; 4) elimination of high-seas drift-net fisheries by foreign nations; 5) a well-managed hatchery production system; and 6) some reductions of salmon bycatch in fisheries for other species.

Significant declines in commercial catches occurred during the 3 years following the peak harvest in 1995 and were thought by many to possibly indicate the beginning of a major downturn in productivity of Alaska salmon. Historical commercial landings show a distinct cyclic pattern of alternating high and low harvests, often lasting decades. Much of this fluctuation is now believed to be due to inter-decadal climate oscillations in the ocean environment (Mantua et al., 1997; Minobe and Mantua, 1999) that affect marine survival of juveniles. A major climatic regime shift occurred in 1977 and helped Alaska salmon stocks rebound from the previous years of low abundance. There is concern that another regime shift in 1989 (Hare and Mantua, 2000) may lead to a downward trend in Alaska's salmon resources.

An interesting pattern associated with Alaska's cyclic salmon harvest is an inverse production regime with abundance levels of West Coast salmon (Hare et al., 1999). Recent increases in numbers of some West Coast salmon, therefore, may also suggest a declining trend for Alaska salmon. However, no conclusive evidence of a decline is available from recent catch histories. While Alaska's commercial catch did decline in the 3 years following the record 1995 harvest, landings in 1999 reached 217 million fish, nearly matching the peak harvest year of 1995. Landings in 2000 fell to 137 million salmon, rebounded to 175 million fish in 2001, again dropped to 131 million in 2002, increased to 178 million in 2003, and then reached a new all-time high harvest level of 222 million salmon in 2005. Harvest levels in 2006 and 2007 were 141 and 213 million salmon, respectively. All of these recent Alaska harvests are well above the long-term average, in spite of some rebounds that West Coast salmon runs have experienced. Unspoiled freshwater habitats, favorable oceanic conditions, and adequate numbers of salmon returning to spawn in rivers and streams are likely the paramount issues affecting current Alaska salmon abundance. Alaska salmon management continues to focus on maintaining pristine habitats and ensuring adequate escapements.

MANAGEMENT

Alaska's 34,000-mile coast is nearly two-thirds the length of the coastline of the coterminous lower 48 states. Along this coastline, over 14,000 water bodies support populations of five species of salmon. Salmon management over such a vast area requires a complex mixture of domestic and international bodies, treaties, regulations, and other agreements. Federal and state agencies cooperate in managing Alaska salmon fisheries. The Alaska Department of Fish and Game (ADFG) manages salmon fisheries within state jurisdictional waters, where the majority of harvest occurs. ADFG's principal salmon conservation policy is based on escapement-based management, providing adequate spawning escapement into natal streams over any preseason harvest goals. Management in the U.S. Exclusive Economic Zone (EEZ; 3–200 n.mi. offshore) is the responsibility of the North Pacific Fishery Management Council (NPFMC), which has deferred specific regulations to the State of Alaska. Management of state salmon fisheries is based primarily on regional stock groups of each species, and on time and area harvesting by specific types of fishing gear.

Over 25 different commercial salmon fisheries are managed within a special limited-entry permit system that specifies when, where, and what type of fishing gear can be used in each area of the state. These fisheries, extending from Dixon Entrance in southeastern Alaska to Norton Sound in the Bering Sea, are allowed to catch salmon in different fisheries with drift gillnets, set gillnets, beach seines, purse seines, hand trolls, power trolls, or fish wheel harvest gear (CFEC, 1997). Sport fishing is limited to hook and line, while subsistence fishermen may use gillnets, dip nets, or hook and line. Special permits also regulate some native subsistence harvesting of salmon; and in some rivers, fish wheels are allowed.

Management of some Alaska salmon fisheries is also negotiated with Canada under the Pacific Salmon Treaty, first implemented in 1985. The initial fishing agreements between the two countries, setting catch allocations and ceilings for individual fisheries and species, were based on an individual-stock-based management (ISBM) principle. In 1999, a new fishery management regime was reached under the Treaty, based on the aggregate abundance-based management (AABM) principle (PSC, 1999). This new accord, originally proposed by Alaska, sets overall harvest levels based on the fluctuating abundance levels for groups of stocks of different species.

Major issues of concern between the two countries include 1) Chinook salmon catches in southeastern Alaska, where Canadian salmon are caught along with other non-Alaska U.S. stocks; 2) fisheries in the Dixon Entrance area, where each country catches salmon originating in the other nation; 3) transboundary river stocks and fisheries associated primarily with the Alsek, Taku, and Stikine Rivers; 4) Canadian fisheries off the west coast of Vancouver Island that catch salmon bound for Washington, Oregon, and the Columbia River; and 5) Strait of Juan de Fuca fisheries for sockeye and pink salmon bound for the Fraser River in Canada. Chinook salmon issues under the Treaty are among the more important concerns affecting Alaska fisheries (PSC, 1999, 2004). Currently treaty negotiations are underway between the two countries to establish a new 10-year management regime.

Another area involving Alaska salmon and negotiations with Canada concerns the stocks and fisheries in the 2000-mile-long Yukon River system. After 16 years of deadlocked talks, an agreement was recently adopted and signed, setting harvest quotas and establishing restoration, conservation, and management programs for Yukon River Chinook and chum salmon stocks.

On a broader international scope, the management of salmon harvest in the high seas of the North Pacific Ocean from 1957 to 1992 was under the International North Pacific Fisheries Commission (INPFC) and bilateral and multilateral agreements negotiated with Taiwan and the Republic of Korea. In 1993, the North Pacific Anadromous Fish Commission (NPAFC) replaced the INPFC. Initial signatories to the new Commission included Canada, Japan, the Russian Federation, and the United States. In 2003, the Republic of Korea officially joined the Commission, which now provides a broad framework for international cooperation in salmon management and research in the North Pacific Ocean.

The NPAFC Convention prohibits high seas salmon fishing and trafficking of illegally caught salmon. Coupled with United Nations General Assembly (UNGA) Resolution 46/215, which bans large-scale pelagic driftnet fishing in the world's oceans, harvesting of Pacific salmon on the high

Karen Ducey, NMFS

Crew members on a commercial fishing vessel removing salmon from a gillnet in Bristol Bay, Alaska.

Table 13-1
Productivity in metric tons (t) and status of Alaska salmon fisheries resources.

Species/stock	Recent average yield (RAY)[1]	Current yield (CY)[2]	Sustainable yield (MSY)[2]	Stock level relative to B_{MSY}	Harvest rate	Stock status
Chinook salmon	5,106	5,200	5,200	Below	Not overfishing	Not overfished
Chum salmon[3]	61,636	51,600	51,600	Above		
Coho salmon[3]	15,642	17,600	17,600	Below		
Pink salmon[3]	179,632	135,300	135,300	Above		
Sockeye salmon[3]	115,433	108,200	108,200	Above		
Total	377,449	317,900	317,900			

[1]2001–03 average.
[2]1980–2003 average.
[3]Part of the Coho Salmon Assemblage. Collectively, the Assemblage is not overfishing and not overfished.

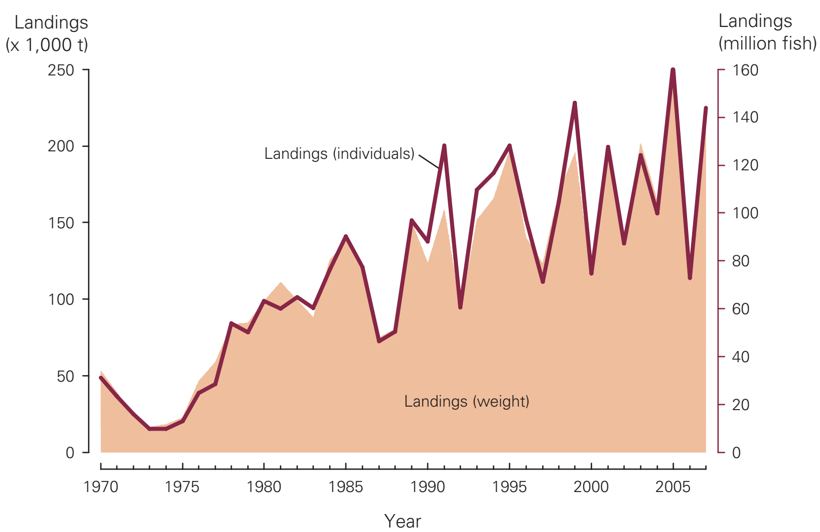

Figure 13-2
Commercial landings of Alaska pink salmon in metric tons (t) and individual fish, 1970–2007.

seas, except for illegal fishing, no longer exists. Thus, effective management control was returned to the salmon-producing nations. A basic premise of NPAFC policy is that the country of origin has proprietary ownership of its stocks even as free-swimming adults in the open ocean. NPAFC, with agreement among the five parties, has also established a formal science plan to help direct priority research for better knowledge of salmon stocks around the Pacific Rim.

Because salmon are anadromous and spend a portion of their lives in freshwater streams, rivers, and lakes, the health of salmon populations in Alaska is directly influenced by land management practices. The quality of freshwater habitats determines the success of both reproduction and initial rearing of juveniles. Several agencies, entities, and groups have significant influence on the quality of freshwater spawning and rearing habitats for salmon throughout the state. Included among these are the U.S. Forest Service, Bureau of Land Management, National Park Service, National Wildlife Refuges, Alaska State Parks and Forests, and Alaska Native Regional and Village Corporations, as well as municipalities, boroughs, and private landowners that control watersheds used by salmon.

SPECIES AND STATUS

All five species of Alaska salmon (pink, sockeye, chum, coho, and Chinook) are fully utilized, and stocks in most regions of the state have rebuilt to near or beyond previous high levels (Table 13-1). Research into all aspects of the life histories of Pacific salmon has been extensive (Groot and Margolis, 1991), and this information has been used to regulate fisheries by monitoring escapement size and catch numbers by species, season, and area. Although there has been a high statewide abundance of salmon, there are issues of serious concern for some stocks, especially for certain species and regions. For example, stocks in western Alaska (especially Chinook and chum salmon) have generally been at very depressed levels since the mid 1990's. Some of the same issues implicated in the declines of Pacific Northwest salmon stocks are of concern in certain areas of Alaska. These issues include overfishing, incidental take of salmon as bycatch in other fisheries, and loss of freshwater spawning and rearing habitats.

Pink Salmon

Pink salmon are the most abundant species of Pacific salmon in Alaska (Figure 13-2), account-

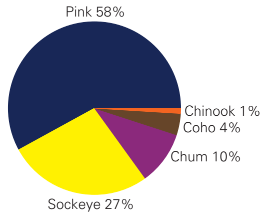

Figure 13-3
Alaska commercial salmon landings by numbers of fish, averaged over 1970–2007.

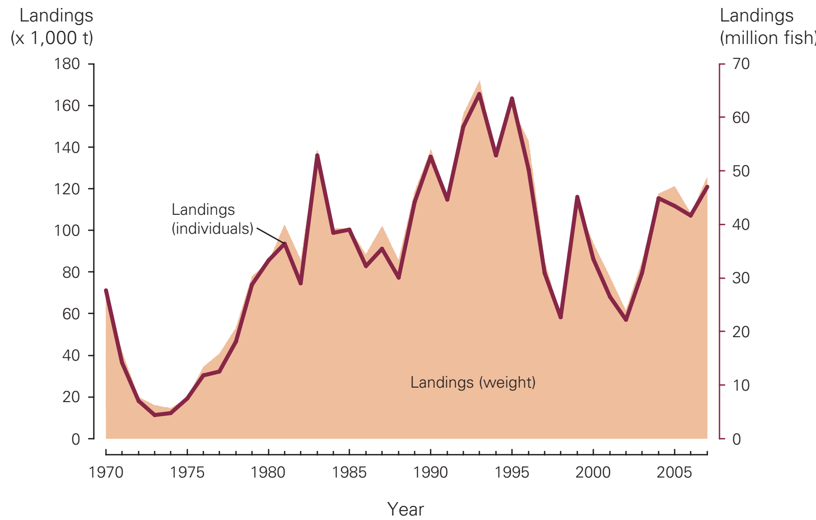

Figure 13-4
Commercial landings of Alaska sockeye salmon in metric tons (t) and individual fish, 1970–2007.

ing for 40 to 70% of the total harvest each year. During the past 37-year period (1970–2007), pink salmon comprised 58% of the average annual commercial harvest of salmon in Alaska (Figure 13-3). Pink salmon are mostly harvested by purse seines in southeastern and central southern Alaska, as well as around Kodiak Island. In Prince William Sound, hatcheries produce a large portion of the pink salmon catch.

Unique among Pacific salmon, pink salmon have a fixed life history cycle whereby the species always matures and spawns at 2 years of age. This cycle is genetically set so that spawners in even-numbered years are always separate and distinct from spawners in odd-numbered years. Throughout much of its range, the species has viable populations in both odd- and even-numbered years; however, in some areas pink salmon only occur in one or the other cycle year. In Bristol Bay and western Alaska, for example, pink salmon are near the effective limit of their northern range and occur mostly in even-numbered years. At the southern limit of their range (the Pacific Northwest), they occur primarily in odd-numbered years. There is, however, growing evidence of population increases of pink salmon and other salmon species in northern parts of western Alaska (Norton Sound and Kotzebue Sound), perhaps due to climatic changes.

Sockeye Salmon

Sockeye salmon, the second most abundant species caught in Alaska fisheries (Figures 13-3, 13-4), accounted for 27% of the harvest in recent years (ADFG, 2007). Sockeye salmon, however, provide a greater dollar value than all other commercially caught salmon in Alaska combined, usually yielding between 60 and 70% of the ex-vessel value of the annual harvest. Bristol Bay sockeye salmon in southwestern Alaska is the most valuable wild capture fishery for salmon in the world, previously yielding $300 to $400 million (ex-vessel) per year in the 1980's and early 1990's. In the late 1990's and early 2000's, prices declined significantly, and the ex-vessel value of Bristol Bay sockeye salmon has averaged only $77 million per year during the past 10-year period of 1998–2007 (ADFG, 2007). A recent upswing in Alaska sockeye salmon prices in Bristol Bay from 2004–06 has averaged $103 million per year in ex-vessel value.

Sockeye salmon are harvested by purse seine in southeastern Alaska, Kodiak Island, and Chignik fisheries and by drift gillnet or set gillnet throughout the state. The largest fisheries for sockeye salmon occur in Bristol Bay, Cook Inlet, the Alaska Peninsula and Aleutian Islands, and Kodiak Island regions. Other significant fisheries also occur in southeastern Alaska, Prince William Sound, and Chignik.

Juvenile sockeye salmon most commonly grow in lakes for 1 to 2 years before migrating seaward as smolts. The large lake complexes associated with Bristol Bay rivers provide this necessary life history component and form a critical part of the important fishery in this region. The Bristol Bay fishery, based on drift and set gillnet catches, is concentrated in a narrow window of time from late June until mid July when millions of returning adult sockeye salmon pour into Bristol Bay rivers from the ocean.

Commercial sockeye salmon catches in Bristol Bay in 1997 (12.1 million fish) and 1998 (10.0

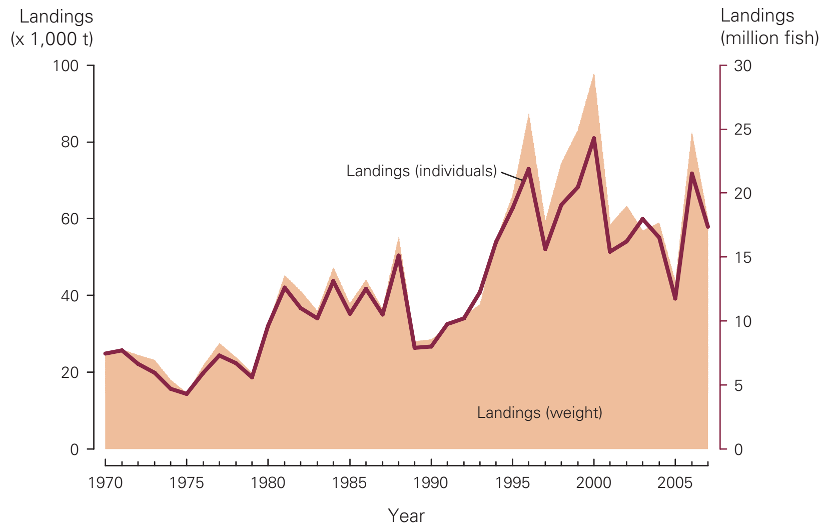

Figure 13-5
Commercial landings of Alaska chum salmon in metric tons (t) and individual fish, 1970–2007.

million) fell sharply, relative to harvest levels that averaged 36.5 million sockeye salmon per year during the previous 5-year period, 1992–96. Returns improved somewhat in 1999 and 2000, with commercial catches of 26.1 and 20.5 million sockeye salmon respectively, but declined again in 2001, 2002, and 2003 with commercial catches of only 14.2, 10.7, and 14.9 million fish, respectively (ADFG, 2007). Beginning in 2004, commercial catches again improved to 26.3 million, followed by catches of 24.5, 28.5, and 29.5 million, respectively, in 2005, 2006, and 2007. Most of these recent harvest levels of sockeye salmon in Bristol Bay are well below previous decadal averages. These low returns continue to create significant hardships to state residents and fishermen dependent on this fishery.

Several hypotheses have been suggested to explain recent declines in sockeye salmon returning to Bristol Bay. One hypothesis suggests that unusually warm and calm summer weather has resulted in warmer water temperatures. Elevated water temperatures may cause high mortality and changes in migration of adult salmon entering Bristol Bay. Other hypotheses include changes in freshwater or ocean rearing conditions affecting the growth and survival of juveniles and immature adults, increased predation at sea, interception by other fisheries, disease, and in some instances, over-escapements on spawning grounds. The true causes likely involve a combination of many factors and remain unknown. It is also unknown whether these shortfalls are due to a shift in cyclical oceanic conditions, which could lead to lower survival and smaller sockeye returns in future years.

Chum Salmon

Chum salmon (Figure 13-5) are harvested commercially by purse seines, drift and set gillnets, and in large western Alaska rivers by fishwheels in subsistence fisheries. Over the 37-year period from 1970 to 2007, chum salmon accounted for 10% of Alaska's salmon harvest (Figure 13-3). Statewide average annual catches of chum salmon were 18.6 million fish during 1996–2003. The harvest in 2000 was well above this average, with a record harvest of 24.3 million fish (ADFG, 2007). Currently, 60–70% of the commercially harvested chum salmon in Alaska occur in the southeastern region, where hatcheries produce a significant portion of the catch.

Recently, chum salmon runs in southwestern and western Alaska, similar to sockeye salmon in Bristol Bay, have been well below long-term averages, which has added to the hardships experienced by fishermen in those regions. Western Alaska chum salmon may spend part of their ocean life in the Gulf of Alaska and then funnel through the Aleutian Island passes as maturing adults on their return migration. Management of chum salmon fisheries in western Alaska is complicated because a fishery (targeting sockeye salmon returning to Bristol Bay) at False Pass in the Aleutian Islands incidentally harvests chum salmon destined for the Kuskokwim and Yukon Rivers in western Alaska. The Alaska Board of Fisheries has placed major restrictions on the False Pass fishery in an effort to help rebuild depleted chum salmon resources in western Alaska; however, at more recent Board meetings those restrictions were somewhat relaxed.

In some years significant numbers of chum salmon are incidentally caught as bycatch in Bering Sea groundfish fisheries that target walleye pollock and other groundfish species. Bycatch of chum salmon in these fisheries may have negative impacts on populations of stock originating from western Alaska rivers. Chum salmon in western Alaska are not only an important part of commercial fisheries in that region, but also a significant subsistence resource for local residents.

Coho Salmon

Coho salmon are caught commercially by purse seines in southeastern and central southern regions, by drift or set gillnets in all regions, and by hand and power troll gear in the southeastern region. Coho, along with sockeye and Chinook salmon, are popular target species in recreational fisheries throughout Alaska.

Commercial catches of coho salmon across Alaska in 2002 totaled 5.1 million fish and have averaged 4.5 million fish during the most recent 10-year period, 1998–2007 (ADFG, 2007). These harvest levels are well above the record low catches in the 1970's (Figure 13-6). This recent period of relatively high commercial harvests was due to generally favorable returns of both hatchery and wild coho salmon in the southeastern region, where over 3.0 million coho salmon were harvested in 1999, 2001, 2002, and 2004. Exceptionally high marine survivals of coho salmon smolts, averaging over 20% in some systems in this region, are thought to be the main reason for these harvest levels (Shaul et al., 2007). This favorable survival pattern, however, may be shifting. In 2007 the statewide harvest of coho salmon was 3.7 million fish, with 2.1 million from the southeast region (ADFG, 2007).

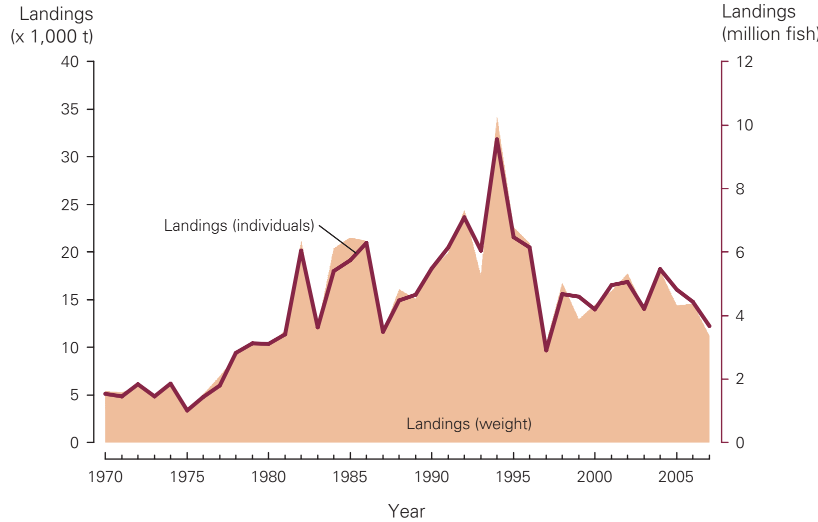

Figure 13-6
Commercial landings of Alaska coho salmon in metric tons (t) and individual fish, 1970–2007.

Chinook Salmon

The annual commercial harvest of Chinook salmon has ranged between 360,000 and 800,000 fish over the past two decades (Figure 13-7). The statewide 10-year (1998–2007) average annual harvest was 568,000 fish (ADFG, 2007). Chinook salmon, like coho salmon, are commercially harvested by purse seines in southeastern and central southern regions, by drift or set gillnets in all regions, and by hand and power troll gear in the southeastern region. In addition, fishwheels harvest Chinook salmon in western Alaska rivers for commercial sales and for subsistence uses.

In general, Chinook salmon are the first species each calendar year to begin spawning migrations into Alaska rivers. Fisheries are permitted to directly target these early returning runs of Chinook salmon in only a few Bristol Bay and western Alaska rivers. However, Chinook salmon are often taken as bycatch in fisheries targeted on other salmon. Sockeye salmon migrations into many larger river systems begin during the later portion of Chinook salmon runs in the same rivers. In these cases (such as certain Cook Inlet and southeastern rivers and in the Copper River near Cordova), significant numbers of Chinook salmon may be caught incidentally in fisheries targeting sockeye salmon. Some of these fisheries may have a quota in place limiting the catch of Chinook salmon.

Chinook salmon stocks thoughout Alaska in

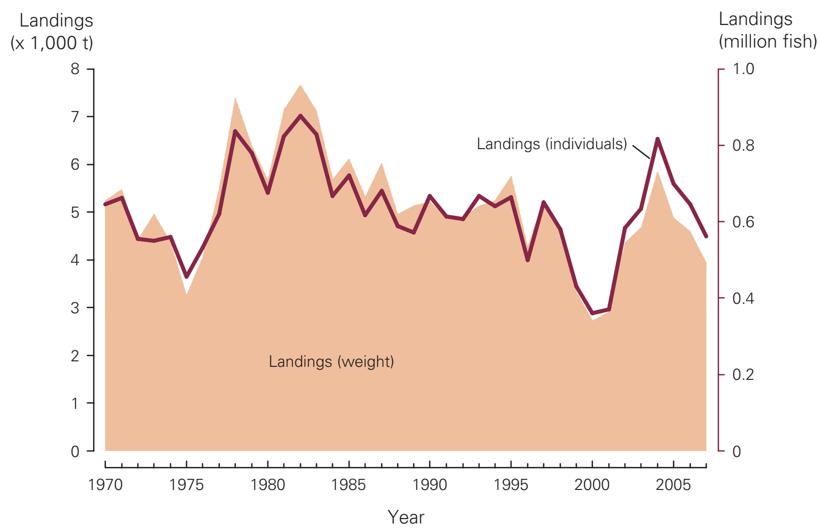

Figure 13-7
Commercial landings of Alaska Chinook salmon in metric tons (t) and individual fish, 1970–2007.

Figure 13-8

Ex-vessel value of Alaska commercial salmon landings, 1970–2007.

general have relatively stable sustainable populations (Heard, et al., 2007; Wertheimer, 1997). Western Alaska, however, is the one region of the state where there is concern over trends in abundance of this species. Harvest levels of Chinook salmon in Bristol Bay and in the Kuskokwim and Yukon Rivers have been in a declining mode since the 1980's. In 2001, runs into the Yukon River, a transboundary river originating in Canada and managed under a separate U.S.–Canada Treaty Annex, were so low that no commercial fishery was allowed. Another area of concern is the often large bycatch of Chinook salmon in Bering Sea groundfish fisheries and the likelihood that a significant part of this bycatch is from western Alaska stocks. In 2007 a total of 130,000 Chinook salmon were caught as bycatch in those fisheries (see groundfish catch reports at http://www.fakr.noaa.gov/).

A quota, under provisions of the Pacific Salmon Treaty, normally regulates the Chinook salmon harvest in southeastern Alaska, where significant numbers of non-Alaska-origin fish are caught. The Alaska Board of Fisheries, a jurisdictional body dealing with allocation of fisheries resources, then reallocates this annual harvest quota among various fisheries. For example, the troll fishery (both hand and power troll), which historically has been highly dependent on Chinook salmon, is allocated the largest portion of the southeastern Chinook salmon quota. Net fisheries in the region (purse seine and drift gillnet) primarily target pink, chum, or sockeye salmon but are provided quotas to take a limited catch of Chinook salmon in pursuit of other target species. The remaining allowable quota is allocated to guided and non-guided sport fisheries.

ISSUES

Value of Alaska Salmon

Although commercial harvests have been at high levels in recent years, the value of the catch has declined significantly due to a number of complex worldwide factors. The record 1995 statewide catch of 451,000 metric tons (t) was worth $466 million (ex-vessel), far less than the smaller 1992 harvest (312,000 t), valued at $546 million. The fluctuating but downward trend in ex-vessel value has persisted over much of the last decade (Figure 13-8), although there has been a moderate upward trend in ex-vessel value over the last 3 years (2005–07) primarily due to aggressive marketing campaigns. Along with this general decline in value is a rising trend in total worldwide salmon production (ASMI, 1993). Increases in world salmon supplies are due to rapid growth in the worldwide production of farmed salmon (Folsom et al., 1992), in addition to record catches of wild salmon and of fish produced from hatcheries and ocean ranching programs in Alaska, Japan, and Russia.

Total world production from capture and farmed fisheries in 2002 was about 1.8 million t, including 983,000 t of farmed salmon (Knapp, 2003). This production represents a continuation of recent trends for increased production of farmed salmon and lower prices paid to fishermen in capture fisheries (Heard, 1996, 1997). Decreases in the price paid for wild-caught salmon also characterize capture fisheries for salmon in Japan (Kaeriyama and Urawa, 1993) and elsewhere. Although Alaska's salmon harvest represents about 45% of all wild salmon caught, it only represents 19% of total world salmon production. While more than 15 countries now produce farmed salmon, over 70% of production comes from just three countries: Norway, Chile, and the United Kingdom (Knapp, 2003). Beginning in 2000, Norway's farmed Atlantic salmon annual production has exceeded the total Alaska commercial salmon harvest.

Recreational Salmon Fisheries

Recreational fishing continues to grow and be an important component of the Alaska lifestyle. This is partly due to the fact that many households use sport fishing as a convenient method to collect wholesome seafood for the table. Some part of the total recreational salmon fishery in Alaska, therefore, might more appropriately be included in subsistence fishery statistics. Much of the recent growth in recreational fishing is due to an increase in guided fishing trips for visitors and tourists. Sport fishing for salmon in Alaska as a recreational outlet is an important pursuit for both residents and visitors alike. Since 1990, the number of sport fishing licenses sold to nonresidents has exceeded the number sold to Alaska residents (Howe et al., 2001). A total of 392,980 sport fishing licenses were issued in 2002; 71% of these licenses were issued to nonresident anglers.[1] Sport fishing for salmon is a vital part of the recent rapid growth in Alaska tourism.

Coho salmon are the most popular recreational salmon species in Alaska, representing 38% of the 3.2 million salmon caught by recreational fishermen in 2002. This is followed by pink salmon (25%), sockeye salmon (21%), chum salmon (7%), Chinook salmon (5%), and non-anadromous landlocked salmon (4%).[2]

Bycatch and Multispecies Interactions

Salmon bycatch by U.S. groundfish fisheries in the Bering Sea and the Gulf of Alaska continues to be a problem in fisheries management. Although the groundfish fisheries are prohibited from retaining any salmon, many are taken incidentally, especially in trawl fisheries. Most of the bycatch are chum salmon and Chinook salmon. The problem is being addressed by the NPFMC through time–area closures and bycatch limits set for different gear types in the groundfish fisheries.

Protecting Salmon Habitats

Responsible conservation of Alaska's salmon resource is a national issue shared with the State of Alaska. Maintaining this renewable resource requires conservation of the thousands of miles of riparian habitat in the state that support salmon production. Competing uses for this habitat include logging, mining, oil and gas development, and industrial and urban development. Although progress has been made in setting Federal and state land-use guidelines, conflicts still occur. Natural resource managers continually face increasing demands from extractive industries to log, drill, or fill riparian habitats while working to change land-use laws. For example, the debate continues between land managers and the logging industry over the required size of clear-cut buffer zones along anadromous fish streams. In its recent review of timber harvest in the Tongass National Forest, the U.S. Forest Service concluded that long-term application of current timber harvest procedures could lead to (or continue) declines in habitat productivity and the eventual loss of salmon stocks. However, efforts are being made to protect the salmon resource and the habitats they depend on; the recent buy-back of Federal gas and oil leases in Bristol Bay is one such effort. A new proposed development in the Bristol Bay drainage area is the controversial Pebble Mine project that would build one of the largest open-pit gold and copper mines in the world. Many fisheries resource groups oppose this project.

William Heard, AFSC

A young sport fisherman with his coho salmon catch. Recreational salmon fishing is popular among state residents and draws many tourists from outside Alaska as well.

[1]Alaska Dept. of Fish and Game, data files.
[2]Alaska Dept. of Fish and Game, Sport Fish Division, data files.

William Heard, AFSC

Pink salmon fry.

Hatcheries and Ocean Ranching

Alaska's salmon enhancement programs produce significant numbers of fish for commercial and sport harvest. While most hatcheries are now operated by private-sector regional aquaculture associations, the state maintains oversight of the hatcheries and manages them to minimize catches of wild salmon in fisheries that catch large numbers of returning hatchery fish (McGee, 2004). However, overfishing is of concern where wild stocks are in low abundance and spawning escapement goals may not be achieved. Prince William Sound is an area of particular concern where large returns of hatchery pink salmon mix with lower numbers of wild fish. In a recent analysis, one group of scientists argued that the pink salmon hatchery program in Prince William Sound has essentially replaced the wild stock production that would have occurred in the absence of hatcheries (Hilborn and Eggers, 2000). Other scientists, however, have examined the same data sets and concluded that hatcheries in the region were primarily supplementing wild stock production, with net gains of 17.5–23.7 million pink salmon to fisheries in the region annually (Wertheimer et al., 2001, 2004).

The present statewide hatchery program, which began in 1974, contributed almost 73 million salmon to the total commercial salmon harvest in Alaska and 348,983 salmon to sport fisheries in 2003 (Farrington, 2004). Contributions to salmon fisheries from Alaska hatcheries vary considerably by species and region. Hatcheries make important contributions in southeastern Alaska to catches of chum, coho, and Chinook salmon; in Prince William Sound to catches of coho, pink, and sockeye salmon; in Cook Inlet to catches of coho, Chinook, and sockeye salmon; and in Kodiak to catches of coho salmon (Farrington, 2004; White, 2008).

Interception Fisheries

Significant progress has been made to control the interception and incidental take of Alaska's salmon resources. First, a former high-seas salmon fishery by Japan that was authorized by an international convention from 1952–92 was terminated under the new Convention for the Conservation of Anadromous Stocks in the North Pacific Ocean. Second, high-seas driftnet fisheries for squid by various countries that also intercepted U.S.-origin fish in the central North Pacific were terminated by United Nations General Assembly Resolution 46/215. The NPFMC actively manages the problem of salmon bycatch in U.S. groundfish fisheries in the Bering Sea and Gulf of Alaska through time–area closures and bycatch limits. Interceptions of nontarget salmon species within Alaska-managed salmon fisheries continue to be addressed by the Alaska Board of Fisheries. Additionally, negotiations continue between the United States and Canada under the Pacific Salmon Treaty to resolve long-standing interception issues, particularly in the northern British Columbia and Alaska boundary area.

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Pacific Coast and Alaska Pelagic Fisheries

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Photo above:
Close-up view of a California market squid.

INTRODUCTION

Several stocks of coastal pelagic species (CPS) support fisheries along the Pacific Coast from northern Mexico to Alaska. The major ones are Pacific sardine, northern anchovy, Pacific chub mackerel), jack mackerel, California market squid, and Pacific herring. Sardine, anchovy, and the two mackerels are primarily concentrated and harvested off California and Baja California, although a major sardine fishery has recently developed off the Pacific Northwest. Market squid are distributed from the Pacific Northwest to Baja California, Mexico, but the population is mostly harvested in northern and southern California. Pacific herring are taken along the West Coast from California to Alaska.

Sardine and anchovy are the most prominent of the CPS fisheries from a historical perspective. These small pelagic fish, like Peruvian anchovy and Japanese sardine, tend to fluctuate widely in abundance from year to year. California sardines supported the largest fishery in the western hemisphere during the 1930's and early 1940's, when total annual catches averaged 500,000 metric tons (t). Sardine abundance and catches declined after World War II, and the stock finally collapsed in the late 1950's. In the mid 1940's, U.S. processors began canning anchovy as a substitute for sardine. Consumer demand for canned anchovy, however, was low, and catches from the mid 1940's to mid 1950's averaged only 20,000 t per year. Catches declined and remained low before starting to increase in 1965 after the sardine collapse. Together with catches from Mexico, the total catch increased

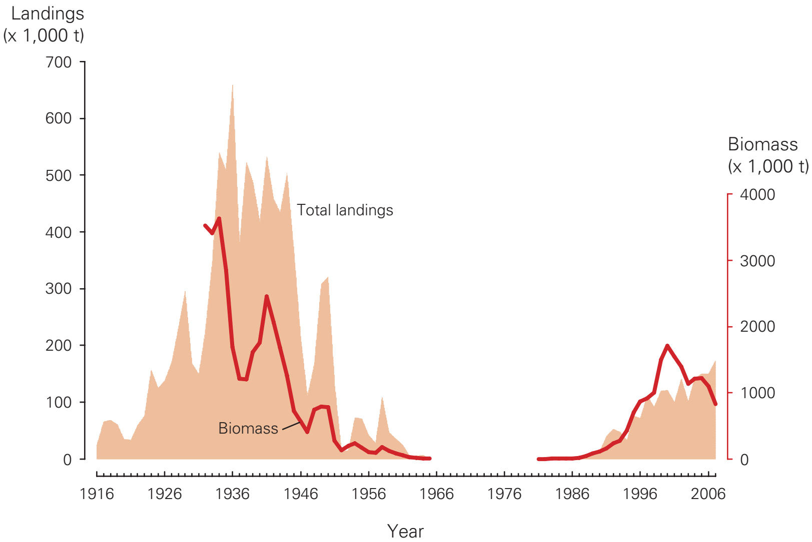


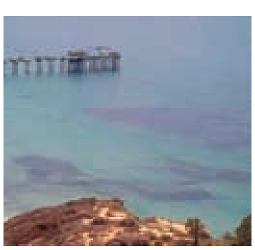
Figure 14-1

Pacific sardine landings and biomass in metric tons (t), 1916–2007. No data are available for 1966–80, when the biomass had declined to immeasurable low levels.

to 250,000 t per year during 1975–80. Thereafter, U.S. catches declined mainly due to significant price reductions for fishmeal. Low prices and market problems continue to prevent a significant U.S. reduction fishery for anchovy in recent years. The other small pelagic species also have a tendency to fluctuate widely in abundance.

All of these pelagic fishery resources are under state or Federal management. The fisheries for Pacific sardine, northern anchovy, Pacific chub mackerel, and jack mackerel are managed under the CPS Fisheries Management Plan (FMP) by the Pacific Fishery Management Council; California market squid are monitored under this FMP as well, but management has been transferred to the State of California. The State of California also manages the Pacific herring fishery in the waters off California. The State of Alaska manages its inshore Pacific herring fishery.

The wellbeing of ecologically related species in the marine ecosystem is an important factor in management of CPS resources. For example, the endangered brown pelican depends on anchovy as an important food source. Thus, the CPS FMP has specified a threshold for its optimum-yield determination to prevent severe depletion and provide adequate forage for marine fishes, mammals, and birds.



Anne Allen, SWFSC

Dense schools of anchovy seen from the coast of southern California.

PACIFIC COAST PELAGIC FISHERIES

Pacific Sardine

California's Pacific sardine abundance has gone through multiple boom-and-bust cycles (Figure 14-1). The decline of the resource, from a biomass of more than 3.6 million t in the 1930's to immeasurably low levels (a few thousand t) in the 1970's, stimulated much debate as to whether fishing or an adverse natural environmental period was to blame. In retrospect, the intense fishing pressure on the resource in the 1930's and 1940's probably accelerated a long-term pattern of natural decline. The biomass of sardines remained negligibly low for about 40 years. Stock biomass increased rapidly through the 1980's and 1990's, peaking at 1.71 million t in 2000, but has since decreased to 832,706 t in July 2007 (Hill et al., 2007).

In the past, sardines were harvested for fishmeal, bait, and human consumption. However, there is currently no fishmeal (reduction) fishery. Sardines are now taken for human consumption, bait, and aquaculture feed. Commercial demand for sardines is strong and, as resource abundance has grown, the coastwide fishery has revived. Recent average yields (2005–07) for the United States are 105,667 t per year and 157,573 t for combined fisheries of Pacific North America (Table 14-1). The current U.S. yield is 135,946 t, or about 77% of the maximum sustainable yield for the U.S. fishery. However, the most recent stock assessment indicated a decline in abundance and resulted in a significantly lower harvest guideline for 2008 (Hill et al., 2007).

Northern Anchovy

Northern anchovy, fished off California and Mexico, are divided into several subpopulations. The central subpopulation of the resource is the one that supports most of the U.S. fisheries. Historically, anchovy have been harvested for reduction into fishmeal, oil, and soluble protein products. Other uses include human consumption (fresh, frozen, canned, and paste), and as bait (live and frozen) for recreational fisheries.

Anchovy landings in California have fluctuated more in response to market conditions than

Species/stock	Recent average yield (RAY)[1]	Current yield (CY)	Sustainable yield (MSY)	Stock level relative to B_{MSY}	Harvest rate	Stock status
Pacific Coast						
California market squid[2]	51,458	Unknown	Unknown	Unknown	Unknown	Unknown
Jack mackerel[3]	705	646	48,000	Unknown	Not overfishing	Undefined
Northern anchovy[4]	14,946	13,297	31,000	Unknown		
Pacific herring[5]	85	34	Unknown	Unknown		
Pacific chub mackerel[6]	13,657	16,623	102,327	Above	Not overfishing	Not overfished
Pacific sardine[7]	157,573	173,119	175,361	Above	Not overfishing	Not overfished
Subtotal, Pacific Coast	238,424	255,177	408,180			
Alaska						
Pacific herring (Bering Sea)[8]	23,541	Unknown	Unknown	Near		
Pacific herring (Gulf of Alaska)[8]	17,212	Unknown	Unknown	Near		
Subtotal, Alaska	40,753	40,753	40,753			
Total	279,177	295,930	448,933			
U.S. subtotal	216,742	207,232	372,438			

[1]2004–06 coastwide average, unless otherwise noted.

[2]Currently, California market squid are managed based on an egg escapement model, which evaluates the interaction between the population's reproductive output and levels of fishing pressure. This assessment approach does not provide estimates of historical or current total biomass, so a definitive yield (e.g. quota, CY, MSY, etc.) cannot be determined at this time. Values are the U.S. share only.

[3]RAY and CY are 2005–07, U.S. share only. MSY is a crude coastwide estimate calculated using 1995 data.

[4]RAY and CY are 2005–07; the U.S. share of the RAY is 11,641 t. Status determinations are based on two subpopulations and are not available for the coastwide stock. The central subpopulation is not overfishing and has undefined stock status; the northern subpopulation has undefined harvest rate and stock status.

[5]RAY is 2000–02, U.S. share only. Harvest rate and stock status determinations are not available for this stock.

[6]U.S. share of the RAY is 6,433 t.

[7]RAY and CY are 2005–07; the U.S. share of the RAY is 105,667 t.

[8]Harvest rate and stock status are not available for this stock.

Table 14-1

Productivity in metric tons (t) and status of Pacific Coast and Alaska pelagic fisheries resources.

to stock abundance. Figure 14-2 shows the historical catch trend for the United States and Mexico. Landings by the United States have varied from 1,000 t to nearly 160,000 t. Since 1983, U.S. landings have been low, and have been used mostly for live bait and other non-reduction uses. The biomass trend for the anchovy resource (Figure 14-2) hit a peak of 1.6 million t in 1973 and declined steadily to 392,000 t by 1994. The anchovy resource, last assessed in 1995 (Jacobson et al., 1995), is assumed to be at a moderate level of abundance. The default acceptable biological catch (ABC) for the United States is 25,000 t or 30% of the maximum sustainable yield (Table 14-1). Recent catches have been much lower (about 11,000 t) due to a lack of commercial markets.

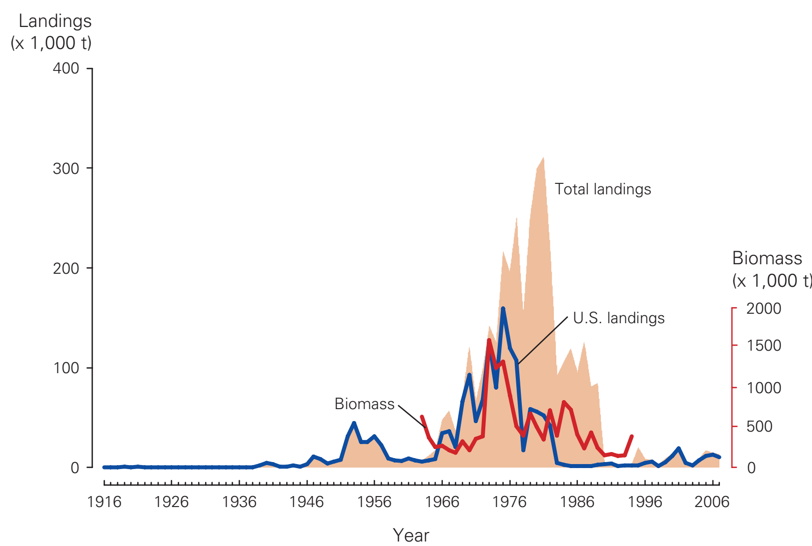


Figure 14-2

Northern anchovy landings and biomass in metric tons (t), 1916–2007.

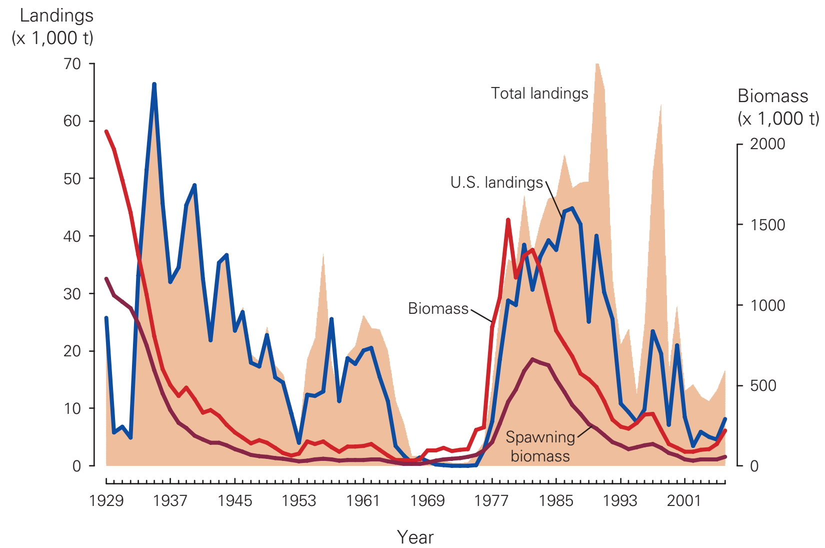


Figure 14-3

Pacific chub mackerel landings and biomass in metric tons (t), 1929–2006.

Pacific Chub Mackerel

Pacific chub mackerel has a worldwide distribution in temperate and subtropical seas. On the Pacific Coast, it is most abundant south of Point Conception, California. Pacific chub mackerel supported one of California's major fisheries during the 1930's and 1940's and again in the 1980's and 1990's. It was second only to sardine during the heyday of the southern California sardine fisheries in the 1930's and 1940's. The peak catch in that era was 66,600 t in 1935, and catches generally declined throughout the 1940's and 1950's before reaching a low in the mid 1960's and early 1970's (Figure 14-3). In 1970, a moratorium was placed on the fishery after the stock collapsed.

A series of successful year-classes in the late 1970's stimulated a recovery of the stock, and the fishery was reopened under a quota system in 1977. Three separate fisheries now harvest the resource: the California commercial fishery, a sport fishery, and a Mexican commercial fishery. From 1980–89, the California recreational catch averaged 1,500 t per year. The combined fisheries of the United States and Mexico landed 71,551 t in 1990 and 62,823 t in 1998 (Figure 14-3). A harvest guideline of about 40,000 t currently restricts the U.S. commercial catch (Dorval et al., 2008), but the recent average yield has been only 6,400 t (Table 14-1). If the biomass dips below 18,200 t, commercial fishing will be stopped.

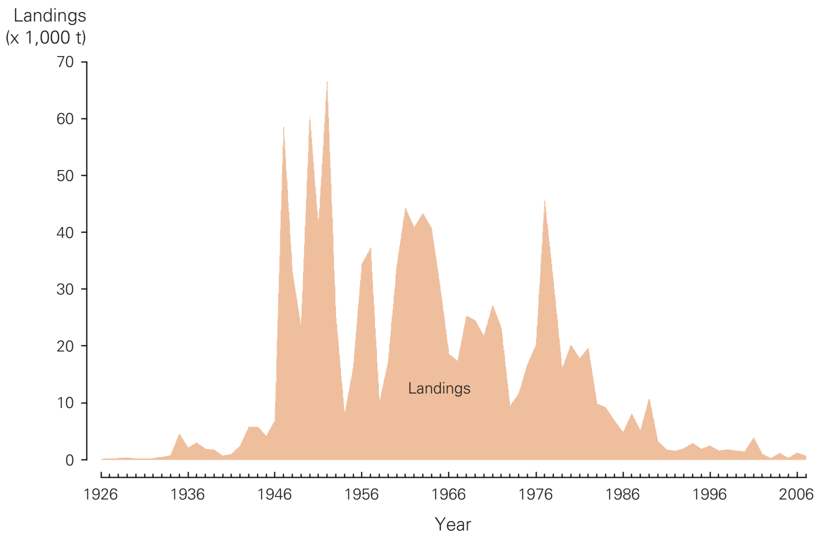
The historical trend in Pacific chub mackerel biomass is shown in Figure 14-3. Recent peak abundance was 1.34 million t in 1982. Biomass declined to a recent low of about 90,000 t in 2001 and since then has risen to a recent average of about 280,000 t. Analyses of fish-scale deposits in ocean bottom sediments off southern California and Baja California indicate that the prolonged period of high Pacific chub mackerel biomass levels during the late 1970's and 1980's may have been unusual and would only be expected to occur, on average, about once every 60 years.

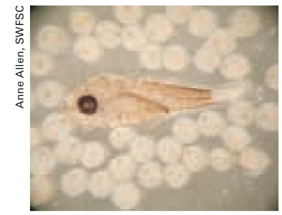
Jack Mackerel

Jack mackerel catches have fluctuated widely with changing market demands and the ability of the fleet to fish for other species that were more valuable or available, especially sardine, Pacific chub mackerel, and California market squid. Additionally, the availability of jack mackerel can be very erratic. Jack mackerel has two distinct behavior patterns during its life cycle: juveniles are found inshore off southern California and Baja California, while adult fish are distributed offshore and farther north, as far as the Gulf of Alaska in some years. Adult jack mackerel found offshore are sometimes caught incidentally by trawlers, particularly those targeting Pacific hake.

The foreign trawl fishery of the 1970's resulted in jack mackerel being placed in the groundfish FMP. Jack mackerel are now managed under the CPS FMP and have a default ABC for the United States of 31,000 t per year. The history of jack mackerel commercial landings is shown in Figure 14-4. Landings for the U.S. fishery peaked at 66,500 t in 1952. Recent average yield for the U.S. is only about 705 t (Table 14-1). Jack mackerel have occasionally been important to the recreational fishery off southern California.

Assessment and management of jack mackerel are difficult because of limited data and broad distribution of the species. The most recent estimate of biomass was made in 1983. Spawning biomass was estimated at 1.5 million t and total biomass was estimated at 1.6–1.9 million t. Its maximum sustainable yield is little more than an educated guess at this time (Table 14-1).





Jack mackerel larvae.

Figure 14-4
Landings in metric tons (t) of jack mackerel in the United States, 1926–2007.

California Market Squid

California market squid range from southeastern Alaska to Bahia Asunción, Baja California, Mexico, and play an important role in the food web of many organisms along California's coast. Market squid are mollusks and members of the Family Loliginidae. This species is milky white to iridescent in color and, like most squid species, has eight arms and two feeding tentacles. Adults caught in the fishery average 130 mm dorsal mantle length and are believed to live roughly 6–8 months, dying within days following spawning (Macewicz et al., 2004). Distinguished by its high productivity, the California market squid fishery fluctuates in response to environmental conditions, coupled with rapid changes in the export market (Figure 14-5). With significant expansion of fishing activity in southern California waters during the 1980's and 1990's, the California market squid fishery has emerged as one of the most important in the state in terms of revenue and tons landed.

The California market squid fishery was an unregulated, open-access fishery before 1 April 1998. In order to ensure sustainability of the resource, new legislation placed a moratorium on the number of vessels in the fishery. In 2001, legislation transferred authority for management of the market squid fishery to the California Fish and Game Commission. In compliance with this legislation, the California Department of Fish and Game (CDFG) adopted the Market Squid FMP in 2005, with implementation of the management recommendations for the 2005–06 fishing season.

The vast majority of California market squid are frozen for human consumption and exported to China, Japan, and Europe. Other uses include fresh and canned squid for human consumption, and fresh or frozen squid for use as bait in other fisheries. The role of international buyers in the temporal success of the California market squid fishery is substantial. After decades of generally low catches, volume increased during the 1990's because of new (primarily Asian and European) markets and higher prices paid for squid from California waters. Although the volume of squid produced by California markets depends on the international market, the price paid to fishermen can influence both effort exerted toward fishing operations and the overall volume of catch. Additionally, the price paid to fishermen for their catch depends not only on market demand but availability of the resource.

California's market squid fishery is separated at Point Conception, California, into northern and southern fisheries. Historically, the northern fishery accounted for the majority of the catch; however, the southern fishery has dominated landings since the mid 1980's. Although market squid are caught year-round in some years, the northern fishery typically occurs during the summer–fall months, and the southern fishery occurs in the winter–spring

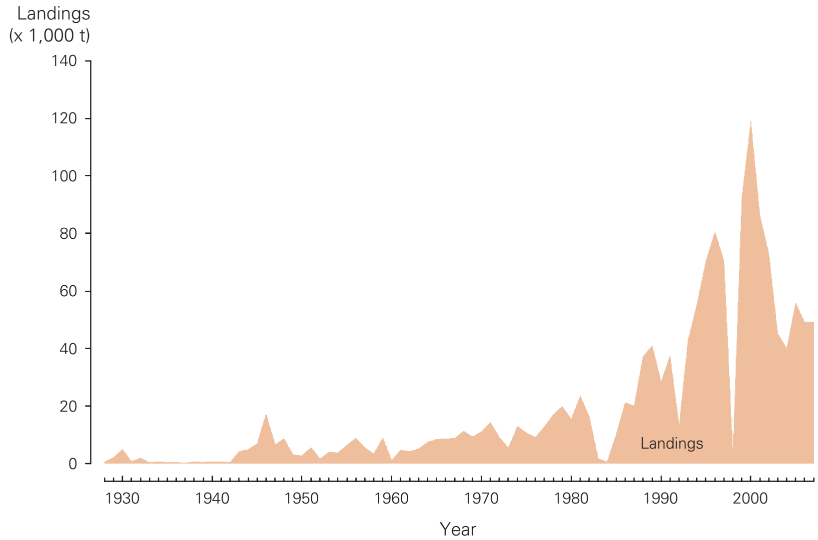


Figure 14-5
Landings in metric tons (t) of market squid in California, 1928–2007.

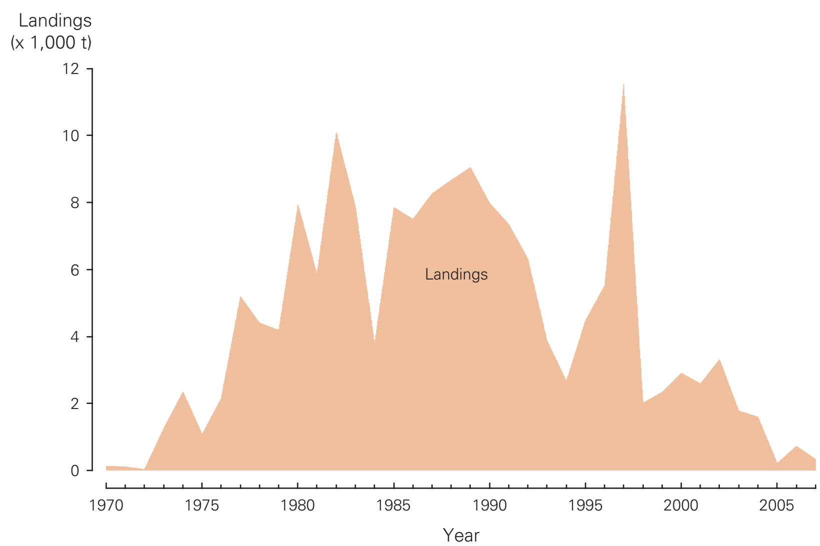


Figure 14-6
Commercial landings in metric tons (t) of Pacific herring off the Pacific Coast, 1970–2007.

months. California landings plummet during the cyclical El Niño oceanographic regimes, but increase considerably when these relatively warm-water oceanic events are displaced by cool-water processes (i.e. La Niña regimes). For example, during the 1997–98 El Niño, landings declined to an estimated 2,900 t, but they rebounded during the 1999 La Niña to nearly 92,000 t and hit a record high in 2000 with approximately 119,000 t landed statewide (Figure 14-5). A moderate El Niño event in 2002–03 likely contributed, to some degree, to an overall decrease in landings coastwide (estimated 73,000 t). Although the southern fishery for market squid was hampered during this oceanographic phenomenon, the northern fishery experienced record landings. The U.S. recent average yield for California market squid is nearly 52,000 t (Table 14-1).

Currently, California market squid are monitored and managed based on a catch limit of 118,000 t and a 2-day weekend closure. The stock is also monitored using biological proxies developed from the interactions between this species' reproductive output (egg escapement) and fishing pressure (fishing mortality, F). Egg escapement is defined here as the number (or proportion) of a female squid's potential lifetime fecundity that she is able to spawn, on average, before being harvested in the fishery. The egg escapement model is based on conventional yield and spawning biomass-per-recruit theory and application. Ultimately, the population assessment method can be used to assess whether the fleet is fishing above or below a predetermined sustainable level of exploitation, and in this context can be used as an effective management tool.

Pacific Herring

In the contiguous United States, Pacific herring are fished primarily off California. The fishery in Puget Sound, Washington, is small by comparison. The fishery off California has peaked three times in recent decades: in 1982 at over 10,000 t, in 1989 at about 9,000 t, and in 1997 around 11,500 t (Figure 14-6). Landings have since decreased to a recent average of 85 t. In the earlier years, Pacific herring were harvested for reduction into fishmeal and for pet food or bait. Some were canned to supplement the declining supply of sardines. Canned herring proved to be a poor substitute for sardines, and the fishery for human consumption ended in 1954.

Since 1973, Pacific herring in California have been harvested primarily for their roe to export to the Japanese market. Landings declined in 1984 when an El Niño episode caused a corresponding decline in the herring population. However, most stocks have recovered somewhat and so have catches. The herring roe fishery is limited to California's four largest herring spawning areas: San Francisco Bay, the Tomales–Bodega Bay area, Humboldt Bay, and the Crescent City harbor. San Francisco Bay has the largest spawning population of herring and supplies more than 90% of the state's herring catch. The four spawning areas are managed separately by CDFG, with catch quotas based on population estimates.

Another lucrative segment of the Pacific herring industry is the roe-on-kelp fishery (Figure 14-7). Beginning in 1965, scuba divers harvested species of marine vegetation with herring eggs attached in Tomales and San Francisco Bays. This product is exported to Japan as a holiday delicacy. The fishery has evolved into the present roe-on-kelp fishery. Giant kelp is harvested from the Channel Islands off Southern California, brought to San Francisco Bay, and suspended from 60- by 40-ft floating rafts. The rafts are towed to areas where herring spawning is expected to occur and are anchored. After spawning has ended, the kelp with herring eggs attached is removed from the rafts and packed in salt. Catches have been generally low (Figure 14-7) but valuable.

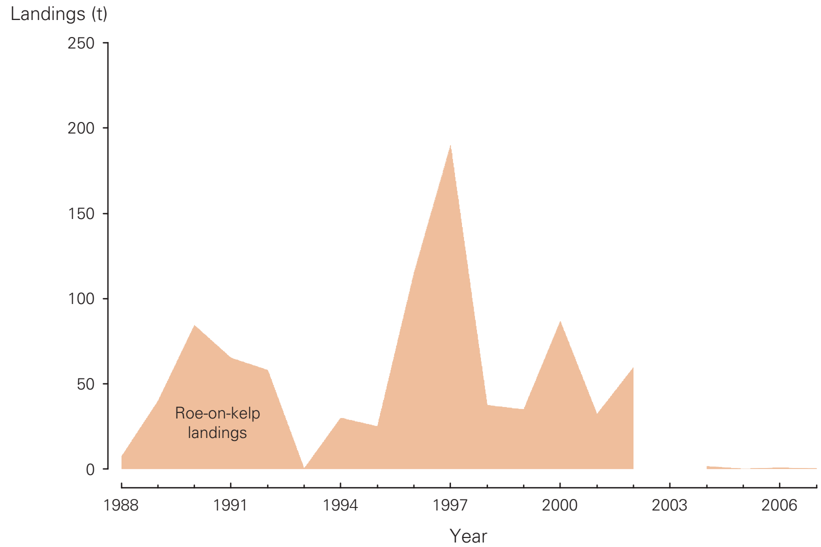


Figure 14-7
Landings in metric tons (t) of herring roe and kelp from the roe-on-kelp fishery in California, 1988–2007. Data unavailable for 2003.

ALASKA PELAGIC FISHERIES

Pacific Herring

Pacific herring is the major pelagic species harvested in Alaska. The fisheries occur in specific inshore spawning areas of the Gulf of Alaska and the Bering Sea. In the Gulf of Alaska, spawning fish concentrate mainly in Southeast Alaska, in Prince William Sound, and around the Kodiak Island–Cook Inlet area. In the Bering Sea, the centers of spawning abundance are in northern Bristol Bay and the eastern shore of Norton Sound. This fishery occurs within state waters (0–3 n.mi. offshore), and is therefore monitored and managed by the Alaska Department of Fish and Game (ADFG). ADFG manages the fisheries by 20 separate fishery statistical areas.

Herring spawn every year after reaching sexual maturity at 3 or 4 years of age. The number of eggs varies with the age of the fish and averages 20,000. The average life span for these fish is about 8 years in Southeast Alaska and up to 16 years in the Bering Sea.

Alaska's herring industry began as early as 1878 when about 14 t were marketed for human consumption. The fishery expanded rapidly in the late 1800's and early 1900's, with markets shifting from salt-cured herring to reduction products for fishmeal and oil. By 1934 the catch from the Gulf of Alaska alone had reached a record 140,000 t. The Bering Sea fishery began in the late 1920's, initially with a small salt-cure plant in Dutch Harbor. A large foreign offshore fishery developed in the 1950's and peaked dramatically in 1970 at more than 145,000 t. It then fell off sharply to 16,000 t in 1975 (Figure 14-8). Since 1977, Bering Sea herring have been harvested primarily in inshore sac roe fisheries, and catches have since risen slowly but steadily. A portion of the Bering Sea harvest is taken as bycatch in the offshore Federally managed groundfish fishery. Retention of herring in these fisheries is prohibited, with regulations limiting herring bycatch to no more than about 1,000 t annually. From 2003 to 2007 the actual herring bycatch averaged 763 t.

From catch records, it is evident that herring biomass fluctuates widely due to influences of strong and weak year-classes. Herring abundance levels typically increase abruptly following major recruitment events, then decline over a number of years because of natural and fishing mortality. Prince William Sound herring continue to be de-

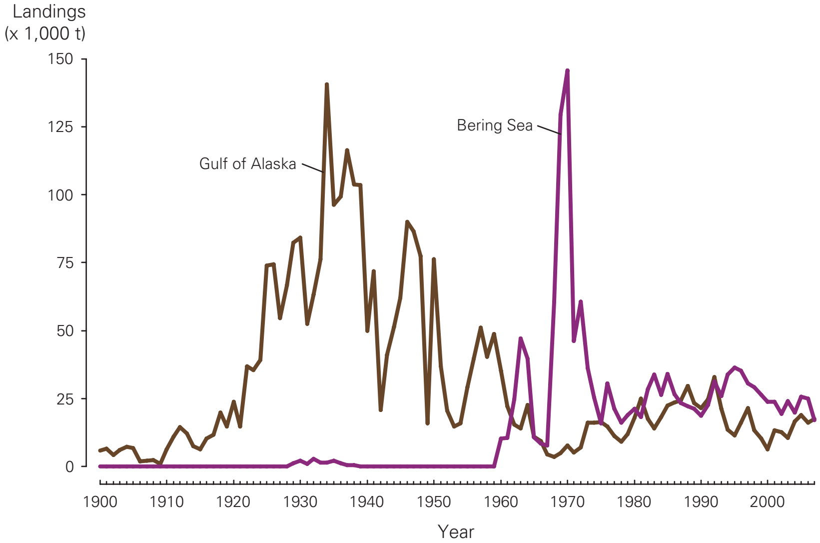


Figure 14-8
Landings in metric tons (t) of Pacific herring off Alaska, 1900–2007.

pressed from a disease outbreak in 1993. In the past 5 years, statewide herring harvests have averaged about 38,000 t, with a value averaging around $12,000,000. About 5% of the commercial harvest is taken for food and bait, and the rest is taken in the sac roe fisheries. In addition, there is a roe-on-kelp fishery that harvests about 300 t of product annually, with a value of around $2,900,000. Currently, the herring populations in Alaska remain at moderate levels and are in relatively stable condition, with the exception of Prince William Sound and Cook Inlet.

ISSUES

Transboundary Stocks and Jurisdiction


Anne Allen, SWFSC

Pacific sardine.

Sardine, anchovy, and mackerels are transboundary stocks exploited by both U.S. and Mexican fleets, but no bilateral management agreement has yet been reached for coordinated management of the stocks. Harvest policies in the CPS FMP take into account approximate stock portions residing in U.S. waters and prorate allowable harvest accordingly. Aside from minimum size requirements, CPS harvest levels are unregulated in Mexican waters, and the absence of a governing bilateral agreement is compromising management of the stocks that are fished by both countries. This problem is confounded by ongoing uncertainty regarding stock structure, distribution, and environmental influences on these highly dynamic populations.

Underutilized Species

Jack mackerel and northern anchovy are underutilized species and may support increased harvest by U.S. fishermen in the near future.

PROGRESS

Scientists from the National Marine Fisheries Service continue to work closely with state biologists and the Pacific Fishery Management Council in assessing and managing the stocks. Stock assessment models have been developed for northern anchovy, Pacific sardine, and Pacific mackerel. The models now use more data, including fish-spotter data from pilots employed by commercial fishermen, and the California Cooperative Oceanic Fisheries Investigations' (CalCOFI) long-term ichthyoplankton data base. Recent progress has been made toward improving collaborative research and data sharing between U.S. and Mexican scientists.

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Pacific Coast Groundfish Fisheries

NWFSC, FRAM Division

Unit 15

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INTRODUCTION

The Pacific Coast groundfish fishery is conducted along the entire coastline of Washington, Oregon, and California, and includes a diverse range of habitats, species, and participants. The Pacific Fishery Management Council's (PFMC) Groundfish Fishery Management Plan (FMP) contains more than 90 species organized into several sub-fisheries, including 1) the Dover sole, thornyheads, and sablefish (DTS) complex; 2) nearshore rockfishes, lingcod, and cabezon; 3) shelf and slope rockfishes; 4) flatfishes; and 5) Pacific hake (whiting). Many of the stocks included in the FMP have geographic ranges that extend beyond the U.S. Exclusive Economic Zone (EEZ) into Canadian or Mexican waters. The fishery has four general sectors: commercial limited-entry, commercial open-access, recreational, and tribal. These sectors use a variety of gears including trawl gear, an array of hook-and-line gears, and pots/traps. Participation in one gear group does not necessarily preclude participation in another. Most vessels targeting groundfish deliver to shoreside processors. However, within the Pacific hake trawl fishery, there are vessels that deliver their catch to motherships as well as to shoreside processors, and there are other vessels that process their own catch at sea.

A number of dramatic changes have occurred in the Pacific Coast groundfish fishery since the last publication of *Our Living Oceans* (NMFS, 1999). Between 1999 and 2002, nine stocks were declared overfished, with spawning estimated to be below 25% of unfished levels. Rebuilding plans were implemented, reducing allowable fishing mortality for overfished and associated species throughout

Photo above:
Yelloweye rockfish.

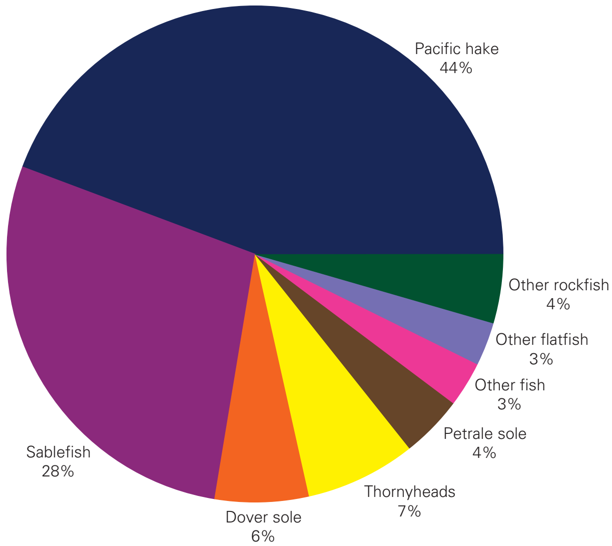


Figure 15–1

Relative components of Pacific Coast groundfish total ex-vessel value in 2006.

all sectors of the groundfish fishery and resulting in historically low allowable harvests. In addition to lower allowable harvest levels for overfished species and co-occurring species, major portions of the Continental Shelf off the U.S. West Coast have been closed to fishing since September 2003. Two of the overfished stocks, Pacific hake and lingcod, have since been rebuilt to target levels. Rebuilding for the overfished rockfish stocks is expected to require longer periods of time due to their relatively low productivity, which limits their ability to recover quickly to B_{MSY}. In addition to rebuilding plans for overfished stocks, many strides have been made toward improving management of the groundfish fishery and research necessary to support management. These include completion of a fixed-gear permit-stacking program and a trawl permit buy-back to reduce fishing capacity, implementation of a coast-wide observer program to monitor bycatch, expansion of groundfish resource surveys, and identification of essential fish habitat and habitats of particular concern.

The recent average yield (2004–06) of Pacific Coast groundfishes in the U.S. was 288,604 metric tons (t; Table 15-1). In 2006, U.S. commercial landings of Pacific coast groundfish totaled 288,990 t, generating $81 million in ex-vessel revenue. Pacific hake accounted for 91% of the 2006 landed catch and 44% of the associated ex-vessel value. Other important species in 2006 were sablefish ($23 million), Petrale sole ($6 million), Dover sole ($5 million), and thornyhead rockfish ($3 million; PSMFC, 2008; Figure 15-1). The trawl fleet (including Pacific hake) is the largest sector of the commercial fishery, generating 75% of the ex-vessel revenue (PSMFC, 2008).

SPECIES AND STATUS

Stock status has been estimated for nearly 30% of the groundfish stocks throughout at least a portion of their Pacific coast range. Of the assessed stocks, more than 70% are near or above target levels. However, many of the assessed stocks, whether currently below target levels or not, experienced declines in biomass throughout much of the 1980's and 1990's. These declines coincided with a period of reduced productivity of the California Current that lasted from 1977 into the late 1990's. It is likely that this decline in ocean productivity contributed to the decline in overall abundance, but the effect appears to have been variable across species and is not well understood at this time. In the most recent period of improved ocean productivity, increases in recruitment and abundance have been observed for many species.

In addition to the role of ocean productivity, harvest levels have contributed to the current status of these species. In the 1980's and 1990's, harvest rates for many Pacific Coast groundfish species were based upon knowledge of the productivity of other, similar species. This was a reasonable approach in the absence of species-specific information and given the paucity of fishery-independent trend information, but many Pacific Coast rockfish species now appear to be less productive than originally thought. As a result, managers set harvest rates for many species at levels that, in hindsight, were too high. Harvest metrics were re-evaluated during the 1990's and again in 2000, resulting in lower harvest rates for most species.

Dover Sole, Thornyheads, and Sablefish Complex

The DTS complex, consisting of Dover sole, longspine and shortspine thornyheads, and sablefish, represents some of the most valuable species in the Pacific Coast groundfish fishery. Dover sole have been targeted along the West Coast since

Table 15–1

Productivity in metric tons (t) and status of Pacific Coast groundfish fisheries resources.

Species/stock	Recent average yield (RAY)[1]	Current yield (CY)[2]	Sustainable yield (MSY)[3]	Stock level relative to B_{MSY}[4]	Harvest rate[5]	Stock status[4]
Flatfish						
Arrowtooth flounder	4,160	5,800	5,148	Above	Not overfishing	Not overfished
Dover sole	7,483	8,589	16,505	Above	Not overfishing	Not overfished
English sole	1,262	3,100	3,452	Above	Not overfishing	Not overfished
Petrale sole	2,536	2,762	3,164	Near	Not overfishing	Not overfished
Other flatfishes[6]	1,939	6,781	Unknown	Unknown		
Subtotal, flatfish	17,380	27,032	35,050			
Rockfish						
Black rockfish (coastwide)[6]	980	1,276	1,443	Above		
Blackgill rockfish[7]	130	343	223	Above	Not overfishing	Not overfished
Bocaccio[7]	81	549	1,974	Below	Not overfishing	Overfished
Canary rockfish	55	270	1,574	Near	Not overfishing	Rebuilding
Chilipepper[7]	125	2,700	2,155	Above	Not overfishing	Not overfished
Cowcod[7]	2	24	61	Below	Not overfishing	Overfished
Darkblotched rockfish	186	294	621	Below	Not overfishing	Overfished
Longspine thornyhead	800	2,461	3,687	Above	Not overfishing	Not overfished
Pacific ocean perch[8]	104	934	1,411	Below	Not overfishing	Rebuilding
Shortbelly rockfish[9]	11	13,900	Unknown	Above	Not overfishing	Not overfished
Shortspine thornyhead	805	1,077	1,720	Above	Not overfishing	Not overfished
Splitnose rockfish[7]	262	615	Unknown	Unknown	Not overfishing	Unknown
Widow rockfish	196	3,059	2,000	Near	Not overfishing	Rebuilding
Yelloweye rockfish	15	55	44	Below	Not overfishing	Overfished
Yellowtail rockfish[8]	840	3,681	4,680	Above	Not overfishing	Not overfished
Other rockfishes[6]	1,538	6,749	Unknown	Unknown		
Subtotal, rockfish	6,130	37,987	42,857			
Other groundfish						
Cabezon (California)	92	108	137	Near	Not overfishing	Not overfished
Lingcod	821	2,716	3,378	Above	Not overfishing	Not overfished
Pacific cod	898	3,200	Unknown	Unknown	Unknown	Unknown
Pacific hake (whiting)[10]	351,643	364,842	576,688	Near	Not overfishing	Not overfished
Sablefish (blackcod)	6,416	8,175	6,328	Near	Not overfishing	Not overfished
Other groundfishes[6,11]	5,023	14,600	Unknown	Unknown		
Subtotal, other groundfish	364,893	393,641	604,331			
Total	388,403	458,660	682,238			
U.S. Subtotal	288,615	390,363	531,607			

[1]2004–06 average of total mortality including commercial and recreational catch as well as estimated discards.

[2]2006 allowable biological catch (ABC).

[3]MSY as calculated in assessment model using management proxies (SSB or SPR) or as estimated by model.

[4]Stock level relative to target and stock status are taken from estimates in most recent stock assessment models.

[5]Overfishing status is based on 2006 total mortality estimates as reported in Hastie and Bellman (2007) compared to 2006 ABC targets.

[6]Harvest rate and stock status are not available for this stock.

[7]The RAY and CY apply to the stock south of 40°10′N latitude. Northern catch and CY are included in the "Other rockfishes" category.

[8]The RAY and CY apply to the stock north of 40°10′N latitude. Southern catch and CY are included in the "Other rockfishes" category.

[9]RAY is based on 2006 catch rather than average of 2004–2006.

[10]Values shown are for coastwide stock (U.S. and Canadian portions). The U.S. RAY is 251,844 t, and the U.S. MSY is 426,057 t.

[11]Category includes sharks, skates, rays, ratfish, morids, grenadier, kelp greenling, and other groundfishes. See Appendix 5 for a complete listing.

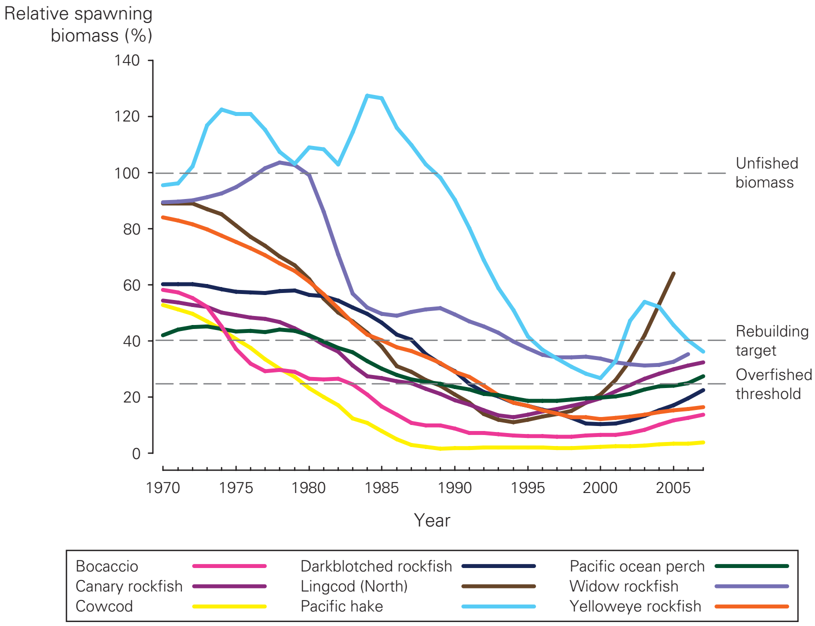


Figure 15–2

Relative spawning biomass or output of Pacific Coast groundfishes declared overfished since 1999 for the period 1970–2007 (if available). The overfished threshold for Pacific Coast groundfish is 25% of the estimated unfished spawning biomass. Lingcod and Pacific hake have been rebuilt to the target level of 40% of the estimated unfished spawning biomass. While previous assessments estimated widow rockfish spawning stock output to be below the overfished threshold, the most recent assessment estimated the stock has not fallen below the overfished threshold. There is considerable uncertainty surrounding these point estimates and the stock is still considered in rebuilding.

World War II, almost exclusively with trawl gear. Annual landings from U.S. waters averaged 18,872 t during the 1980's, 12,368 t during the 1990's, and 7,483 t from 2004–06 (Sampson, 2006; PSMFC, 2008). Following a period of decline in the mid 1990's, Dover sole biomass is steadily increasing; the current estimated spawning stock biomass is 63% of the unexploited level (Sampson, 2006).

Landings of thornyheads peaked in 1990 at 10,082 t and then steadily declined, with recent landings dipping below 2,500 t. An increasing percentage of shortspine thornyhead has been caught with hook-and-line gear (from 7% in 2000 to more than 20% since 2003). Much of this increase is delivered to lucrative live-fish markets. Thornyheads are long-lived and slow growing, with estimated maximum ages of 45 years for longspine thornyhead and 100 years or more for shortspine thornyhead (Love et al., 2002). However, recent stock assessments of shortspine and longspine thornyheads estimate spawning biomass to be above their targets, at 63% and 71% of unfished levels, respectively (Hamel, 2006; Fay, 2006).

NWFSC, FRAM Division

Dover sole.

Sablefish (also known as blackcod) are highly valuable, making up only 2% (6,470 t) of groundfish catch but generating 28% of total groundfish revenues for 2006 (Hastie and Bellman 2007; PSMFC, 2008). Sablefish are harvested by using trawl nets and fixed gear such as hook-and-line and pot gear. Sablefish biomass steadily declined during the 1990's, but has been increasing in recent years. Current spawning stock biomass is estimated to be 38% of the unfished level (Schirripa, 2008).

Rockfishes

Rockfishes make up the majority of managed species under the Pacific Coast Groundfish FMP, accounting for about $3.6 million in revenue in 2006 (PSMFC, 2008). They vary greatly in their morphological and behavioral traits, with some species found in mid-water schools and having semi-pelagic behavior, and others leading solitary, sedentary, bottom-dwelling lives (Love et al., 2002). Rockfishes inhabit a wide range of depths, from nearshore kelp forests and rock outcrops to varied deepwater (greater than 150 fathoms) habitats on the Continental Slope. Despite the range of behaviors and habitats, most rockfishes share general life history characteristics, which include slow growth rates, bearing of live young, and large but infrequent recruitment events. These life history characteristics contribute to relatively low average productivity that may reduce their ability to withstand heavy exploitation (Parker et al., 2000), especially during periods of unfavorable environmental conditions. The combination of high historic exploitation, generally low productivity, and changes in oceanic conditions have resulted in the decline of seven rockfish stocks below the overfished threshold (25% of unfished spawning potential, often measured as spawning biomass; Figure 15-2). According to the most recent assessments, three of the species were below the overfished threshold by the mid 1980's, well before the implementation of fishery management plans.

The overfished species are currently estimated to be between 3.8 and 35% of unfished levels; however, all appear to be increasing in abundance under their respective rebuilding plans.

Not all rockfishes have declined in abundance over the past two decades. A number of species such as chilipepper, yellowtail rockfish, gopher rockfish, and blackgill rockfish are above their target levels, with estimated spawning biomass ranging from 52 to 97% of unfished levels (Figure 15-3). These rockfish inhabit a wide range of habitats which span nearshore, shelf, and slope depths. Although relatively abundant, landings for some of these species are near historical lows as a result of catch restrictions associated with rebuilding species that co-occur with these abundant stocks.

The majority of rockfish landings in shelf and slope depths are made with trawl gear, but there are important commercial and recreational hook-and-line fisheries, especially within nearshore and rocky reef habitats. There is growing concern about local and regional depletions of some rockfishes and other nearshore groundfish species. One source of concern is the concentration of recreational removals from fishing grounds near various ports, while another is the level and concentration of effort in the high-valued live-fish fishery[1] that originated in California, but has gradually moved up the coast into Oregon.

Lingcod and Cabezon

Lingcod and cabezon are important targeted species in both commercial and recreational fisheries. Lingcod is found throughout rocky shelf and nearshore habitats along the entire Pacific Coast. The longer-lived females of the species can reach 20 years in age. The Pacific Coast lingcod stock was designated as overfished in 1999, with a spawning biomass that was less than 20% of its unfished level. However, the stock quickly rebuilt to the coast-wide target level by 2003, following the recruitment of very large year-classes in 1999 and 2000, and was officially declared rebuilt in 2005, which is 4 years earlier than the target rebuilding year established in the rebuilding plan (PFMC, 2008). Annual combined commercial and recreational landings declined from roughly 4,800 t in the mid 1980's to less than 500 t in 2000–01, but have increased to an average of 821 t between 2004 and 2006 (PSMFC, 2008; Table 15-1).

Cabezon are primarily a nearshore species found intertidally and among jetty rocks (Miller and Lea, 1972). Cabezon are one of the largest species in the Family Cottidae, attaining a length of nearly 1 m and a weight in excess of 11 kg (Feder et al., 1974). Similar to lingcod, males are reported to show nest-guarding behaviors (Garrison and Miller, 1982). The commercial catch of cabezon has increased over the past 10 years and has become a major source of removals because of the developing live-fish fishery off California and Oregon. The stock has only been assessed in California waters because the available data sources remain insufficient to form the basis for a reliable assessment of cabezon in Washington and Oregon. The California stock is estimated to be 38% of unfished levels (Cope and Punt, 2006).

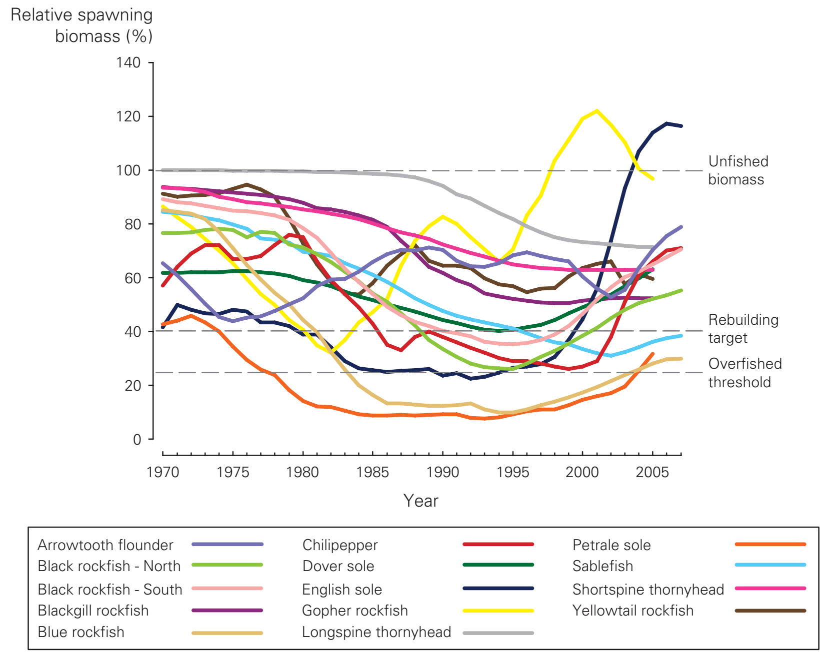


Figure 15–3
Relative spawning biomass or output of selected groundfish stocks for the period 1970–2007. The target MSY-proxy is 40% of the estimated unfished spawning biomass, while the overfished threshold is 25% of the estimated unfished spawning biomass. Many groundfish stocks are near or above target levels.

[1]This fishery targets smaller-sized fishes from nearshore areas; fish are kept alive and transferred to markets on the same day as capture. Growth of the nearshore live-fish fishery for thornyheads and rockfishes has been propelled by ex-vessel prices that are commonly ten times higher than those for dead fish of the same species. The previously large number of small, open-access boats participating in this fishery has been reduced through the initiation of state permit programs.


Hanumant Singh, WHOI

Groundfishes, including a longnose skate, a Dover sole, an unidentified thornyhead, and a hagfish, observed using the Seabed AUV on Santa Lucia Bank, California.

Flatfishes

Shelf flatfishes such as Petrale sole, English sole and starry flounder are found in low-relief mud, sand, or gravel habitats, and are harvested primarily with commercial trawl gear. Arrowtooth flounder are an abundant flatfish commonly found in depths from 50 to 800 m. Some flatfish species can attain ages of 15–27 years, while other flatfishes are unlikely to live beyond 10 years. Petrale and English sole experienced protracted periods of generally poor recruitments from the mid 1970's through the mid 1990's that left the stocks near historically low levels. Higher recruitments since the mid 1990's have produced substantial increases in both populations.

Current spawning stock biomass is estimated to be above target levels for English sole, arrowtooth flounder, and starry flounder (116%, 79%, and 50%, respectively) while Petrale sole is near target levels at 32% of unfished spawning biomass (Figure 15-3; Stewart, 2008; Kaplan and Helser, 2008; Ralston, 2006; Lai et al., 2006). The increasing trends in spawning stock biomass estimated in assessments for these species are mirrored by increasing trawl survey catch per unit of effort (CPUE) for several unassessed flatfish species. Combined landings of shelf flatfish in recent years are roughly half of what they were around 1990. These declines have resulted from changes in markets, as well as from restrictions imposed on flatfish catch to reduce rockfish bycatch in the flatfish fishery.

Pacific Hake

The coastal stock of Pacific hake (whiting) is the most abundant groundfish population in the California Current system (Helser and Martell, 2008). The stock is characterized by highly variable recruitment patterns and a relatively short lifespan when compared to other groundfish stocks. Pacific hake was declared overfished in 2002 following many years of poor recruitments. However, similar to lingcod, a strong year-class in 1999 led to substantial spawning biomass increases as this year-class reached maturity. The 2007 stock assessment shows the stock had declined to historically low levels in 2000 (although not below the overfished threshold as previously thought), and had increased to target levels by 2002. The volatility of this stock is reflected in the doubling of the spawning biomass between 2000 and 2003 due to the recruitment of a single strong year-class. The stock is now considered rebuilt, and the 2007 spawning biomass was estimated to be 36.2% of unfished levels (Figure 15-2; Helser and Martell, 2008). Coastwide (United States and Canada) landings of Pacific hake peaked at 360,000 t in 2005 and 2006 but are expected to decline as the 1999 year-class makes its way through the population. A recent treaty between the United States and Canada (2003) establishes an annual assessment and management process, a research commitment, and a harvest-sharing agreement providing 73.9% of the coastwide allowable catch for U.S. fisheries and 26.1% for Canadian fisheries. The treaty is expected to be ratified by the end of 2008, with implementation of the agreement starting for the 2009 fishing season.

Other Groundfish

The Pacific Coast Groundfish FMP also includes species such as sharks, skates, rays, ratfish, codlings, grenadiers, kelp greenling, and other species that are neither common nor targeted by commercial and recreational fisheries. Two of these stocks, kelp greenling (Oregon substock) and longnose skate (coastwide) were assessed for the first time in 2005 and 2007, respectively. Both kelp greenling and longnose skate are estimated to be above target levels, at 49% and 66% of unfished levels, respectively (Cope and MacCall, 2006; Gertseva and Schirripa, 2008).

ISSUES AND PROGRESS

Recent years have brought sweeping changes to the Pacific Coast groundfish fishery and the research and science supporting the management of this fishery. Many important issues cited in prior editions of *Our Living Oceans* have been addressed. For example, a comprehensive observer program to monitor total catch in at-sea hake fisheries and discards in the remaining groundfish fisheries has been implemented coastwide. In addition, an allocation scheme between the United States and Canada for Pacific hake has been formalized, although it is still awaiting ratification. Furthermore, additional progress has been made in several other areas to continue to improve management of groundfish.

Resource Surveys and Stock Assessments

Scientific surveys to collect vital information on the distribution, relative abundance, and age structure of Pacific Coast groundfish populations are conducted along the West Coast using bottom trawls, fixed-gear, and acoustic technology. Many of these surveys have been expanded in spatial and depth coverage as well as an increase in frequency of occurrence. For example, in 1998 an annual cooperative research[2] bottom trawl survey of slope groundfish resources was implemented along the West Coast using locally chartered commercial fishing vessels. In 2003, the survey's coverage was expanded to include the area south of Point Conception, California, and shallow depths on the Continental Shelf (Keller et. al., 2007). Likewise, a mid-water trawl survey to estimate relative abundance of pelagic juvenile rockfish and Pacific hake was expanded from a core area off central California to a coastwide survey in 1999. Additionally, the integrated acoustic and trawl survey used to assess the distribution and abundance of coastal Pacific hake is now conducted on a biennial instead of triennial basis, in collaboration with Canada's Department of Fisheries and Oceans. These expanded surveys have provided additional information to improve the precision of groundfish assessments.

NWFSC, FRAM Division

Flag rockfish as seen from an ROV.

Habitat surveys are being conducted using sidescan and multibeam sonar, human-occupied submersibles, and remotely operated vehicles (ROV's). With these surveys, scientists are exploring, mapping, and documenting the interactions between groundfishes, other demersal fishes, invertebrates, and benthic habitats. Of particular importance in the future will be the determination of the distribution and abundance of biogenic species[3] including deep water corals and their role and importance to the groundfish ecosystem (Whitmire and Clarke, 2007).

Great strides have also been made in standardizing and improving the integrated age/length modeling framework used for many of these assessments, as well as reporting the scientific uncertainty associated with the assessment results. There are, however, remaining challenges, particularly to develop survey and assessment methods for data-poor and data-limited species, especially those occurring in rocky, untrawlable habitats. Non-extractive

[2]Research in which industry and other stakeholders partner with NMFS, state agencies, and university scientists in the collection of fundamental fisheries information to support the development and evaluation of management options.

[3]Plants and animals that create physical structures that may be used as habitat by other species.

Longspine thornyhead.

surveys utilizing ROV's, autonomous underwater vehicles (AUV's), and acoustic methods are being tested as appropriate tools for surveying in rocky habitats and are needed to develop fishery-independent indices of abundance in order to assess many of the data-poor species.

Bycatch

In addition to understanding the status and trends of groundfish populations, it is crucial to document and quantify total fisheries removals, including landed catch and discards. Groundfish landings have long been documented by state fishery agencies. However, until 2001, at-sea discard had not been systematically monitored outside of the at-sea processing hake fleet and isolated research projects. This lack of discard information contributed to greater uncertainty in stock assessments and in evaluating management performance relative to harvest benchmarks. An observer program was initiated in 2001 to collect information on the magnitude and composition of discard within the groundfish industry. These data are used to document total mortality to assess whether overfishing has occurred, and are also used to study patterns of co-occurrence among target and bycatch species, identify gear-specific bycatch and discard activity, and note changes in fishing behavior as vessels approach limits for target species. Many of the observers are assigned to permit-holders within the trawl fleet, with the remainder accompanying permitted fixed-gear vessels or open-access boats.

Harvest Policy

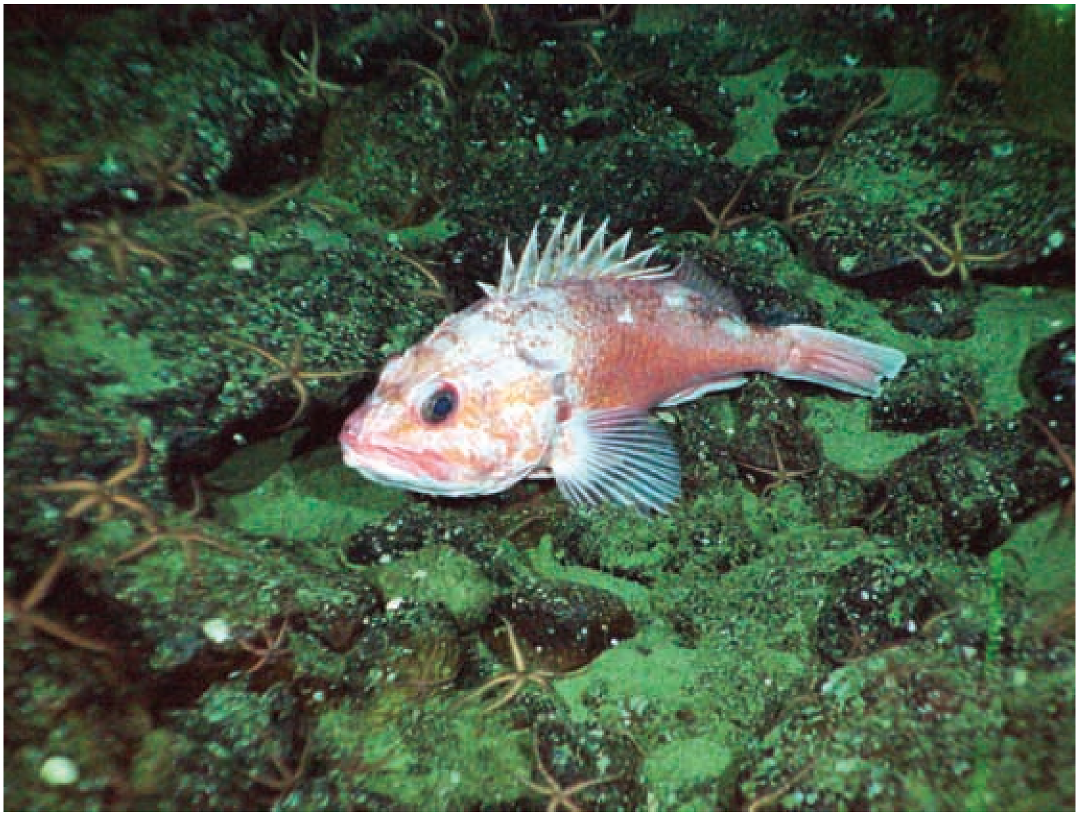
Harvest rates for most assessed groundfish stocks have been reduced in recent years, and allowed harvests of unassessed and data-poor species have been set with greater precaution. Assessed species are generally managed with a constant proportional rate of harvest such that the expected level of spawning potential (egg production or female spawning biomass) per recruit will be reduced to some fraction of the estimated unfished level. In circumstances where the maximum sustainable yield (MSY) harvest rate is not reliably estimated, the PFMC's harvest policy uses spawning potential values of 50% for rockfishes and thornyheads, 40% for flatfishes and Pacific hake, and 45% for other species including sablefish and lingcod (Ralston et al., 2000). These rates are now believed to be more sustainable than the 35–40% rates used for most assessed stocks during the 1990's because research has since shown rockfishes and thornyheads have less resilient spawner–recruit relationships than previously believed. Allowable harvests for unassessed species and complexes that were set based on historical levels are now reduced by 50%.

In addition to a reduction in harvest rates, Pacific Coast groundfish are managed under the 40–10 Rule, where species with abundance levels between $SB_{25\%}$ and $SB_{40\%}$ are designated as being within a precautionary zone. Under this policy, yield is reduced linearly from the amount available when the stock is at 40% of the unfished level ($SB_{40\%}$) to zero catch when the stock is at 10% of the unfished level. In practice, stocks are designated as overfished when spawning biomass falls below 25% of the unfished level ($SB_{25\%}$), and a rebuilding plan, including a species-specific rebuilding harvest rate, must be developed.

Gear Changes

Prior to 2000, trawl vessels were able to use gear with very large footropes—including some configurations with large truck tires—in order to fish in rocky shelf and slope habitat areas. Beginning in 2000, measures were adopted to restrict the

NWFSC, FRAM Division



Pink rockfish.

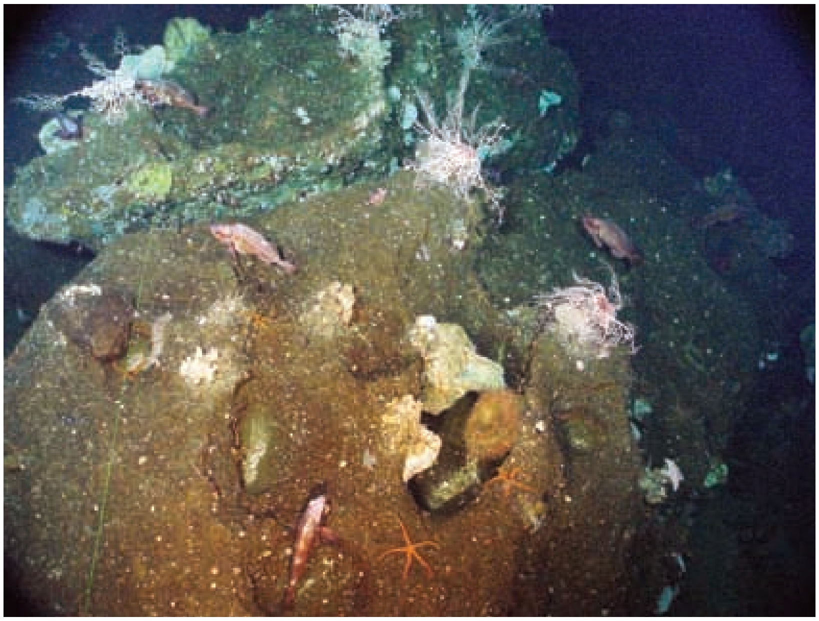
use of gear in shelf depths to footropes no larger than 8 inches in diameter. This greatly limited the ability of the trawl fleet to fish in habitats that are believed to be the most critical for rockfish recovery. Since then, additional research and experimental fisheries have been conducted on modified trawl net designs that provide greater opportunity for rockfish to escape, while preserving CPUE for targeted flatfish species. In particular, research conducted off the northern part of the U.S. West Coast developed a more flatfish-selective trawl gear design to reduce bycatch of co-occurring rockfish (King et al., 2004; Hannah et al., 2005). This gear is now required in nearshore waters north of Cape Mendocino, California.

Groundfish Fishing Capacity Reduction Programs

In 2001, the National Marine Fisheries Service (NMFS) implemented a permit stacking program for the limited-entry, fixed-gear sablefish fishery. This program allows eligible permit owners to stack up to three permits on a single vessel in order to access the sablefish limits associated with each of those permits. This simplified individual quota program has reduced the number of vessels participating in the primary sablefish fishery by about 50%.

A trawl permit buy-back program was implemented in 2003 to reduce the capacity of the groundfish fishery. The program removed 91 groundfish trawl permits (about 35% of then-existing trawl permits) and many state crab and shrimp permits owned by the same operators. Coast Guard fishing endorsements were removed from each vessel actively using these permits, meaning that they can never again be used for commercial fishing in U.S. waters. Remaining permit holders are responsible for repaying roughly $30 million in Federal loans that enabled the buy-back.

The PFMC is now midway through the development of a trawl rationalization program that will implement, depending on the fishery, either individual transferable quotas or co-operatives. The Council is also seeking to convert the open-access portion of the groundfish fishery into a limited-entry fishery.



A diversity of rockfish and megafauna invertebrates associated with a rock outcrop located off Cherry Bank in Southern California's borderlands region.

Closed Areas and Essential Fish Habitat

West Coast groundfish fisheries are managed with a variety of closed areas intended to either minimize the bycatch of overfished groundfish species or to protect sensitive habitats. Many of the closed areas are gear-specific, meaning that they are closed to some particular gear types, but not others.

The rockfish conservation areas (RCA's) are large-scale closed areas that extend along the entire length of the U.S. West Coast and are intended to protect a complex of species, such as the overfished shelf and slope rockfish stocks. The RCA's differ between gear types (e.g. trawl, non-trawl, and recreational RCA's), and have boundaries that may be seasonally adjusted to facilitate harvest of abundant stocks in seasons and areas with the least impact on overfished stocks. Although both the eastern and western RCA boundaries have changed over time for all of the gear groups, a 5,500 mi^2 area between the trawl RCA boundary lines approximating the 100- and 150-fathom (fm) depth contours has remained closed since January 2003. The Cowcod Conservation Areas are two areas in southern California that have been closed to most commercial and recreational fishing since January 2001.

Essential fish habitat (EFH) along the West Coast is described as all water and substrates in areas with a water depth less than or equal to 3,500 m, as well as seamounts in depths greater than 3,500 m (NMFS, 2005). In 2006, 51 areas encompassing over 130,000 mi^2 were closed to protect sensitive habitats associated with EFH or habitat areas of particular concern (HAPC's) (Whitmire and Clarke, 2007). The closed areas are fully protected from bottom trawl impacts; in addition, some sensitive areas are closed to all fishing gears that contact the bottom. The largest of these closures prohibits the use of bottom trawls deeper than 1,280 m (700 fm) and out to the extent of EFH (i.e. 3,500 m), essentially freezing the footprint of recent bottom trawl activity.

In addition to closures implemented by the PFMC and NMFS, the States of California, Oregon, and Washington are developing and implementing protected areas within their waters. California has implemented a network of marine protected areas as part of the Marine Life Protection Act (MLPA) and anticipates expanding the network. Oregon is engaged in an ongoing process to designate a system of marine reserves in Oregon's territorial sea, and Washington is initiating a process to update its inventory of state marine protected areas as well as identify criteria for the potential creation of additional marine protected areas in the future.

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Western Pacific Invertebrate Fisheries

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Unit 16

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INTRODUCTION

The Western Pacific fisheries for invertebrates target myriad species in state, territorial, commonwealth, and remote island waters, including lobsters, shrimp, squid, octopus, precious corals, and other species. Most of these fisheries are small scale and regulated only by the island fisheries agencies in the region.

The now-closed Northwestern Hawaiian Islands (NWHI; Figure 16-1) lobster trap fishery was the major commercial marine invertebrate fishery in the Western Pacific. A small-scale, primarily recreational, fishery for different species of lobster exists in the Main Hawaiian Islands (MHI), American Samoa, Guam, and the Northern Mariana Islands. A deepwater shrimp resource is found throughout the Pacific Islands but currently is lightly exploited. A resource of deepwater precious coral (gold, bamboo, and pink corals) and shallower coral (black corals) exists in Hawaii and possibly other Western Pacific areas. A short-lived domestic precious coral fishery operated in Hawaii from 1974 to 1979, but there was no significant precious coral harvest for 20 years until 1999–2001.

Management Situation

Fisheries management in this area is guided by the Western Pacific Fishery Management Council (WPFMC), approved by the Secretary of Commerce, and implemented by the National Marine Fisheries Service (NMFS). The NWHI lobster fishery and the Hawaii precious coral fishery are the only invertebrate fisheries managed by NMFS in this area.

Photo above:
Banded spiny lobster, Northwestern Hawaiian Islands.

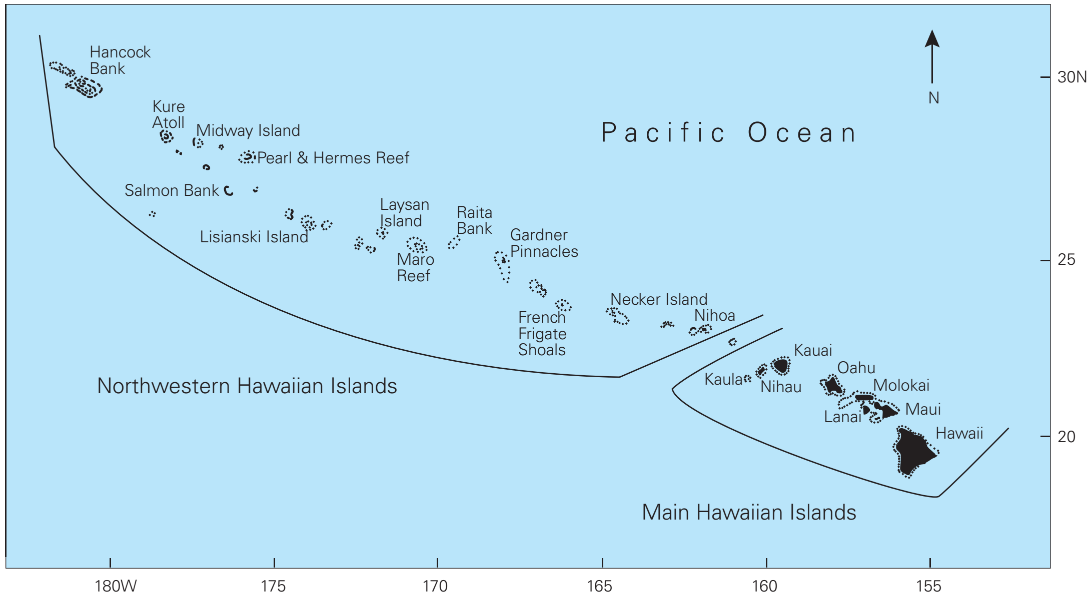


Figure 16-1
The Main Hawaiian Islands and the Northwestern Hawaiian Islands.

The NWHI comprises an isolated range of islands, atolls, islets, reefs, and banks that extend 1,500 n.mi. west-northwest of the Main Hawaiian Islands from Nihoa to Kure Atoll (Figure 16-1). A commercial lobster trap fishery operated in the NWHI from the mid 1970's through 1999. It was a multispecies fishery, primarily targeting the banded (Hawaiian) spiny lobster and blunt slipper lobster (ula-pāpapa). Three other species, pronghorn spiny lobster ('ula-hiwa), Aesop slipper lobster, and sculptured mitten lobster (ula-pehu), were also caught in low abundances. The Fishery Management Plan for the Crustaceans of the Western Pacific Region (Crustaceans FMP) combines all species of lobster into a single management unit. The MHI lobster fishery is managed by the State of Hawaii, although fishing on a few offshore banks is included under the Crustaceans FMP.

The Crustaceans FMP was implemented in 1983 and has since been amended nine times. Many of the earlier amendments were in response to requirements to eliminate any likelihood of interactions with the Hawaiian monk seal (Amendments 2 and 4), protect spiny and slipper lobster reproductive potentials (Amendments 3 and 5), and specify overfishing definitions (Amendment 6). A significant change occurred in 1992 when, in response to continuing declines in commercial lobster catch per unit of effort (CPUE), Amendment 7 was approved to include an annual 6-month closed season (January–June); limit entry into the fishery to 15 vessels; and establish an annual catch quota. Amendment 9 implemented in 1996 a lobster quota system based on a constant harvest rate that allows only a 10% risk of overfishing in any given year, but allows the retention of all lobsters caught (i.e. replacing the previous size restrictions). Spatial management of the lobster fishery commenced in 1998 with the identification of four management areas in the NWHI: Necker Island, Maro Reef, Gardner Pinnacles, and all other banks combined. The lobster fishery was closed in 2000 by the WPFMC because of uncertainty in the population and assessment models used to assess stock status, and remains so to this date. In December 2000, President Clinton, through Executive Order (EO) 13178 and later through EO 13196, established the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve. These EO's also established reserve preservation areas in which fishing activities, including lobster trapping, are prohibited. To continue protection of the NWHI, President Bush designated the NWHI as a National Monument in 2006. The Papahānaumokuākea Marine National Monument is cooperatively managed by the U.S. Fish and Wildlife Service and the National Oceanic and Atmospheric Administration, in close coordination with the State of Hawaii.

Precious corals occurring in the U.S. exclusive economic zone (EEZ) are managed under a fishery management plan implemented in 1983. Three types of coral are recognized targets of the fishery, including pink (*Corallium* spp.), gold (*Gerardia* spp., *Narella* spp., *Calyptrophora* spp., and *Callogorgia* spp.) and bamboo (*Lepidisis* spp. and *Acanella* spp.). Quotas are set based on visual surveys of the one fully surveyed coral bed at Makapu'u, Oahu. Exploratory permits with very limited quotas are available for unsurveyed coral beds found elsewhere. The fishery was reinitiated in 1999 and ended in 2001 with fishing conducted at the Makapu'u and Keahole beds.

Surveys using submersibles in 1997 provided solid evidence of recovery of pink coral at the Makapu'u, Oahu, bed that has been the historical focus of the fishery. In prior years no permits for coral harvesting outside of Makapu'u had ever been issued. Nonetheless, it appears that illegal foreign fishing in some remote areas at the north end of the archipelago during the 1970's and early 1980's likely had a very significant impact on some coral beds.

SPECIES AND STATUS

NWHI Lobster

The commercial lobster fishery in the NWHI was initiated with two-chambered wire traps but shifted to plastic traps in the 1980's. Although the traps contained escape vents, the decreased mesh size of the new traps resulted in an increase in the catch of smaller lobsters. Approximately 10 strings of 100 traps each are fished overnight at depths generally ranging from 15 to 35 fathoms (27–64 m). Historically, traps set at the deeper depths caught slipper lobster while the shallower sets caught spiny lobster. In later years, slipper lobsters (particularly at Maro Reef) have been caught at shallow depths, possibly due to the "fishing down" of spiny lobsters and the availability of suitable lobster habitat formerly occupied by spiny lobster; the effect of environmental fluctuations on lobster recruitment may also affect the relative abundance of lobster species.

Historically, most of the lobster catch was processed at sea and landed as frozen tails. In the late 1990's, however, the opening of several foreign markets led to an increase in live landings. Nonetheless, most lobsters continued to be landed as processed frozen tails.

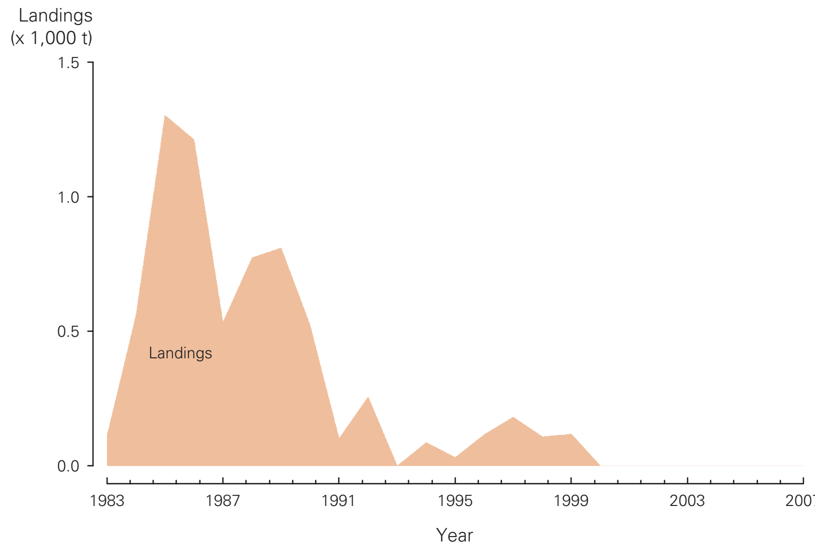


Figure 16-2
Hawaiian lobster (spiny and slipper lobsters) landings in metric tons (t), 1983–2007. The seasons were shortened in 1994 and 1995, and the fishery was closed in 1993 and again from 2000 to the present.

Although as many as 16 banks within the NWHI were fished on an annual basis before the closure in 2000, the proportion of fishing effort at each bank varied both spatially and temporally. The observed spatio-temporal shifts in fishing effort between banks are attributed to declines in spiny lobster CPUE; as spiny lobsters were fished down and catch rates at a particular bank fell below some minimum economic threshold, fishing effort shifted to more productive banks. By the mid 1990's, fishing was generally limited to Necker Island where spiny lobsters were highly concentrated. With the adoption of spatial management in 1998, fishing effort was redistributed throughout the NWHI, and the major target of the fishery changed to slipper lobster.

The combined landings of lobsters peaked in 1985 at 1,075 metric tons (t; worth $5,888,000) and generally declined from 1986 to 1995 (Figure 16-2). The fishery was closed in 1993 and had shortened seasons in 1994 and 1995. Landings in 1999 were 118 t whole weight and consisted of about 87,000 spiny lobster and 149,000 slipper lobster, valued at $1,200,000. The fishery was closed in 2000 as a precautionary measure to prevent overfishing of the lobster resource and currently remains closed (Table 16-1).

Uncertainty exists with the current parameterization of the NWHI lobster population and

Table 16-1
Productivity in metric tons (t) and status of Western Pacific invertebrate fisheries resources.

Species/stock	Recent average yield (RAY)[1]	Current yield (CY)	Sustainable yield (MSY)	Stock level relative to B_{MSY}	Harvest rate	Stock status
Spiny and slipper lobsters (NWHI)[2]	0	Unknown	Unknown	Unknown	Not overfishing	Unknown
Total	0	0	0			

[1]2004–06 average.
[2]Northwestern Hawaiian Islands; fishery has been closed since 2000.

Blunt slipper lobster, Northwestern Hawaiian Islands.

assessment models, and the status of NWHI lobster stocks is indeterminate. Many of the model assumptions may be invalid, and independent estimates of key fishing performance and biological parameters are inconsistent with estimates derived from current NWHI lobster population and assessment models. Much of the uncertainty stems from processes that are related to spatial scale and the treatment of data, which has been pooled across species. Previous assessments did not recognize the importance of spatial heterogeneity and assumed synchronous dynamics among local populations of NWHI lobsters, regardless of species. Improving lobster stock assessments will require better population models with sufficient spatial and species resolution that explicitly characterizes the dependence between local lobster populations. The development of spatially structured population models for NWHI lobster populations is progressing and should provide for more reliable stock assessments.

The estimated populations of spiny and slipper lobsters declined dramatically from the mid 1980's through the mid 1990's. Much of this decline has been attributed to a shift in oceanographic conditions affecting recruitment in the mid 1980's. While vagaries in oceanography may have contributed to the decline of NWHI spiny lobster, improvements in our understanding of the spatial structure of the NWHI spiny lobster population, the dynamics of larval transport, and commercial fishery data suggest that spiny lobster populations in the NWHI constitute a metapopulation[1] and that a suite of factors (both anthropogenic and biotic) contributed to the observed decline. As the population size is reduced, the chance of population collapse due to environmental stochasticity increases, particularly when the population is spatially structured. Although oceanographic conditions have returned to a more typical long-term state and the fishery has been closed since 2000, recent NMFS research surveys have not indicated any increase in spiny lobster populations at Necker Island. While increases in spiny lobster relative abundance have been detected in isolated locations around Maro Reef, it is premature to assess the impact of this change at the population level.

The primary objective of the Crustaceans FMP is to prevent overfishing and is defined in terms of recruitment overfishing.[2] The criterion used to assess overfishing is the spawning potential ratio (SPR), defined as the ratio of the spawning potential of a population in a fished condition relative to that in an unfished condition. The FMP defines

[1]A group of populations inhabiting discrete patches of suitable habitat that are connected by the dispersal of individuals between patches; the degree of isolation for local populations may vary depending on the distance between habitat patches.
[2]Recruitment overfishing refers to a level of fishing intensity that reduces the adult spawning stock to the point that the number of recruits produced is greatly reduced and is insufficient to maintain the population.

the 20% level as a minimum SPR threshold, below which the stock is considered overfished, and establishes a warning SPR threshold at 50%, indicating the need for additional conservation measures. The NWHI lobster fishery was managed with a constant harvest rate such that there was only a 10% chance in any given year that the fishing mortality will exceed the mortality associated with the minimum SPR threshold.

Precious Coral

For the first time since the mid 1970's, deepwater precious corals (pink, gold, and bamboo corals) were harvested beginning in 1999 through 2001. Historical landings of precious corals are shown in Figure 16-3. A single company collected corals at the established coral bed of Makapu'u, Oahu, and in the exploratory bed off Keahole, Hawaii. Because only one company was fishing, it is not possible to report data on landings without compromising NMFS confidentiality provisions; however, the allowable harvest quotas were not filled in either location. Makapu'u, Oahu, has a 2-year quota for 2,000 kilograms (kg) of pink coral and 600 kg each for bamboo and gold coral. The exploratory beds have a combined quota of 1,000 kg of any of the coral target species. Single-person submarines were used to selectively harvest coral colonies and minimize collateral damage to the habitat. Although the fishery remains open, the company has suspended harvesting due to the high cost of operating submarines and the low bid price for coral. The only shallow water coral species currently harvested are black corals (*Antipathes dichotoma, A. grandis,* and *Myriopathes ulex*). Black corals are collected by three independent divers working 80 m and shallower, all within the Au'au channel, Maui.

In 2000 and 2001, scientists surveyed all known precious coral beds in the Hawaiian Archipelago using the submersibles of the Hawaii Undersea Research Laboratory. These surveys have provided the first real insight as to the relative abundance of precious corals across the archipelago. Post-harvest inspections of the coral beds at Makapu'u and Keahole found numerous live colonies with little evidence of damage associated with harvesting. The 2001 survey of the Makapu'u bed will be compared with a pre-harvest survey data collected at Makapu'u in 1997 to evaluate possible harvesting impacts. Both divers and submersibles also surveyed the black coral bed of the Au'au channel in 2000 and 2001. Submersible surveys at depths below 80 m observed an invasive species of soft coral (*Carijoa riisei*) overgrowing black coral trees. At depths shallower than 80 m, divers surveyed the size structure of black coral trees and their associated fish assemblages. A follow-up survey of size structure was conducted in 2004 and will be used to revisit the harvesting regulations presently in place.

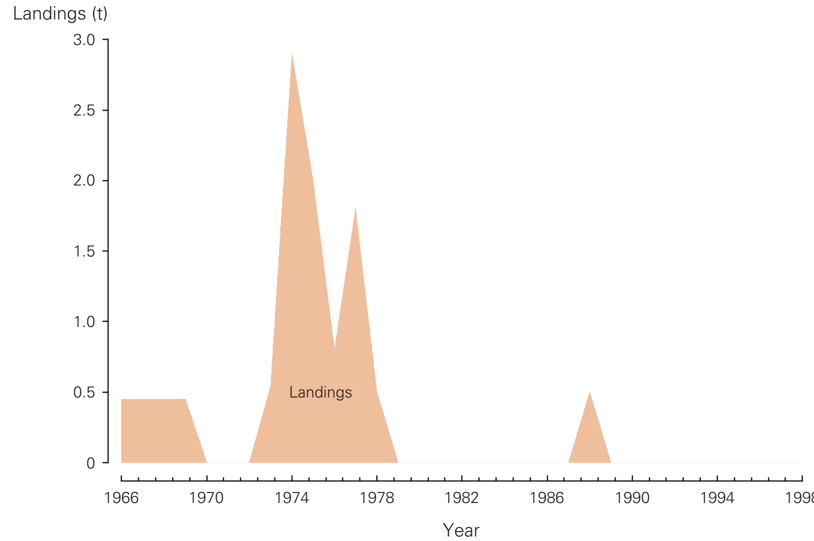
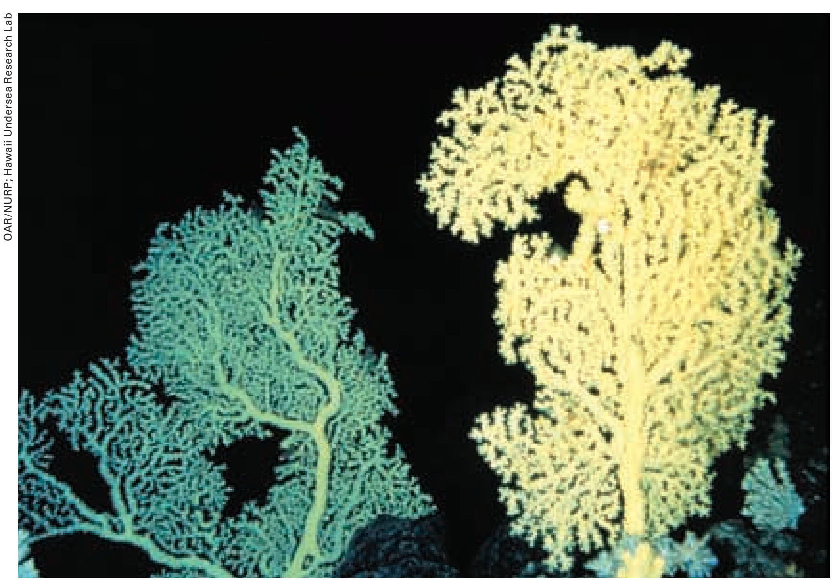


Figure 16-3
Historical precious coral landings in metric tons (t), 1966–98. No fishery occurred in 1998; data are not available for 1999–2001 because only one company was fishing and confidentiality provisions prevent the release of landings information. Although the fishery remains open, harvest has been suspended due to high operation costs.

Photo below:
Gold coral in Hawaii.

OAR/NURP; Hawaii Undersea Research Lab



Joseph O'Malley

Northwestern Hawaiian Islands lobster phyllosoma larva.

ISSUES

Scientific Information and Adequacy of Assessments

Despite the multispecies nature of the NWHI lobster fishery and regulatory measures, most of the biological research has been directed at spiny lobster. Future research is needed to address knowledge shortfalls of slipper lobster biology. Estimates of the exploitable population of lobsters in the NWHI have been based solely on commercial catch and effort data from the NWHI lobster fishery as a whole. This approach neglects the fact that fishermen target areas with higher concentrations of lobsters and may lead to estimates of exploitable biomass that are biased. More accurate assessments will require the integration of fishery-independent data, such as the annual NWHI lobster resource survey and the lobster-tagging program, into assessments to fine-tune the parameter estimates and assessment of exploitable biomass on a bank-specific basis.

Biological information necessary for management of precious corals remains limited. Estimates on the growth rate of pink coral and black coral have been documented, but the growth rate of gold coral is unknown. Understanding the growth rate is essential to effectively evaluating the rate of recruitment and setting a reasonable harvest size to protect the reproductive population. During the 2000 and 2001 surveys of coral beds, gold coral colonies large and small were marked and will be measured again in following years. Archival temperature recorders were also deployed at these sites to account for environmental variables that could influence differences in growth rates between sites.

Factors Affecting Abundance

In predicting the response of the NWHI lobster population to fishing harvest, it must be noted that research to date has identified a dynamic change in the spatial and temporal structure of the NWHI lobster population. One major fishing area, Maro Reef, continues to be characterized by low spiny lobster abundance. Based on oceanographic research, size class and genetic structure analysis, and trends in CPUE, recruitment in the NWHI spiny lobster population appears to differ between the southeastern and northwestern segments of the archipelago, and remains depressed in the northwestern segment relative to 1975–85 levels. Numerous hypotheses have been advanced to explain population fluctuations of lobsters in the NWHI, including environmental, biotic (e.g. habitat and competition), and anthropogenic (e.g. fishing). Each hypothesis by itself offers a plausible, but simple, explanation to a rather complex phenomenon operating in a system of high dimensionality. It is likely that population fluctuations of lobsters in the NWHI will be more accurately explained by a mix of the hypotheses presented, each describing a different set of mechanisms.

Multispecies Interactions

The long-term effects of fishing on ecosystems are not well understood, and cautious management controls are required. The removal of one species, or complex of species, could result in species composition shifts. Although both spiny and slipper lobsters are harvested in the NWHI lobster fishery, spiny lobster is the primary target at most banks. As large numbers of spiny lobster were removed from banks in the NWHI, the abundance and spatial distribution of slipper lobster on these banks apparently increased; areas traditionally defined as spiny lobster habitat appear now to be occupied by slipper lobster. However, it is unknown if this sort of shift has occurred at all banks because NMFS lobster resource surveys occur only at Necker Island and Maro Reef.

Activities related to the precious coral fishery might interfere with the endangered Hawaiian monk seal. Studies of monk seal foraging patterns using seal-mounted satellite tags documented a small number of seals visiting sites with deepwater precious coral beds. Depth-of-dive records from one study show that a small percentage of the seals' dives reached depths of 350–500 m. In another study of diving behavior, three seals at French Frigate Shoals in the NWHI dove below 350 m. One seal was documented foraging at subphotic depths, while all three of the seals were heard making feeding sounds at depth. A follow-up study also recorded seals visiting black coral beds on successive nights to feed on eels hiding among the corals. This feeding behavior is considered analogous

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Researchers PIT tagging a slipper lobster (left) and a spiny lobster (right) during the 2003 Northwestern Hawaiian Islands lobster tagging cruise. These lobster tagging cruises are a cooperative effort between the NMFS Pacific Islands Fisheries Science Center and Hawaiian commercial fishermen.

to the foraging activity proposed for seals in the subphotic deepwater precious coral beds. These studies have spurred concern that coral harvesting might impact the seals' use of the deepwater fish community. Consequently, surveys conducted at all the coral beds (in 2000–01) included assessment of fish populations both in and outside of coral beds to evaluate the degree to which the corals aggregate deepwater fish species. Comparative surveys of bank summits at the northern extreme of the NWHI were conducted in 2002, and these data will be combined with data from the 2000 and 2001 surveys for full analysis. In 2003, a seal was observed by a submersible at 540 m near precious coral, further strengthening the link between seals and precious coral beds.

Metapopulation Approach

Treating spiny and slipper lobsters in the NWHI as metapopulations is consistent with the available data and represents a departure from the status quo. Given the dependence among local populations of spiny lobster in the NWHI, overfishing or depletion of local populations could result in catastrophic impacts to the population as a whole (e.g. reduction in average recruitment or recruitment failure), particularly when a large number of local populations, or the most productive populations, are heavily exploited. Also, when spatial correlation among local populations is high (as it appears to be for NWHI spiny lobsters), bank-specific relationships between population size and fishing can become decoupled, masking the true impact of fishing. The decline of spiny lobsters at Laysan Island may provide an example of this decoupling.

This paradigm shift also changes the data requirements for NWHI lobster stock assessments. While the discrete population model relied solely on commercial catch and effort data as input, metapopulation models require data (both biological and fishery related) with greater spatial resolution. Because of life history differences between spiny and slipper lobsters, the models may also need to be species-specific.

Invasive Species

Recent surveys of the Au'au channel bed have documented an infestation by an invasive soft coral, *Carijoa riisei*, which settles on and smothers black coral colonies. *Carijoa* has infested nearly every black coral below depths of 80 m where light levels are dim enough for *Carijoa* to colonize. Black corals in shallower depths are exposed to more light that constrains the *Carijoa* to the undersides of ledges. The loss of deep black corals, beyond the reach of coral divers, removes a functional reproductive reserve for the black coral stock. Consequently, the black coral stock and any associated fishery parameters are in need of revaluation.

Progress

Much progress in assessing the status of exploited lobster stocks of the Western Pacific region has been made during recent years. At-sea sampling of the commercial fleet by biological technicians was conducted in 1995 and 1997–99, providing information to characterize the commercial catch as well as spatial heterogeneity of lobster abundance and size composition. These data were used to enhance the annual NWHI lobster fishery-independent survey and provided a more representative basis for future stock assessments.

To provide independent estimates of population size and updated estimates of population dynamics and fishery parameters, a NWHI lobster tagging program was implemented. Spiny lobsters at Necker Island were tagged with external ribbon tags in 1998, 1999, and 2002 on both Federal and chartered commercial vessels. In 2003, spiny lobsters at Necker Island and slipper lobsters at Maro Reef were tagged with internal PIT (passive integrated transponder) tags aboard chartered commercial vessels. Further population and assessment model development will require an increase in the program's scope to include tagging at other banks.

Significant progress in population and assessment model development, as well as CPUE standardization, has also occurred. A spatially explicit population model has been developed for spiny and slipper lobsters and feasibility testing of the model is progressing. In situ research is focusing on the behavior of lobsters in and around traps to better interpret CPUE time series. Larval drift models are being developed to further understand the role oceanographic conditions have on recruitment.

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Western Pacific Bottomfish and Groundfish Fisheries

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Unit 17

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INTRODUCTION

The Western Pacific bottomfish fishery geographically encompasses the Main Hawaiian Islands (MHI), the Northwestern Hawaiian Islands (NWHI), Guam, the Commonwealth of the Northern Mariana Islands (CMNI), and American Samoa. In contrast, North Pacific (pelagic) armorhead are harvested from the summits and upper slopes of a series of submerged seamounts along the southern Emperor–northern Hawaiian Ridge. This chain of seamounts is located just west of the International Date Line and extends to the northernmost portion of the NWHI.

The Guam, CNMI, American Samoa, and MHI bottomfish fisheries employ relatively small vessels on 1-day trips close to port; either part-time or sport fishermen take much of the catch. In contrast, bottomfishes in the NWHI are fished by full-time fishermen on relatively large vessels that range far from port on trips of up to 21 days. Fishermen use the handlining technique in which a single weighted line with several baited hooks is raised and lowered with a powered reel. The bottomfish fisheries are managed jointly by the Western Pacific Fishery Management Council (WPFMC) and territorial, commonwealth, or state authorities.

The commercial seamount fishery for armorhead was started by bottom-trawl vessels of the former Soviet Union in 1968. During 1969, Japanese trawlers entered this fishery, and by 1972 the catch per unit of effort (CPUE; based on Japanese data) peaked at 54 metric tons (t) per hour (Figure 17-1). The United States has never been a participant in this fishery. By the end of 1975, the two foreign fleets had harvested a combined

Photo above:
NWHI bottomfish awaiting sale at the Honolulu fish auction.

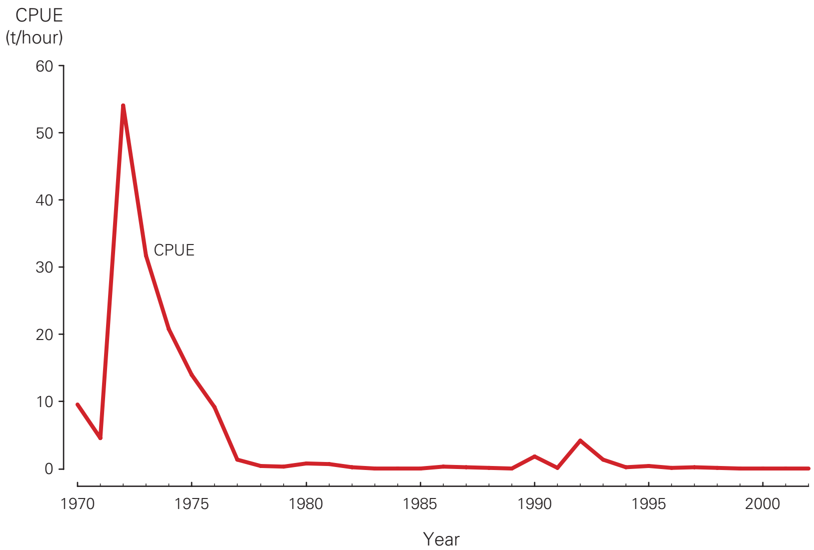

Figure 17-1
Catch per unit of effort (CPUE) in metric tons (t) per hour for North Pacific armorhead taken by the Japanese trawl fishery, 1970-2002.

cumulative total of 1 million t of North Pacific armorhead. Facing a steady decline in CPUE after 1972, the former Soviet fleet left the fishery after 1975. The combined catch index for all seamounts has remained depressed since the late 1970's. The inclusion in 1977 of the southernmost seamounts (Hancock Seamounts) into the U.S. Exclusive Economic Zone (EEZ) allowed for a small portion of the fishery to be managed in a limited way. A preliminary Fishery Management Plan (FMP) was developed that year and provided for limited foreign harvesting at the Hancock Seamounts under a permit system during 1978–84. However, catches remained low, and all fishing ceased after 1984. Under the FMP for the Bottomfish and Seamount Groundfish Fisheries of the Western Pacific Region, a 6-year fishing moratorium was imposed on the Hancock Seamounts in 1986. The moratorium was extended for three additional 6-year periods, the latest starting in 2004 and ending in 2010.

SPECIES AND STATUS

Bottomfishes

In Hawaii, the bottomfish species fished include several snappers (ehu, onaga, opakapaka, and uku), jacks (ulua and butaguchi), and a grouper (hapu'upu'u). In the more tropical waters of Guam, CNMI, and American Samoa, the fishes include a more diverse assortment of species within the same families as in Hawaii, as well as several species of emperors. These species are found on rock and coral bottoms at depths of 50–400 m. Catch weight, size, and fishing effort data are collected for each species in the five areas. However, the sampling programs vary in scope between the areas. About 90% of the total catch is taken in Hawaii, with the majority

Table 17-1
Productivity in metric tons (t) and status of western Pacific bottomfish and groundfish fisheries resources.

Species/stock	Recent average yield (RAY)[1]	Current yield (CY)	Sustainable yield (MSY)	Stock level relative to B_{MSY}	Harvest rate	Stock status
Bottomfish						
Hawaiian Islands total	274	287	368	Below	Not overfishing	Not overfished
Main Hawaiian Islands[2]	159	69	164	Below		
Mau Zone, NWHI[2,3]	47	46	46	Near		
Ho'omalu Zone, NWHI[2,3]	68	172	158	Near		
American Samoa	22	34	34	Above	Not overfishing	Not overfished
Guam	15	25	25	Near	Not overfishing	Not overfished
CNMI[4]	6	78	78	Above	Not overfishing	Not overfished
Seamount Groundfish[5]					Unknown	Overfished
Alfonsino[2]	0	0	Unknown	Unknown		
North Pacific armorhead[2]	0	0	2,123	Unknown		
Raftfish[2]	0	0	Unknown	Unknown		
Total	317	424	2,628			

[1]2002–04 average for Hawaii and 2003–05 average for other island areas.
[2]Harvest rate and stock status are not available for this stock.
[3]Northwestern Hawaiian Islands.
[4]Commonwealth of the Northern Mariana Islands.
[5]A fishing moratorium on seamount groundfish has been in effect within the U.S. EEZ since 1986.

of the catch taken in the MHI as compared to the NWHI (Figure 17-2). Data on recent average, current, and maximum sustainable yields for the five areas are in Table 17-1.

The most recent stock assessment for American Samoa, Guam, and CNMI bottomfish resources used catch and effort data collected through 2005 in a risk-based, Baysian, state-space surplus production model. Although CPUE data were not particularly informative about the ratio of initial biomass to carrying capacity and, therefore, maximum sustainable yield (MSY), the set of credible models for each island group provided a consistent evaluation of current bottomfish status. In all cases the risk of overfishing and overfished status conditions was very low.

The status of Hawaiian bottomfish resources is based on a surplus production model applied to commercial bottomfish data collected through 2004. This assessment indicates that Hawaiian bottomfish stocks are not overfished, but are experiencing overfishing. A closer look at biomass and harvest metrics for the three fishing zones in the Hawaiian Islands suggests that fishing in the MHI is the major source of excess harvest and that biomass in this zone is well below that necessary to produce MSY. Biomass and harvest metrics for both NWHI zones, on the other hand, suggest no cause for concern in these areas. Based on the results of this assessment, management measures including a summer closed season and an annual catch limit were established for the MHI in 2007. The next assessment of Hawaiian bottomfish resources is scheduled for late 2008.

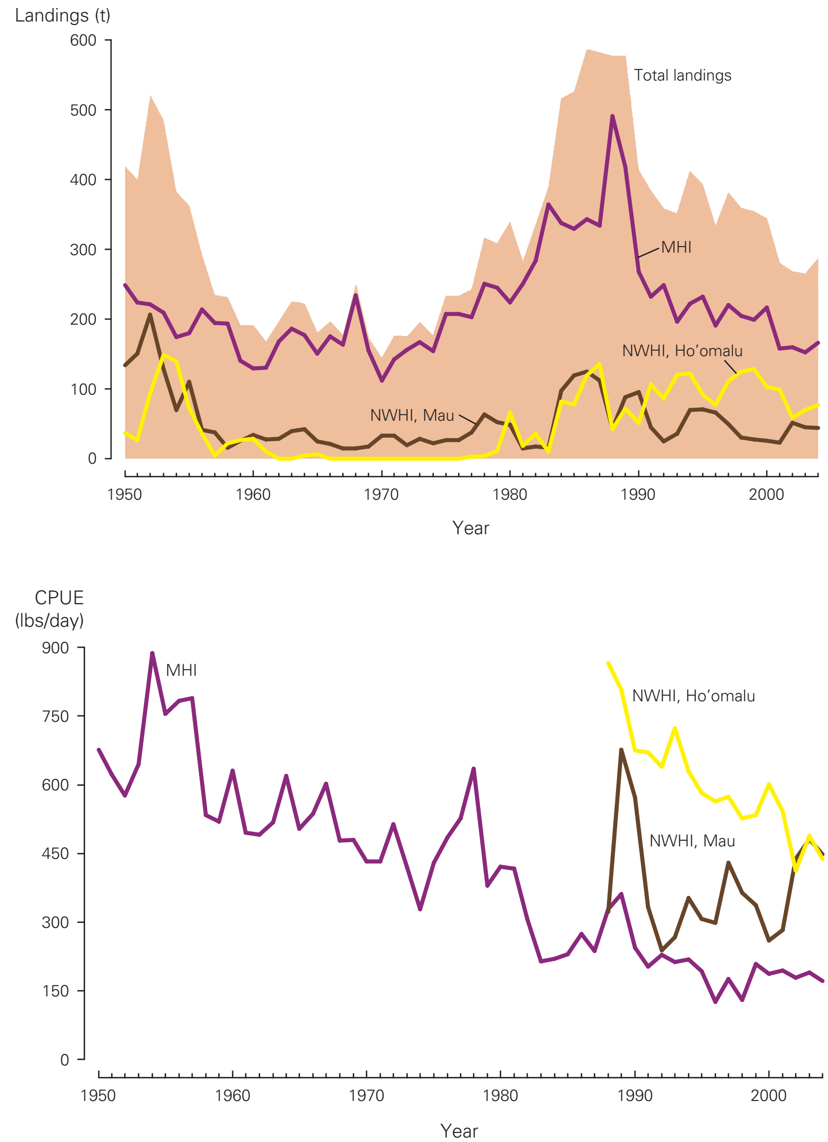

Figure 17-2
Bottomfish landings in metric tons (t; top) and catch per unit of effort (CPUE; bottom) in pounds per day, 1950–2004.

North Pacific (Pelagic) Armorhead

The seamount groundfish fishery has targeted just one species: the North Pacific (pelagic) armorhead. Since 1976, Japanese trawlers fishing the seamounts in international waters beyond the Hancock Seamounts have almost exclusively conducted this fishery. The fishing grounds comprising the Hancock Seamounts represent less than 5% of the total fishing grounds. The maximum sustainable yield (Table 17-1) is 2,123 t, but recovery to these former levels has not yet occurred.

Standardized stock assessments were conducted during 1985–93. Research cruises were focused on Southeast Hancock Seamount, and the armorhead stock was sampled with bottom longlines and calibrated against Japanese trawling effort. Catch rates vary but have not shown the increases expected after the fishing moratorium was implemented (Figure 17-3). Furthermore, the increase in the 1992 seamount-wide CPUE (Figure 17-1) caused by high recruitment was apparently short-lived, as CPUE declined appreciably in 1993 and thereafter. Closure of only the small U.S. EEZ portion of the armorhead's demersal habitat may not be sufficient to allow population recovery because these seamounts remain the only part of the fishery currently under management.

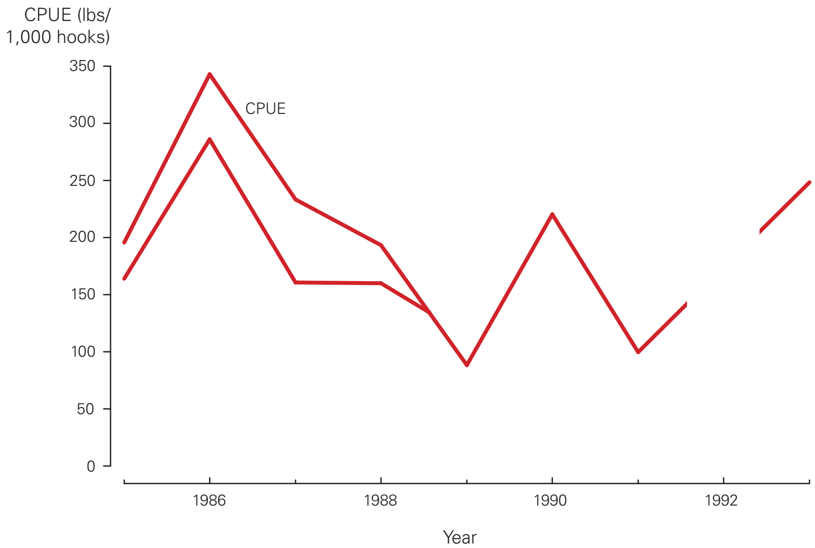

Figure 17-3
Catch per unit of effort (CPUE) in pounds per 1,000 hooks for North Pacific armorhead from bottom longline sampling during research cruises, 1985–1993. Biannual samples were taken from 1985–88, and annual samples thereafter. No samples were taken in 1992.

Seamount groundfish stocks within the U.S. EEZ have not been assessed since 1993; however, more recent data for adjacent areas outside of the EEZ suggest that these stocks remain overfished. Although poaching in this remote area is possible, it is assumed that harvest has not occurred within the EEZ since the 1986 moratorium. Even if true, however, overfishing on the stock as a whole could be occurring, with harvest applied to seamounts outside the EEZ. Data on current harvest rates for these outside areas are not available, so harvest status remains unknown.

ISSUES

Scientific Advice and Adequacy of Assessments

Adequacy of the biological and catch data collected is a primary management concern for the Western Pacific bottomfish fishery. For example, the reproductive biology of many of the important species in Guam, CNMI, and American Samoa is unknown, and spawning stock biomass cannot be computed.

Transboundary Stocks and Management Jurisdictions

The primary issue for the armorhead seamount fishery is how to implement some form of management on an international basis to provide conditions more conducive for stock recovery. The recruitment event of 1992 and subsequent stock decline (probably from overfishing) reinforce the need for some form of management if this fishery is to recover to early 1970's levels.

Management Concerns

NMFS determined that overfishing of the bottomfish species complex was occurring within the Hawaiian Archipelago, with the primary problem being excess fishing mortality in the MHI. The WPFMC was notified by NMFS of this overfishing determination in May 2005. A stock assessment completed by the Pacific Islands Fisheries Science Center in 2006 concluded that the required reduction in fishing mortality based on 2004 data would be 24%. In addition, a phase-out of the bottomfish fishery by 2011 in the NWHI was mandated through the Presidential designation of the Papahānaumokuākea Marine National Monument.[1] This may be significant because the bottomfish are assessed as a stock complex combining the MHI and the NWHI, and because larval transport may allow for one area to serve as a source of recruitment to other areas such that management actions in one area may affect fish stocks in the other. This permanent closure will also result in the elimination of one of the major sources of locally caught bottomfish for use in local markets and restaurants. After the NWHI closure, experienced NWHI commercial bottomfish vessel operators will either begin fishing in the MHI or discontinue fishing for bottomfish.

To end bottomfish overfishing, the WPFMC supports a stepped approach by first controlling fishing mortality in 2007 and 2008 through the use of seasonal closures in all sectors of the MHI bottomfish fishery, in conjunction with a total allowable catch (TAC) limit in the commercial sector and bag limits for the non-commercial sector. In 2009 and beyond, a single fleetwide TAC would be applied to both the commercial and non-commercial sectors. Adaptive management would be utilized to address new information or significant changes in the fishery or fishery conditions.

[1]Federal Register 36443, 26 June 2006.

Progress

Researchers continue to identify nursery habitat for juvenile snappers and groupers in Hawaii, and age and growth curves have been extended to include early juvenile stages. Improvements have been made in the collection of more complete catch-and-effort data from the NWHI fishery. Fishery discard patterns and interactions with sharks and protected species have also been examined.

Improvements will be made to the state's MHI bottomfish commercial data collection program. Major changes will require fishermen to report on a per-trip basis instead of on a monthly catch report and to provide GPS position recording. NMFS will implement a MHI recreational bottomfish permit and reporting program to capture catch and effort data from this sector of the fishery.

Recent international consultations have begun on the establishment of new mechanisms for the management of high-seas bottom fisheries by vessels operating in the northwestern Pacific Ocean. Representatives from Japan, the Republic of Korea, the Russian Federation, and the United States have met to continue efforts toward establishing interim management measures that would include the bottom fishery for North Pacific armorhead. Cooperative exchanges of fishery data with scientific colleagues in Japan have provided annual commercial catch data by seamount through 2002. Biological data of importance for future management considerations indicate that armorhead undergo a pelagic phase of 2 or more years prior to recruitment into the fishery and that the seamount populations comprise a single stock. Recent analysis of otolith increment width patterns among recruits sampled across years of high to low recruitment at the Hancock Seamounts suggests that in low recruitment years, recruits are larger at settlement and deposit narrower growth increments on their otoliths during the first year of the pelagic phase.

Hawaii Undersea Research Laboratory

Gindai seen off of southwestern Molokai from the submersible *Pisces IV* at a depth of about 200 m.

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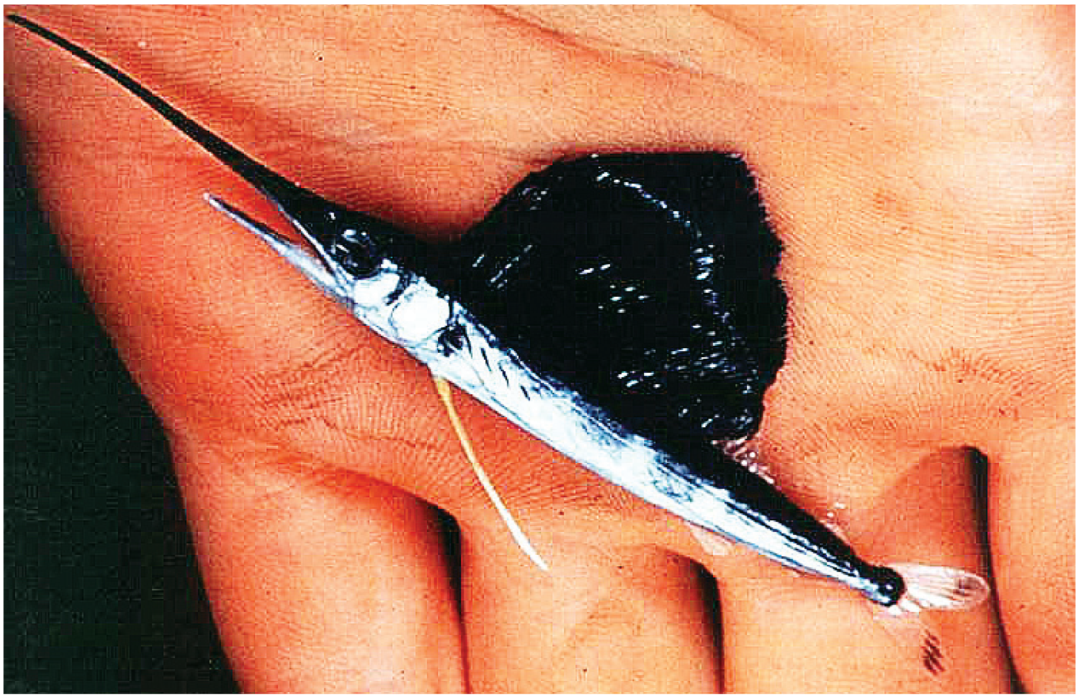
Pacific Highly Migratory Pelagic Fisheries

SEFSC Pascagoula Laboratory



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INTRODUCTION

Adult fishes in this group are large pelagic predators found primarily in oceanic waters across the Pacific Ocean, from the tropics to temperate latitudes. Many of these fishes routinely travel great distances performing trans-Pacific migrations, crossing the waters of several nations and the high seas in their pursuit of forage and ideal habitat for reproduction. Collectively referred to as highly migratory species, these fishes include yellowfin tuna, skipjack tuna, bigeye tuna, albacore, blue marlin, swordfish, dolphinfish (mahi mahi), large pelagic sharks, and others. Many are valuable and highly prized by both commercial and sport fishermen. The status of most tuna stocks is relatively well known, while the status of many stocks of the other species is either uncertain or unknown (Table 18-1).

Fleets belonging to coastal and distant-water fishing nations target highly migratory species throughout the Pacific Ocean. Some of the fleets are capable of operating across the Pacific as well as in other oceans during a single fishing season. These fleets use larger purse-seine nets or longline gear, and the vessels have fish-holding capacities of several hundred to 2,000 metric tons (t) each. Other small fleets operate only in coastal waters with handline, troll, gillnet, harpoon, and longline gears and produce fresh fish for local economies and for subsistence use. Several Pacific Island communities and nations also depend on highly migratory species for income, largely from the sale of fishing access licenses to foreign tuna fishermen.

Photo above:
Very young sailfish collected on a NMFS research cruise.

Table 18-1
Productivity in metric tons (t) and status of Pacific highly migratory pelagic fisheries resources.

Species/stock	Recent average yield (RAY)[1]	Current yield (CY)	Sustainable yield (MSY)	Stock level relative to B_{MSY}	Harvest rate	Stock status
Tropical tunas						
Bigeye tuna					Overfishing	Not overfished
Eastern Pacific[2]	109,987	103,322	81,350	Below		
Central Western Pacific[3]	130,836	114,247	87,000	Above		
Skipjack tuna						
Eastern Pacific[4]	274,974	322,004	Unknown	Unknown	Not overfishing	Not overfished
Central Western Pacific[5]	1,494,421	1,538,112	2,700,000	Above	Not overfishing	Not overfished
Yellowfin tuna						
Eastern Pacific[6]	252,412	174,780	285,000	Near	Overfishing	Not overfished
Central Western Pacific[7]	399,378	399,828	554,000	Above	Not overfishing	Not overfished
Subtotal, tropical tunas	2,662,008	2,652,293	4,029,354			
Temperate tunas						
Albacore						
North Pacific[8]	74,013	67,541	Unknown	Near	Unknown	Unknown
South Pacific[9]	37,602	32,108	117,000	Unknown	Not overfishing	Not overfished
Pacific bluefin tuna (Pacific)[10]	25,100	24,196	Unknown	Unknown	Unknown	Unknown
Subtotal, temperate tunas	136,715	123,845	208,737			
Billfishes						
Black marlin (Pacific)	1,705	1,705	Unknown	Unknown	Unknown	Unknown
Blue marlin (Pacific)	17,369	17,369	17,369	Near	Not overfishing	Not overfished
Sailfish (Pacific)	5,153	Unknown	Unknown	Unknown	Unknown	Unknown
Striped marlin (CWP)[11]	8,065	8,065	Unknown	Unknown	Unknown	Unknown
Swordfish (North Pacific)[12]	33,000	57,000	57,000	Above	Not overfishing	Not overfished
Subtotal, billfish	65,292	89,292	89,292			
Oceanic sharks						
Bigeye thresher (North Pacific)	4	Unknown	Unknown	Unknown	Unknown	Unknown
Blue shark (North Pacific)	37,386	70,000	Unknown	Above	Not overfishing	Not overfished
Pelagic thresher (North Pacific)[13]	2	Unknown	Unknown	Unknown	Unknown	Unknown
Shortfin mako (North Pacific)	69	Unknown	Unknown	Unknown	Unknown	Unknown
Thresher shark (North Pacific)[14]	323	Unknown	Unknown	Unknown	Unknown	Unknown
Subtotal, oceanic sharks	37,784	70,398	70,398			

United States fishermen have a long history of fishing for Pacific highly migratory species. In American Samoa, Guam, Hawaii, and the Commonwealth of the Northern Mariana Islands, handline fisheries for highly migratory species have operated since antiquity. Immigrants established pole-and-line and longline fisheries for tuna in Hawaii and southern California in the late 1800's and early 1900's. Pole-and-line fishing was the dominant fishery in Hawaii through the 1970's, but in the late 1980's longline fishing for tunas expanded rapidly and diversified to include swordfish in the 1990's. A sizable longline fishery for albacore has developed in American Samoa since 1995. Currently, U.S. fisheries targeting highly migratory species include commercial purse-seine fisheries in the eastern and western tropical Pacific; troll fisheries in the North and South Pacific; longline fisheries operating out of American Samoa, California, and Hawaii; troll and handline fisheries operating in the Exclusive Economic Zones (EEZ's) of U.S. Pacific Islands; and drift gillnet and harpoon fisheries in the West Coast EEZ.

Recreational fishermen in the 1920's were instrumental in drawing attention to the seasonal availability of highly migratory species off Califor-

Table 18-1
Continued from previous page.

Species/Stock	Recent average yield (RAY)[1]	Current yield (CY)	Sustainable yield (MSY)	Stock level relative to B_{MSY}	Harvest rate	Stock status
Other Migratory Species						
Dolphinfish (Pacific)[15]	23,742	23,742	Unknown	Unknown	Unknown	Unknown
Wahoo (Pacific)[16]	831	831	Unknown	Unknown	Unknown	Unknown
Subtotal, other migratory species	24,573	24,573	24,753			
Total	2,926,372	2,960,401	4,442,354			
U.S. subtotal	145,596					

[1]2004–06 average.
[2]U.S. portion of the RAY is 1,504 t. Status determinations are made for the entire Pacific region.
[3]U.S. portion of the RAY is 9,928 t. Status determinations are made for the entire Pacific region.
[4]U.S. portion of the RAY is 1,726 t.
[5]U.S. portion of the RAY is 55,588 t.
[6]U.S. portion of the RAY is 1,749 t.
[7]U.S. portion of the RAY is 55,588 t.
[8]U.S. portion of the RAY is 13,166 t.
[9]U.S. portion of the RAY is 3,950 t.
[10]U.S. portion of the RAY is 148 t.
[11]Central Western Pacific stock.
[12]U.S. portion of the RAY is 1,625 t.
[13]U.S. portion of the RAY is 1 t.
[14]U.S. portion of the RAY is 179 t.
[15]Also commonly known as dorado or mahi mahi.
[16]Average includes U.S. yield of 444 t and FAO Pacific yield of 387 t.

nia. Since then, sportfishing has grown in popularity and now supports important recreational fisheries for marlins, yellowfin tuna, dolphinfish, albacore, pelagic sharks, and other species in locations such as San Diego, California. Recreational highly migratory species fisheries also developed in other locations in the United States, such as Kona, Hawaii. Sportfishing participants contribute several million dollars annually to local economies.

The largest contemporary U.S. commercial fishery for highly migratory species started off the U.S. West Coast and Baja California, Mexico in the 1930's. At that time, U.S. fishermen targeted Pacific bluefin tuna and albacore for the emerging canned tuna market. The fishery rapidly expanded southward and westward with the development of new purse-seine fishing gear and discovery of large stocks of tropical tunas (yellowfin, skipjack, and bigeye tunas). During 1976–80, expansion of the fishery was concentrated in the eastern tropical Pacific. The U.S. fleet dominated the fishery until the 1980's, when fishing became less profitable owing to declining catch rates and increased costs associated with domestic regulations to reduce dolphin mortality. Many U.S. fishermen quit the fishery or moved their fishing operations to the central western Pacific. The U.S. fleet in the eastern tropical Pacific declined to about eight vessels by 2003. Simultaneously, the fleets of Mexico and other Latin American nations expanded and quickly filled the void. In 2006, 226 large purse seiners were active in the eastern tropical Pacific tuna fishery. In 2006, Ecuador (with 85 vessels) and Mexico (with 57 vessels) were leaders in the fishery.

Pacific tuna fisheries east of 150°W longitude have traditionally been managed in accordance with recommendations made by the Inter-American Tropical Tuna Commission (IATTC), to which the United States is a party. The IATTC historically has managed the fisheries with a focus on maintaining the tuna stocks at levels associated with maximum sustainable yield (MSY). The principal conservation measures have been catch quotas for yellowfin tuna. However, the IATTC has broadened the scope of its management program to include consideration of bycatch (including undersized fish), fleet capacity limits, and most recently, time–area closures for purse-seine fishing. Also, for the

Scott Landis, F/V MIDDLEPOINT

A SWFSC albacore troll observer. Observers collect data on catch, effort, and various special projects aboard commercial U.S. troll vessels that operate throughout the North Pacific.


Russell Ito, PIFSC

Unloading tunas from the longline vessel *Gail Ann* to the Honolulu fish auction.

2005–07 fishing seasons, the IATTC agreed to a management scheme of time–area closures for purse-seine gear and national catch quotas for longline gear to reduce fishing mortality on yellowfin and bigeye tuna. For the 2008 fishing season the IATTC parties were not able to reach agreement on management measures to correct overfishing of yellowfin and bigeye tunas. The IATTC has begun monitoring North Pacific albacore catches as well to ensure that the total level of fishing effort is not increased beyond current levels. In addition, under the Agreement on the International Dolphin Conservation Program (AIDCP), the parties to that agreement continued implementation of an overall dolphin mortality limit of 5,000 animals for the fishery by distributing individual vessel quotas to qualified vessels. Furthermore, all large tuna purse seiners operating in the eastern Pacific Ocean are required to carry an observer to collect data on compliance with AIDCP requirements.

In 1988, the United States and 16 South Pacific Island nations concluded a 5-year tuna fishing access agreement called the South Pacific Regional Tuna Treaty. This treaty gave the U.S. tuna purse-seine fleet fishing access to a 26 million km^2 area of the central western Pacific Ocean in exchange for fees. In 1993, the treaty was extended for 10 years, and in 2003 it was extended again for 10 years. The 2003 extension limits the fleet to a maximum of 40 licenses (one per vessel), plus 5 additional licenses for joint venture arrangements with the island parties. The annual industry license fee is $3 million. An additional $18 million is provided annually by the U.S. government for economic assistance to the island parties. In 2007, 18 U.S. purse seiners were licensed to fish under the treaty.

Following 5 years of negotiations involving 24 nations, 19 Pacific nations[1] adopted the Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific (WCPFC) on 4 September 2000, in Honolulu, Hawaii. By 19 December 2003, 13 nations[2] had ratified the convention, triggering its entry into force on 19 June 2004 and creating the Western and Central Pacific Fisheries Commission. The U.S. domestic procedures for ratification of the Convention were completed in 2007, and the United States actively participates in the WCPFC as a member. The WCPFC has authority to manage catch, bycatch, fishing capacity, and effort in order to achieve its goal of conserving the stocks and managing the fisheries for tuna and tuna-like species in the central and western Pacific Ocean west of 150°W longitude and between temperate waters in the North and South Pacific. Means for monitoring and compliance include a vessel register, vessel monitoring systems, an observer program, port monitoring, and reporting of landings, fishing effort, catch, and transshipment. A Scientific Committee was formed when the WCPFC entered into force to provide scientific advice to the Commission for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific.

While WCPFC nations negotiated terms for an overall conservation and management convention for highly migratory species west of 150°W longitude, two informal, international scientific arrangements have been in place in the North

[1]Australia, Canada, Cook Islands, Federated States of Micronesia, Fiji, Indonesia, Kiribati, Marshall Islands, Nauru, New Zealand, Niue, Palau, Papua New Guinea, Philippines, Samoa, Solomon Islands, Tuvalu, United States, and Vanuatu; Japan and Korea voted against, and China, France, and Tonga abstained.

[2]Australia, Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, New Zealand, Niue, Papua New Guinea, Samoa, Solomon Islands, and Tonga.

Pacific for a number of years. The North Pacific Albacore Workshop was established in 1974 for exchange of scientific information useful for assessing the status of North Pacific albacore. Scientists from Canada, Japan, Taiwan, and the United States have participated in this arrangement. The second arrangement, the Interim Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean[3] (ISC), was formed in 1995 to enhance scientific research and cooperation for conservation and rational utilization of highly migratory species resources of the North Pacific. The ISC also establishes the scientific groundwork for any future management regime. Scientists from Canada, Japan, Korea, Mexico, Taiwan, the United States, the IATTC, the Secretariat of the Pacific Community, and the North Pacific Marine Science Organization are active in this arrangement, with collaborative scientific studies and sharing of fishery data. In this regard, a central database and website have been established by the ISC. At the ISC's 2004 meeting in Honolulu, Hawaii, participants concluded that the ISC should continue as an independent body and be available to provide scientific stock advice to other bodies (e.g. WCPFC, IATTC) as needed. The ISC also decided to invite the North Pacific Albacore Workshop to become part of the ISC. With the addition of the albacore workshop in 2005 as the ISC Albacore Working Group, the ISC's primary focus is now on the North Pacific stocks of albacore, bluefin tuna, swordfish, striped marlin, and blue shark.

In 1981, the United States and Canada entered into an agreement, the U.S.–Canada Albacore Treaty, which allows for reciprocal fishing in each party's EEZ and landing privileges at selected ports for albacore fishing vessels of both countries. In 2002, that access agreement was amended to limit access of each party's vessels fishing for albacore in the waters of the other party. Over a period of 3 years, the effort-limitation regime requires by the third year no more than 125 vessels with 4 months fishing for each, or 500 vessel-fishing months regardless of the number of vessels involved, will be allowed by each party in each other's EEZ. In 2007, Canadian vessels fished 339 vessel months in the U.S. EEZ, while U.S. vessels fished 22 vessel months inside the Canadian EEZ. The agreement also had a provision that if at the end of the third year no new agreement was reached, fishing limits would be reduced to 94 vessels for 4 months or 376 vessel-fishing months in each party's EEZ. This provision was implemented for 2006 and 2007.

While international mechanisms for conservation and management of Pacific highly migratory species throughout their range are being developed, the United States has proceeded with managing its domestic fisheries for highly migratory species. Lead management authority for highly migratory species rests with the Western Pacific Fishery Management Council (WPFMC) for the U.S. EEZ in the central western Pacific and with the Pacific Fishery Management Council (PFMC) for the U.S. EEZ along the West Coast. The WPFMC has had a Fishery Management Plan (FMP) for pelagic fisheries since 1986. The most significant provision of that plan is a maximum limit of 164 permits for longline vessels operating from ports in Hawaii and 60 permits for longliners operating from American Samoa. In addition, an amendment to the plan in 2001 prohibited targeting swordfish in the North Pacific with longline gear and imposed time and area closures for longline gear targeting tuna in order to reduce sea turtle interaction and mortality. In 2004, the swordfish-directed component of the Hawaii-based fishery was re-opened but subject to restrictions on the types of hooks and bait to be used, annual fleetwide limits on turtle interactions and fishing effort, and other mitigation measures. The first complete year in which the Hawaii-based longline fishery was allowed to target swordfish was 2005. In the following year, the shallow-set longline fishery reached the annual interaction limit of 17 loggerhead sea turtles and the fishery was closed 20 March 2006. The vessels that targeted swordfish converted to deep-set longline and targeted tunas for the remainder of the year. In 2007, the Hawaii-based shallow-set longline fishery stayed below the annual sea turtle interaction limit and remained open throughout the entire year.

The PFMC began developing an FMP for West Coast highly migratory species in 2000 and approved the FMP in June 2003. The National Marine Fisheries Service (NMFS) approved the

[3]Name was changed in 2005 to the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean.

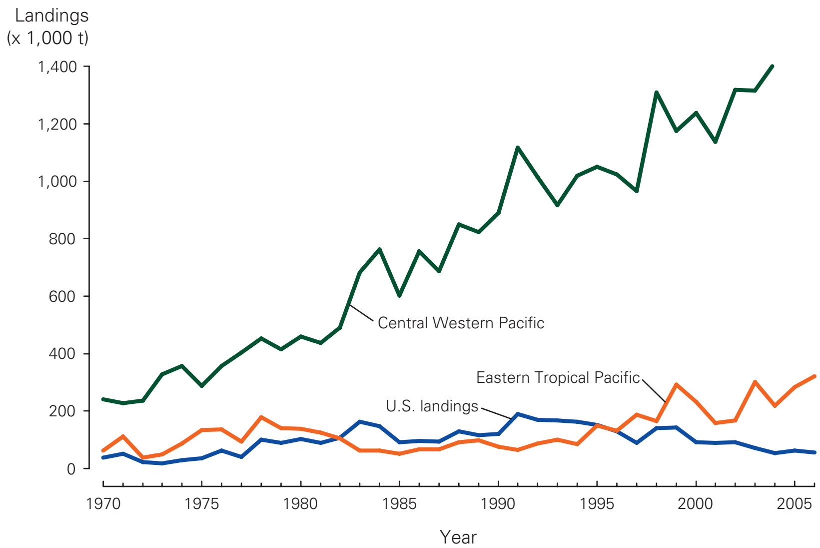


Figure 18-1
Landings in metric tons (t) of skipjack tuna in the Pacific Ocean region, 1970–2006.

FMP in February 2004 and implemented the plan beginning in 2005. Vessels immediately affected most by the plan were those using drift gillnet and longline gear. The plan prohibits shallow setting of longline gear (used largely to target swordfish) west of 150°W longitude because of concerns for sea turtle and seabird interactions. In a separate action, NMFS implemented regulations to prohibit targeting swordfish east of 150°W longitude to prevent jeopardy to sea turtles. Regulations protecting sea turtles from adverse impacts of the drift gillnet fishery had previously been announced and were continued under the FMP; certain new closures within the EEZ off Washington and Oregon have been implemented by the plan.

The United States has also taken steps to manage sharks taken in commercial fisheries. Shark finning (the removal and retention of shark fins only and discarding the carcass at sea) is currently prohibited in all U.S. fisheries. Landing shark carcasses with fins, however, is allowed at U.S. ports. Harvest guidelines have been set for thresher shark and shortfin mako shark by the PFMC, and the white shark and megamouth shark have both been designated protected species under the plan.

SPECIES AND STATUS

Highly migratory pelagic species are often grouped for convenience into tropical tunas (yellowfin, bigeye, and skipjack), temperate tunas (Pacific bluefin and albacore), billfishes (marlins and swordfish), oceanic sharks (thresher, blue, and mako), and other species (dolphinfish and wahoo). Most of these fishes are caught commercially and support large industries. Some, such as tropical tunas and dolphinfish, are important to subsistence fisheries of small Pacific Island nations and U.S. territories. Others, especially marlins, yellowfin tuna, and albacore, support important recreational fisheries.

Tropical Tunas

Yellowfin, skipjack, and bigeye tunas are the principal tuna species categorized as tropical tunas. Their concentrations are highest in the tropics between latitudes 20°N and 20°S. The primary fishing gears used to catch these tunas commercially are longlines and purse seines. Other fishing gears of less importance include ring net, handline, troll, and pole-and-line. In 2002, more than 400 large purse seiners and more than 5,000 longliners participated in Pacific tuna fisheries.

Longline gear is used to catch yellowfin and bigeye tunas across the Pacific, whereas the purse seine is the primary gear used in the eastern and the central western Pacific. In the eastern Pacific, the largest purse-seine fleets are from Ecuador, Mexico, and Venezuela. In the central-western Pacific, Japan, the Republic of Korea, the Philippines, Taiwan, and the United States have major purse-seine fleets. Major longline fleets fishing for yellowfin and bigeye tunas are based in Japan, Korea, and Taiwan.

Skipjack tuna is the volume leader in the Pacific and is caught primarily with purse-seine gear. The catch is used primarily as raw material for canning. Recent average annual yield (2004–06) is 274,974 t for the eastern Pacific and 1,494,421 t for the central western Pacific (Table 18-1, Figure 18-1). The U.S. Pacific-wide catch of skipjack tuna has averaged about 57,314 t recently. The dockside ex-vessel revenue of the total Pacific catch is about $869 million annually. The skipjack tuna stocks are believed to be underutilized, with the MSY for the central western stock at 2.7 million t; MSY for the eastern Pacific stock is unknown.

Yellowfin tuna is another prized species used principally for canning. Recent average yield is 252,412 t for the eastern Pacific fishery and 399,378 t for the central western Pacific fishery (Table 18-1, Figure 18-2). The U.S. catch has averaged 57,337 t in recent years. The ex-vessel value of the Pacific-wide catch is about $474 million. The eastern stock of yellowfin tuna is near the biomass that produces the MSY, but the stock is experiencing overfishing. The central western stock is slightly above the biomass for MSY.

Large-sized bigeye tuna are sold mainly as raw material for the high-priced restaurant trade, particularly sushi restaurants. However, landings by purse seiners of smaller sizes, or subadults, are largely used for canning. Recent average yield for the entire Pacific is about 240,824 t, up significantly from earlier yields owing to increased catches by purse seiners taking young fish with fish-aggregating devices (Figure 18-3). The ex-vessel revenue from the total bigeye tuna catch is about $1 billion annually. Most of the catch is taken by longline fleets of Japan, Korea, and Taiwan. The U.S. catch of about 11,432 t annually is taken mostly with purse seines. However, U.S. longliners catch about 4,000 t annually, valued at about $20 million that includes a significant catch by Hawaii-based longliners. The recent average yield for U.S. longliners is 317 t in the eastern Pacific.

The MSY and current yield for bigeye tuna are undergoing review. The stock structure of the Pacific-wide population is unclear. However, current best estimates of yield potential indicate that the stocks (especially the stock or stock portion in the eastern Pacific) are at full utilization, and overfishing may be occurring.

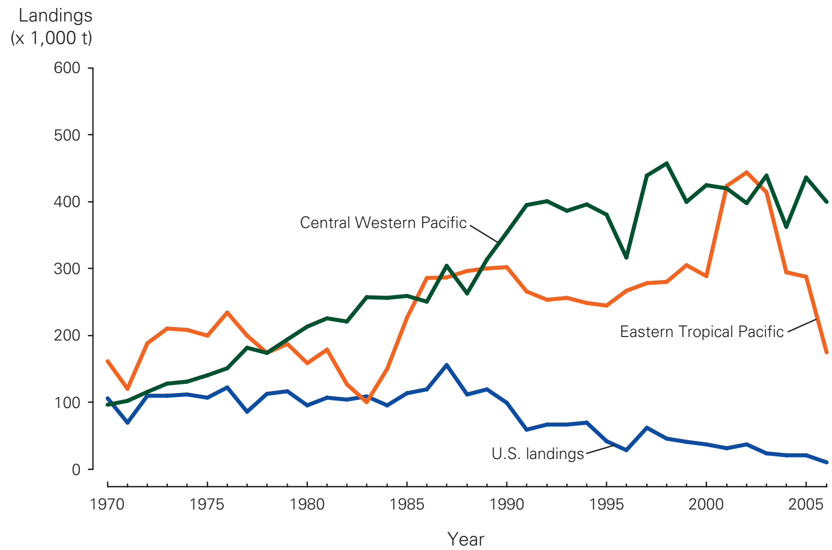


Figure 18-2
Landings in metric tons (t) of yellowfin tuna in the Pacific Ocean region, 1970–2006.

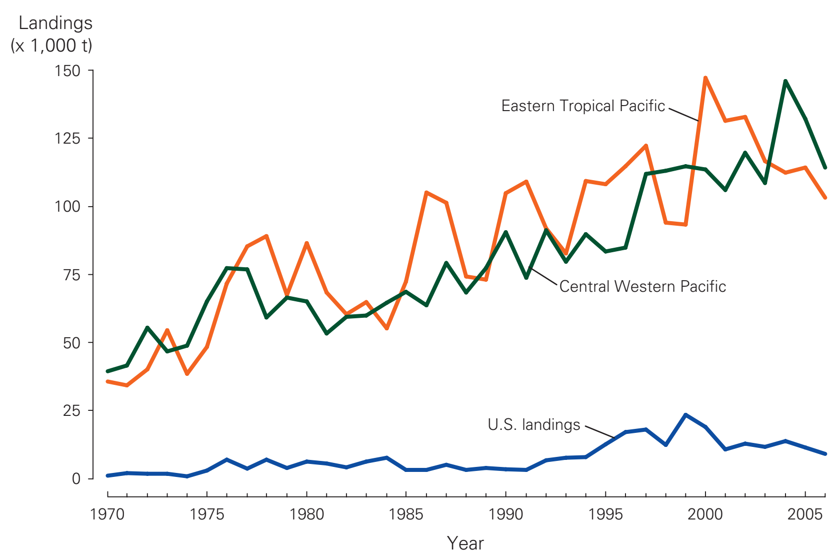


Figure 18-3
Landings in metric tons (t) of bigeye tuna in the Pacific Ocean region, 1970–2006.

Temperate Tunas

Pacific bluefin tuna and North and South Pacific albacore are categorized as temperate tunas. They generally occur in large concentrations in higher latitudes of the North and South Pacific. Adults, however, seasonally migrate to tropical waters for spawning.

U.S. catches of Pacific bluefin tuna have recently been relatively minor. This species is taken seasonally off southern California and Baja California, Mexico, primarily by purse seiners that normally target other species (anchovy, sardine, and mackerel) and by recreational fishermen. In the mid North Pacific, Pacific bluefin tuna are taken sporadically by the Hawaii- and California-based longline fleets targeting swordfish and bigeye tuna. Recent Pacific-wide average (2004–06) yield is about 25,100 t. Approximately 63% of the landings are taken by Japan, 7% by Taiwan, 24% by Mexico, 3% by Korea, and 2% by the United States. Stock status is uncertain and undergoing review.

In the North Pacific, albacore are fished primar-

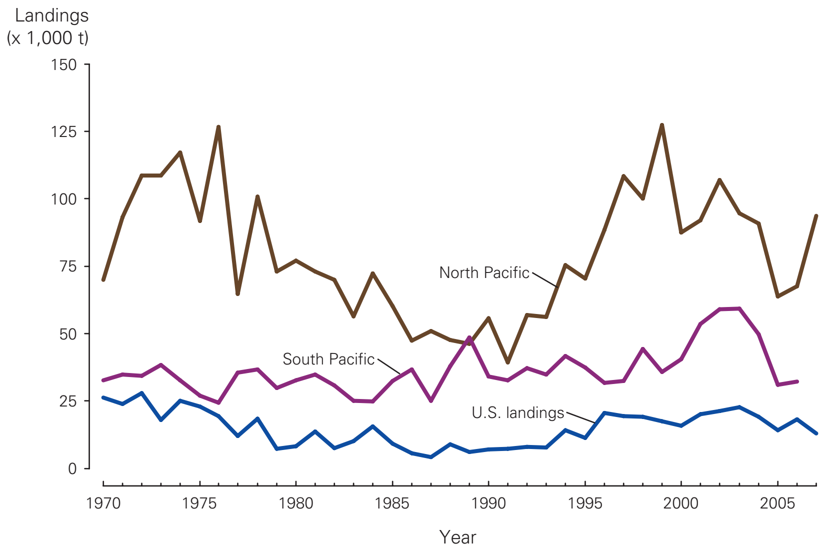


Figure 18-4

Landings in metric tons (t) of albacore in the Pacific Ocean region, 1970–2007.

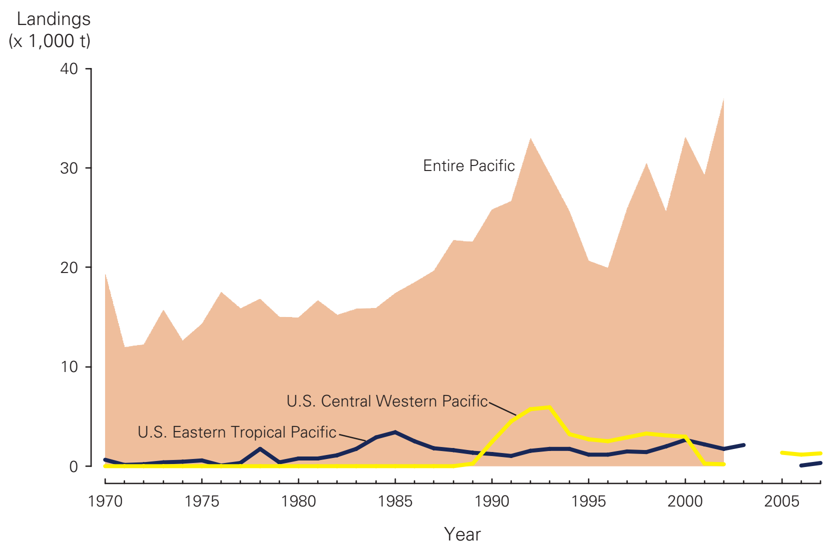


Figure 18-5

Landings in metric tons (t) of swordfish in the Pacific Ocean region, 1970–2007. Data are not available for some recent years.

ily by longline, pole-and-line, troll, and up until 1992, drift gillnet gears. Longline gear is used in the lower latitudes and off the Japanese archipelago and currently accounts for 35% of the catch. Pole-and-line and troll gears are used in the surface fisheries that operate in the North Pacific Transition Zone and higher latitudes. These gears account for 60% of the catch. The 2004–06 average yield was 74,013 t, and the U.S. yield was 13,166 t (Figure 18-4).

Based on a dockside price of $1,973 per ton, the annual ex-vessel revenue of the 2004–06 average North Pacific albacore yield was about $142 million per year. The MSY is unknown. The status of the North Pacific albacore population is reviewed on an ongoing basis by an international team of scientists through the ISC's North Pacific Albacore Working Group. A comprehensive review was conducted in 2006. Although a stock assessment was conducted and a suite of candidate biological reference points have been documented, management bodies (e.g., PFMC and WPFMC) have not established formal harvest control rules to date.

In the South Pacific, fisheries for albacore are expanding with largely longline and troll gears. The 2004–06 average yield was 37,602 t (Figure 18-4). Longline fleets from Japan and Taiwan are the largest producers. Longline gear accounts for 86% of the catch and is the gear of choice for new vessels entering the fisheries. The newer vessels use a large reel with miles of monofilament main line. South Pacific Island countries (French Polynesia, New Caledonia, Fiji, and Samoa), for example, are rapidly building significant longline fleets for albacore. The U.S. fishery, which primarily consists of longliners and troll vessels, landed approximately 3,950 t of albacore in the South Pacific in 2004–06. The troll fishing season is the austral summer (November through April) in the higher latitudes (35° to 45°S) east of New Zealand.

Billfishes

Billfishes, including swordfish, marlins, and spearfish, generally range from North America to Asia and between the North and South Pacific Convergence Zones. These fishes are more abundant near islands, continental slopes, seamounts, and oceanic fronts, and many are important to local economies. They are caught by foreign and U.S. recreational and commercial fishermen.

Swordfish are distributed throughout the temperate, subtropical, and tropical waters of the Pacific. Much of the Pacific-wide catch of swordfish is taken by the Japanese longline fishery as bycatch while targeting tunas. Other longline fleets target swordfish, particularly the longline fleets of the United States, Mexico, Chile, and Australia. Coastal swordfish fisheries occur off the United

States, Japan, Taiwan, Mexico, Chile, and Australia, using various surface gears, such as harpoons and driftnets. Yields increased throughout the 1980's and fluctuated in the 1990's (Figure 18-5), averaging about 33,000 t in recent years (Table 18-1).

Until recently, a substantial fraction of the Pacific catch of swordfish was harvested by the U.S. longline fleet in the central western Pacific (Figure 18-5), and prior to prohibition of the gear in 1993, some of the catch was caught by high-seas drift gillnet vessels. The rest of the swordfish yield is largely taken by surface gears, such as harpoons, handlines, and coastal drift gillnets. From 1989 to 1993, production from the U.S. domestic longline fishery in Hawaii increased rapidly, reaching 5,925 t and an ex-vessel revenue of $26.1 million in 1993. Production from the Hawaii fishery accounted for about 14% of the total Pacific production in the 1990's. The swordfish production from the U.S. domestic gillnet and harpoon fisheries located primarily off California increased markedly between 1975 and 1985, when a peak yield of 3,400 t was landed. Production from these sources declined in the 1990's, while production increased from longline vessels based in California and with seasonal participation by vessels from the Hawaii-based fleet making landings in California. The U.S. eastern Pacific fishery has a recent average annual yield of about 1,400 t worth about $6 million in ex-vessel revenue. Both the U.S. longline and gillnet fisheries have recently been affected by concerns over interactions with protected species. In 2001, the Hawaii-based longline fishery was prohibited from using shallow-set fishing methods that target swordfish, due to high bycatch rates of primarily loggerhead and leatherback sea turtles. This fishery was reinstated in 2004 with new gear, fishing effort, and turtle take limitations. Annual catches in the Hawaii-based fishery during 2001 and 2002 declined to about 225 t due to the regulations prohibiting swordfish fishing. The catch and effort of the California gillnet fishery also plummeted owing to expansion of area and season closures to reduce pinniped and turtle interactions.

The stock structure and status of Pacific swordfish stocks are unclear. Several studies suggest more than one Pacific stock. A stock assessment of a North Pacific population indicated a decline in abundance in the northwest Pacific. The MSY, however, is estimated to be greater than the current yield.

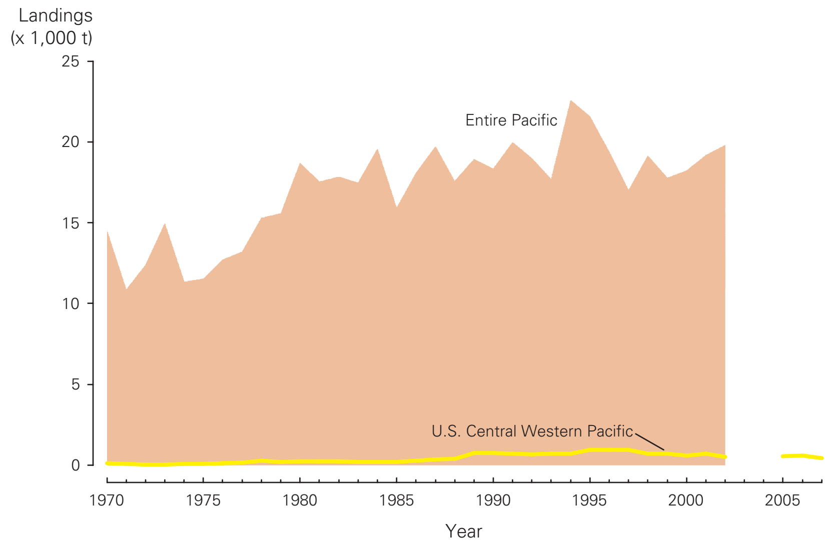


Figure 18-6
Landings in metric tons (t) of blue marlin in the Pacific Ocean region, 1970–2007. Some recent years of data are not available for all metrics.

Other Pacific billfish species include blue, black, and striped marlins; sailfish; and shortbill spearfish. U.S. commercial fishermen primarily use longline, troll, and handline gears to catch marlins and spearfish, while recreational fishing gears include rod-and-reel and handline. The U.S. catch of blue and striped marlin is worth about $2,500 per ton ex-vessel.

Blue marlin are one of the most important big game fish for recreational fishermen and are of great economic value to communities with charter fleets and fishing tournaments for this species. It is also an important commercial species. Pacific-wide commercial yields of blue marlin increased in the 1970's and fluctuated between 16,000 t and 22,000 t in the 1980's and 1990's (Figure 18-6). Annual U.S. Pacific fisheries yields of blue marlin increased in the 1970's and 1980's and leveled out in the 1990's at 700 to 900 t, comprising about 4% of the Pacific total. Concern over the status of blue marlin has prompted several recent efforts to assess the status of the Pacific-wide stock. Earlier, scientists had suggested that the stock might be overfished, as Pacific-wide fishing effort increased in the 1980's and yields remained level. However, the most recent assessment models indicate that effective fishing effort for blue marlin has not increased very much since the early 1980's, and at most, blue marlin are now thought to have a biomass close to the level

Anne Allen, SWFSC

Mako shark.

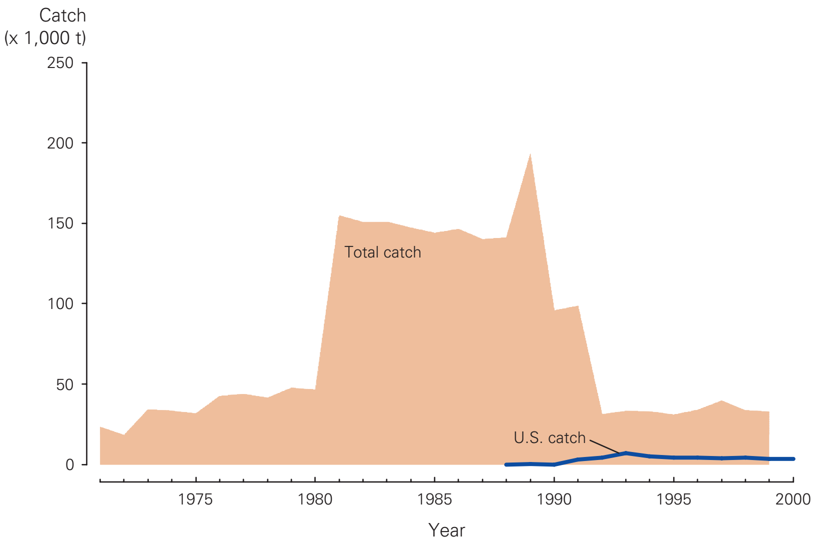


Figure 18-7
Landings in metric tons (t) of blue shark in the North Pacific Ocean region, 1970–2000.

Allen Shimada, NMFS

A freshly landed wahoo on the deck of a NOAA Fisheries Research Vessel.

that supports the MSY (Table 18-1). The status of most other billfish species stocks is unknown or uncertain, although earlier assessments using data through 1985 indicated that striped marlin were underutilized.

Oceanic Sharks

Pacific oceanic shark species include requiem, thresher, and mackerel sharks. Sharks are taken by longline in the central North Pacific and by drift gillnet off the U.S. West Coast. Shark prices vary greatly by product form, and until recently most landings in U.S. fisheries were from the Hawaii-based longline fishery in the form of shark fins, selling for about $40,000 per ton. Shark finning with discarding of the carcass at sea is currently banned in all U.S. fisheries. Limits on non-blue shark landings are being considered for Hawaii-based longline vessels. In Hawaii, whole sharks are sold for about $1,400 per ton.

All pelagic longline fisheries catch appreciable numbers of sharks, but only a few nations report their shark catches. Most foreign longline fisheries collect shark fins to produce a dried product for making soup. The product is marketed primarily through Hong Kong. In some cases, shark finning is conducted by fishing crew members as a separate enterprise from the primary fishery. Because carcasses are discarded at sea, shark catches are often treated as discards and are seldom logged; hence, the total Pacific harvest of pelagic sharks is unknown.

Blue sharks are the most numerous shark species in the North Pacific, and research to estimate yield based on data reported by a subset of fishing vessels has recently allowed an assessment of blue shark to be completed. Estimated yield of sharks (including discards) reached high levels during the era of the North Pacific drift gillnet fishery, which ended in the early 1990's (Figure 18-7). After an international ban on high-seas drift nets, the annual shark yield (mostly by longliners) stabilized at around 33,000 t (weight estimated from number caught multiplied by an assumed average weight of 45 kg per shark). The U.S. North Pacific yield (estimated round weight, including discards) was taken mainly by Hawaii-based longliners and peaked at about 6,800 t in 1993. Yields subsequently declined as the fleet altered its fishing strategy in the mid 1990's, but shark landings continued to increase through 1999 (Figure 18-7) because an increasing fraction of the yield was landed in the form of fins (landings expressed as round weight regardless of product form). The recent North Pacific blue shark stock assessment estimated an MSY of about twice the recent annual yield and indicated that the stock is underexploited. In 2003, a regional MSY and optimum yield were calculated for the U.S. Pacific Coast stock of thresher shark, with harvest guideline established at 340 t per year. The condition of other pelagic shark stocks remains unknown.

Other Migratory Species

Other Pacific highly migratory species include wahoo and dolphinfish (mahi mahi). These species are primarily caught commercially using longline, troll, and handline gears; recreational fishermen use mainly rod-and-reel and handlines. The U.S. catch of dolphinfish and wahoo is worth about $4,200 per ton. The MSY and status for these stocks is unknown, but both species are thought to be near the biomass level that would produce the MSY.

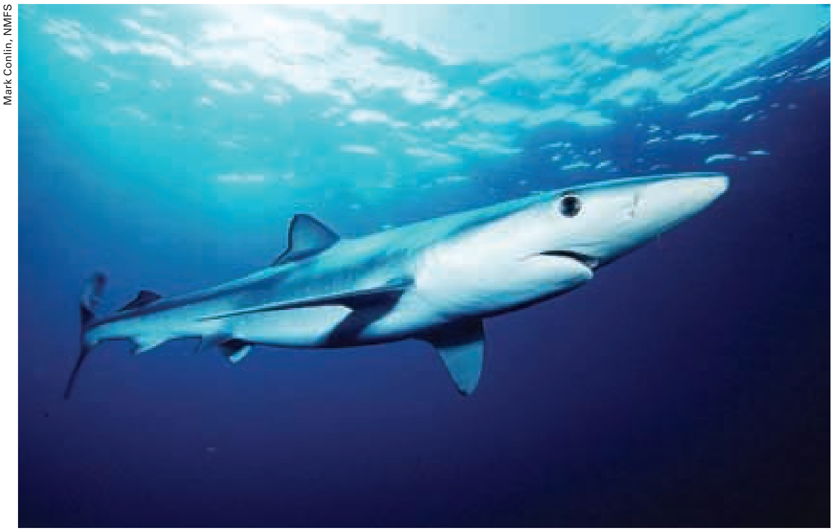
ISSUES

Management Concerns

Growth of total fleet fishing capacity for highly migratory species in the Pacific is of increasing concern to fishery managers, because many of the target species are already fully harvested or harvested above sustainable levels. In addition, the economic impacts of high capacity are becoming more apparent. Regional fishery management organizations and nations are increasingly considering management and limitation of fishing capacity as a major component of a rational fishery conservation and management program. The paradigm is that if fishing capacity can be managed effectively, the need for more restrictive, complicated, and costly management measures (e.g. limitations on fishing effort, catches, sizes, seasons, and area closures) would not be necessary. Therefore it is prudent to manage capacity rather than to limit efficiency. In recent years, the IATTC has been working on limiting purse-seine fishing capacity in the eastern Pacific, and parties involved in developing the WCPFC consider limitation of fishing capacity as a priority topic for consideration.

Closely aligned with fishing capacity is the problem of illegal, unreported, and unregulated (IUU) fishing by vessels that operate outside the control of regional management regimes. In June 2001, the U.N.'s Food and Agriculture Organization Council adopted an international plan of action to prevent IUU fishing. The IATTC has been actively addressing this issue, and the emerging WCPFC deliberated on this issue as part of the groundwork for establishing the Commission for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific.

Another issue in the Pacific is the high fishing mortality (and subsequent reduction in future spawning biomass) being exerted on juvenile bigeye and yellowfin tuna with increasing use of fish aggregating devices by purse seiners and domestic fisheries of the Philippines and Indonesia. The WCPFC, in collaboration with the Secretariat of the Pacific Community, has initiated a program to document the level of mortality, particularly that caused by the Philippine and Indonesian fisheries, for highly migratory species. The IATTC has also been addressing this issue with proposed measures to limit the catch of bigeye tuna and to prevent overall fishing effort from increasing, but conservation measures for 2008 to address overfishing have not been adopted.


Mark Conlin, NMFS

Blue shark in the Southern California Bight, an important nursery area for young blue sharks.

Bycatch and Multispecies Interactions

Of continuing concern is the bycatch of seabirds, sea turtles, and marine mammals by fisheries for Pacific highly migratory species. NMFS has been and will continue to be a strong proponent for accurate reporting of catches of bycatch species as well as for adoption of preventative and mitigative gear and procedures. In this regard, NMFS is promoting the international adoption of fishing gear and techniques (i.e. large circle hooks and mackerel-type bait) developed in the Atlantic Ocean and currently being implemented in the Hawaii-based longline fishery to significantly reduce turtle bycatch in swordfish fishing. The IATTC and the Standing Committee on Tuna and Billfish have had a working group to address the problem of bycatch of protected species as well as incidental catches of fishes for a number of years. A similar working group was established by the WCPFC at its inaugural meeting in December 2004.

Participants in various fisheries under the WPFMC's jurisdiction continue to voice concern about the impacts of competing fisheries on their fishing success (for example, near-island troll and handliners complain about offshore longline and handline fishing, particularly now as handline fishing around privately deployed fish aggregating devices expands offshore into waters fished by longliners). Also, longline fishery participants object to the number and severity of management measures specific to

Removing the hook from a freshly landed juvenile yellowfin tuna.

that fishery. In particular, regulations to protect sea turtles and seabirds are contested in the Hawaii-based longline fishery because the impact of that fishery is believed to be slight compared to that of other fisheries, particularly foreign longliners that continue to operate unhindered on the high seas.

Transboundary Stocks and Jurisdiction

Although they fish the same resources as the Hawaii-based vessels and sometimes fish the same areas, longline vessels operating out of California have not been subject to the management regulations developed by the WPFMC. As noted earlier, however, in 2004 the PFMC approved and implemented a highly migratory species FMP to close this loophole. The plan requires California-based longline vessels fishing highly migratory species on the high seas to follow practices applied to longliners by the WPFMC for prevention of sea turtle and seabird interactions. Combined with a separate regulation issued by NMFS, the FMP results in a prohibition of all shallow swordfish longline sets by West Coast-based longline vessels. The PFMC is considering whether to amend its FMP to require the same gear and techniques as in the WPFMC's FMP and thus restore some swordfish fishing opportunity for the longline fleet. Other provisions of the PFMC's plan apply to conservation of shark resources and involve application of existing state regulations.

International cooperation and conservation measures are a growing management issue emerging for the highly migratory species FMP of the PFMC. If a tuna stock is experiencing overfishing or becomes overfished, FMP regulations could result in limits on the catch of U.S. fishermen, even when the regulations result in no significant advantage to the stock because of the relatively small amount of effort exerted by the U.S. fleet. The FMP regulations would have no effect on the substantial amount of foreign fishing that occurs on the high seas, although this sector of the fishery for highly migratory species may be the root cause of overfishing. United States fishermen would thus be disadvantaged. Efforts of the United States in establishing the WCPFC and strengthening the IATTC are designed to ensure that conservation measures would be equally applied to foreign and U.S. fishermen.

An administrative problem arising in all areas in the Pacific is the increasing need for vessel records and statistical documents for shipments of various tuna from nation or region to nation or region. Fish are easily shipped across regions, and all nations have a stake in ensuring that fishermen are not allowed to circumvent catch restrictions in one area by simply shipping fish to other areas and reporting they were caught there. While cumbersome, catch documentation requirements are increasingly needed to support effective conservation and management of important stocks in the Pacific Ocean.

Scientific Advice and Adequacy of Assessments

The condition is unknown for populations of some of the billfishes, dolphinfish, wahoo, and most shark species, largely because of a lack of comprehensive data on these species, in particular fishery statistics from all fishing fleets. Many of the species with unknown status are not targeted in highly migratory species fisheries but are captured as incidental catch or bycatch. United States fishery data collection through logbooks and observer programs is comprehensive, but is not enough for performing stock assessments. These data represent only a small fraction of the total catch from the stocks. Data collection and exchange on an international scale are required. Recent assessments undertaken for tuna species, swordfish, blue marlin, and blue shark have resulted from international collaboration. This collaborative approach also led to new stock assessment activities and a re-examination of stock structure for striped marlin in 2007. For other species, particularly bycatch species, international data collection must be significantly improved before credible stock assessments can be performed.

The take of protected species by U.S. fisheries is well monitored, and aggressive management measures have been taken to minimize the impacts of U.S. fisheries. However, the impacts of U.S. fisheries on protected species and bycatch in general are relatively minor compared to those of the much larger foreign fleets that fish across the Pacific, because they represent only a small fraction of total fishing effort. Further work on an international scale will be required to minimize these impacts.

The U.S. monitoring of landings (including estimation of total catches), collection of fishing effort and resulting catch data (logbooks), and size data for domestic coastal and high-seas fisheries provide the basis for preparing scientific advice on domestic fisheries. They also comprise a disproportionate amount of the data used by international bodies for stock assessments. At meetings of multinational management bodies, NMFS will continue to strongly advocate participation of all fishing nations to meet their obligations for monitoring their fleets commensurate with their fisheries production. Data collected ought to be shared and made available to international management bodies and scientific working groups tasked to conduct stock assessments and to provide advice on the condition of the highly migratory species stocks.

Progress

Progress has been made on the stock assessment of several important fish stocks and in reducing U.S. fishery impacts on protected and endangered species. An updated blue marlin stock assessment indicates no overutilization. The status of several tuna stocks also has been updated. For central western Pacific tunas, the Secretariat of the Pacific Community annually convenes informal international scientific meetings to assemble fisheries statistics, evaluate fishery developments, and assess the condition of the western and South Pacific stocks. The recent assessments of North Pacific swordfish and blue shark were undertaken cooperatively under the sponsorship of the ISC. This organization now meets regularly to organize such research. The eastern Pacific stocks are assessed annually by the IATTC for providing fishing management advice.

Management of the domestic fisheries has been successful in reducing gear conflicts among longline, troll, driftnet, rod-and-reel, and handline fisheries and in reducing U.S. fishery impacts on Hawaiian monk seals, California sea lions, cetaceans, albatrosses, and sea turtles. Although the swordfish sector of the Hawaii longline fishery was closed between April 2001 and April 2004, the tuna harvest by the fishery continued to increase throughout the 1990’s and early 2000’s.

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Alaska Groundfish Fisheries

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19

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Photo above: Walleye pollock catch.

INTRODUCTION

The groundfish complex is the most abundant fisheries resource off Alaska, with a combined biomass of more than 21.8 million metric tons (t). About 76% of the biomass is found in the Bering Sea and Aleutian Islands region, with the remainder in the Gulf of Alaska. From 2004 to 2006, groundfish catches averaged nearly 2.2 million t or about 10% of the total groundfish biomass, although harvest rates vary for individual species. Prior to 1976, the only groundfish species of significant commercial value to domestic fisheries was Pacific halibut; foreign fisheries harvested most other targeted commercial species. The implementation of the Magnuson Fisheries Conservation and Management Act of 1976 (1976 Act) extended Federal fisheries management jurisdiction to 200 nautical miles (n.mi.), excluding foreign fisheries and stimulating the growth of domestic fisheries. Although the domestic fisheries engaged initially in joint-venture operations with foreign partners after the 1976 Act, exclusively domestic fisheries had replaced these joint-venture operations by 1983. The North Pacific Fisheries Management Council (NPFMC) manages Alaska groundfish fisheries within the U.S. Exclusive Economic Zone (EEZ; 3–200 n.mi. offshore). Inshore groundfish resources (0–3 n.mi.) are managed by the Alaska Department of Fish and Game.

SPECIES AND STATUS

Pacific Halibut

Pacific halibut are found from the Bering Sea to California, with the center of abundance in the Gulf of Alaska. The resource is managed by a bilateral treaty between the United States and Canada and through research and regulation recommendations from the International Pacific Halibut Commission (IPHC). Pacific halibut, considered to be

Table 19-1
Productivity in metric tons (t) and status of Pacific halibut fisheries resources.

Species/stock	Recent average yield (RAY)[1]	Current yield (CY)[2]	Sustainable yield (MSY)	Stock level relative to B_{MSY}
Pacific halibut[3]				
Bering Sea	9,691	9,770	15,000	Above
Gulf of Alaska	39,341	35,431	40,000	Above
U.S. Pacific Coast	1,069	1,079	1,000	Near
Canadian Pacific Coast	9,024	7,811	7,000	Near
Total	59,125	54,091	63,000	
U.S. subtotal	50,101	46,280	56,000	

[1]2001–03 average.
[2]Yield for 2007.
[3]Status determinations for Pacific halibut are coastwide: the stock is classified as not overfishing and not overfished.

one large interrelated biological stock, are regulated by subareas through catch quotas, time–area restrictions, and by individual fishing quotas.

Although the commercial Pacific halibut fishery has a long tradition dating back to the 1880's, the nature of the fishery has changed dramatically in recent years. Both Canadian and Alaskan halibut fisheries have moved from an open-access fishery with short fishing seasons to an individual fishing quota (IFQ) fishery of nearly 8 months' duration. Under the IFQ system there has been a decline in overall size of the fishing fleet. In 2003, 220 vessels fished in Canada and 1,586 fished in Alaska, whereas in 2007, the number of vessels was 212 in Canada and 1,482 in Alaska. In addition, the Pacific Fishery Management Council adopted a catch-sharing plan for Treaty Indian, commercial, and recreational Pacific halibut fisheries for the Washington–California region.

Most components of the halibut fishery have been very successful in recent years, including the growing recreational fishery. The resource has been healthy, and the total catch has been near record levels. The recent average yield (2004–06) of halibut was 59,125 t (Table 19-1); the 2007 catch was slightly lower at 54,091 t. The breakdown by fishery sector in 2007 was 37,986 t for commercial fisheries, 6,004 t for recreational fisheries, 896 t for personal use, 7,321 t as bycatch in other fisheries, and 1,461 t as mortality due to fishing by lost gear and discards.

Because of the long history of the fishery, data on the Pacific halibut stock go back to the 1920's. The stock was depleted by unregulated commercial fishing early in the 20th century but recovered under IPHC management between 1930 and 1950. A combination of adverse environmental conditions, large bycatch of halibut in foreign fisheries in the 1960's, and continued high quotas again depressed the stock to a low level in the early 1970's. In the mid 1970's the IPHC adopted a stock rebuilding plan and greatly reduced commercial quotas. At the same time, the implementation of the 1976 Act limited bycatch of Pacific halibut. These factors, combined with a dramatic shift in the climate of the North Pacific, resulted in much higher reproductive success and a rapid recovery of the stock during the 1980's.

While the history of the halibut stock is well known, the modern assessment is conducted only for the time frame of 1996 to the present. The modern assessment relies heavily on data that have only been collected since the coastwide stock resource surveys began in 1996. The most recent assessment shows that the stock has declined from the very high levels of the late 1990's (Figure 19-1; Clark and Hare, 2002; Hare and Clark, 2008) but is still well above any level of concern for the spawning biomass. On a coastwide basis, removals are very close to the target 20% harvest rate identified for halibut as providing the optimal combination of precaution and exploitation. In the western Gulf of Alaska and Bering Sea and Aleutian Islands region, comprehensive surveys first conducted in the latter half of the 1990's showed a substantially greater abundance of halibut than previously estimated. After several years of increased quotas, harvest rates in those areas are now at the target level, and the actual catch levels are likely right around the MSY. Although status determinations are not made for individual subareas, the coastwide stock is classified as not subject to overfishing and the stock status is not overfished.

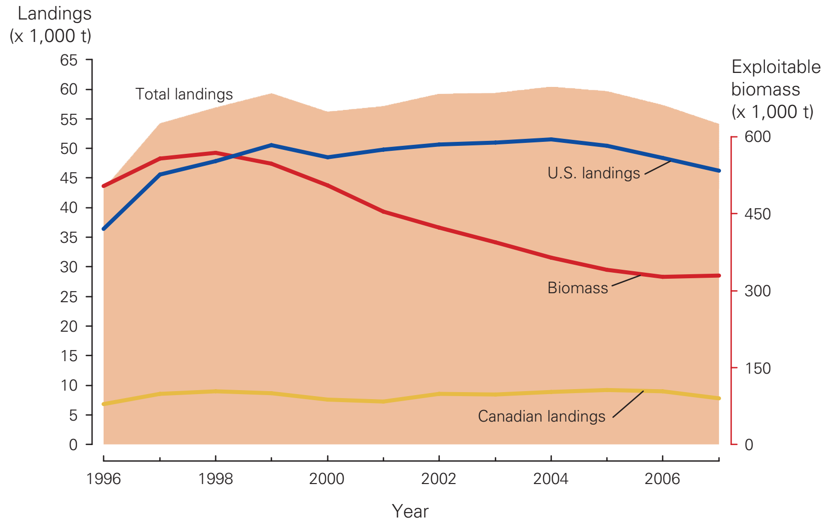

Figure 19-1

Pacific halibut landings and exploitable biomass in metric tons (t), 1996–2007.

Bering Sea and Aleutian Islands Groundfishes

The average eastern Bering Sea and Aleutian Islands groundfish catch in recent years (2004–06) was nearly 2 million t (Figure 19-2, Table 19-2). The dominant species harvested were walleye pollock (75%), Pacific cod (11%), yellowfin sole (4%), Atka mackerel (3%), and rock sole (2%). The rest of the species complex makes up 1% or less of the total catch.

Groundfish biomass has been maintained at relatively high levels since implementation of the 1976 Act in 1977. The current potential yield (2.68 million t) is slightly below the MSY (as estimated from long-term averages of all species combined) of just over 3 million t (Table 19-2). This yield, however, has not been allowed to be fully harvested because catch quotas have been capped at a 2 million t optimum yield limit set in the groundfish fishery management plan (FMP) for the Bering Sea and Aleutian Islands region. The economically more valuable species, such as walleye pollock and Pacific cod, have been allowed to be harvested closer to their full biological potential while many less valuable species are relatively lightly harvested.

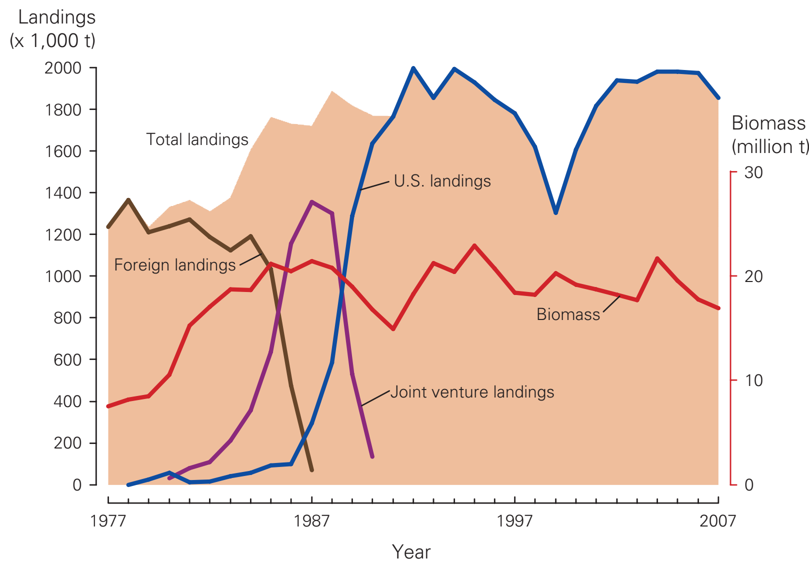

Figure 19-2

Bering Sea and Aleutian Islands groundfish landings and biomass in metric tons (t), 1977–2007.

Walleye pollock: The catch of walleye pollock is the largest of any single species within the U.S. EEZ. The three principal management stocks, in decreasing order of abundance, are eastern Bering Sea, Bogoslof Island (in the Aleutian Basin), and Aleutian Islands. The biomass of eastern Bering Sea pollock has fluctuated in the past three decades as a result of variable strengths of recruiting year-classes. Recent trends indicate that the stock has declined since 2003 due to poor recruitment from the 2001–05 year-classes. This string of consecutive below-average year-classes is unusual, but the two surveys conducted in 2007 indicate that the 2006 year-class may be above average, and if so, the stock should stabilize and begin increasing after 2009. The eastern Bering Sea stock is considered fully utilized and is well managed for bycatch and other issues such as minimizing impacts on Steller sea lion populations. Near-term projections indicate that the recent reductions in quota will persist for 2009.

The Bogoslof Island management stock is considered to be below the peak biomass levels observed during the late 1980's. Recent analyses suggest that due to stock structure uncertainty and

Table 19-2
Productivity in metric tons (t) and status of Alaska groundfish fisheries resources. BSAI = Bering Sea and Aleutian Islands; GOA = Gulf of Alaska.

Species/stock	Recent average yield (RAY)[1]	Current yield (CY)	Sustainable yield (MSY)[2]	Stock level relative to B_{MSY}	Harvest rate	Stock status
Flatfish						
Alaska plaice (BSAI)	11,951	190,000	241,000	Above	Not overfishing	Not overfished
Arrowtooth flounder						
BSAI	14,934	158,000	193,000	Above	Not overfishing	Not overfished
GOA	20,909	184,008	214,828	Above	Not overfishing	Not overfished
Flathead sole						
BSAI	17,164	79,200	95,300	Above	Not overfishing	Not overfished
GOA	2,685	37,110	48,658	Above	Not overfishing	Not overfished
Greenland halibut (BSAI)	2,247	2,440	15,600	Above	Not overfishing	Not overfished
Rex sole (GOA)	2,311	9,100	11,900	Above	Not overfishing	Not overfished
Rock sole (BSAI)	39,835	198,000	200,000	Above	Not overfishing	Not overfished
Yellowfin sole (BSAI)	87,499	225,000	240,000	Above	Not overfishing	Not overfished
Deepwater Flatfishes (GOA)	499	8,707	10,431	Unknown	Not overfishing	Not overfished
Shallow water Flatfishes (GOA)	5,168	51,450	62,418	Unknown	Not overfishing	Undefined
Other Flatfishes (BSAI)	4,167	21,400	28,500	Unknown	Not overfishing	Undefined
Subtotal, flatfish	209,369	1,164,415	1,361,635			
Rockfish						
Northern rockfish						
BSAI	4,157	8,190	9,750	Above	Not overfishing	Not overfished
GOA	4,856	4,938	5,890	Above	Not overfishing	Not overfished
Pacific ocean perch						
BSAI	11,720	21,900	26,100	Above	Not overfishing	Not overfished
GOA	12,130	14,636	17,158	Above	Not overfishing	Not overfished
Shortraker/rougheye rockfishes						
BSAI[3]	285	626	833	Unknown		
GOA[4]	933	1,831	2,270	Above		
Demersal Shelf Rockfishes (GOA)	256	410	650	Unknown	Not overfishing	Undefined
Other Slope Rockfishes (GOA)[5]	844	4,154	5,394	Unknown	Not overfishing	Undefined
Pelagic Shelf Rockfishes (GOA)	2,575	5,542	6,458	Above	Not overfishing	Not overfished
Thornyheads (GOA)	816	2,209	2,945	Unknown	Not overfishing	Undefined
Other Rockfishes (BSAI)	533	999	1,330	Unknown	Not overfishing	Undefined
Subtotal, rockfish	39,105	65,435	78,778			

possibly environmental conditions, expectations to return to the peak stock levels may be unrealistic since pollock fishing within this region has been prohibited since 1992. Survey biomass estimates for Bogoslof since 2000 have all been lower than estimates prior to 2000, ranging from a low of 198,000 t in 2003 to a high of 301,000 t in 2000. The 2007 estimate is the highest since the 2000 estimate.

Similar stock-structure uncertainty exists for the Aleutian Islands region, which was closed to directed pollock fishing from 1999–2005. Age 2+ biomass is estimated to have increased from 1999 to 2004, after which it has been stable. Spawning biomass is estimated to have been increasing slowly since 1999. The 2000 year-class is estimated to have been well above average (third-largest in the time series), and preliminary indications are that the 2005 and 2006 year-classes may be slightly above average. The status of the stock in this region indicates that 28,200 t could potentially be harvested. Current regulations restrict the Aleutian Islands pollock quota to be at or below 19,000 t due to concerns over potential interactions or food competition with Steller sea lions in this area (which contains significant portions of the critical habitat for the species). To better understand interactions between Steller sea lions and fisheries, an exempted fishing permit was granted in 2006 and 2007. This project is restricted to catch fewer than 3,000 t and

Table 19-2
Continued from previous page.

Species/stock	Recent average yield (RAY)[1]	Current yield (CY)	Sustainable yield (MSY)[2]	Stock level relative to B_{MSY}	Harvest rate	Stock status
Other groundfish						
Atka mackerel						
BSAI	60,977	74,000	86,900	Above	Not overfishing	Not overfished
GOA	831	4,700	6,200	Unknown	Not overfishing	Undefined
Pacific cod						
BSAI	208,717	176,000	207,000	Below	Not overfishing	Not overfished
GOA	46,641	68,859	97,000	Near	Not overfishing	Not overfished
Sablefish (blackcod)[6]						
Eastern Bering Sea	1,099	2,980	3,520	Near		
Aleutian Islands	1,083	2,810	3,320	Near		
Gulf of Alaska	14,323	14,310	16,906	Near		
Walleye pollock						
Aleutian Islands	1,502	44,500	54,500	Above	Not overfishing	Not overfished
Bogoslof Island[7]	Trace	5,220	48,000	Unknown	Not overfishing	Undefined
Eastern Bering Sea	1,483,411	1,394,000	1,640,000	Below	Not overfishing	Not overfished
GOA[8]	72,262	68,307	95,429	Below		
Other Species (BSAI)[9]	28,648	68,800	91,700	Unknown	Not overfishing	Undefined
Squids (BSAI)	1,133	1,970	2,620	Unknown	Not overfishing	Undefined
Subtotal, other groundfish	1,920,627	1,926,456	2,353,095			
Total	2,169,101	3,156,306	3,794,108			
Subtotal, BSAI	1,981,062	2,676,035	3,188,973			
Subtotal, GOA	188,039	480,271	605,135			

[1]2004–06 average.
[2]MSY is equal to the overfishing level for all stocks.
[3]Status determinations are made separately for these stocks: shortraker rockfish is not overfishing and undefined stock status; rougheye rockfish is not overfishing and undefined stock status.
[4]Status determinations are made separately for these stocks: shortraker rockfish is not overfishing and has undefined stock status; rougheye rockfish is not overfishing and not overfished.
[5]Other Slope Rockfishes are predominately comprised of harlequin and sharpchin rockfishes.
[6]Status determinations for sablefish are made for the entire Alaska region; this stock is not overfishing and not overfished.
[7]Trace amounts of catch only; the TAC in recent years has been set well below the ABC to account for bycatch in other directed fisheries.
[8]Status determinations are made for individual areas in the GOA: the Western/Central GOA stock is not overfishing and not overfished; the Eastern GOA stock is not overfishing and has undefined stock status.
[9]BSAI Other Species includes sculpins, skates, sharks, and octopus.

AFSC, RACE Division

Arrowtooth flounders.

has strict guidelines for providing scientifically validated survey information. For both the Aleutian Islands and Bogoslof Island regions, stocks of pollock are underutilized by directed fishing.

Pacific cod: Estimated Pacific cod abundance reached a high of about 2.5 million t in 1985, then declined, and has fluctuated between 1.5 and 1.0 million t between 1991 and 2007. Since 2003, estimated biomass has declined to just below 1 million t. The 2007 eastern Bering Sea (EBS) shelf bottom trawl survey estimate is 18% lower than the 2006 survey estimate and is the all-time low in the survey biomass time series. This recent decline is due mainly to a sequence of five consecutive year-classes of the EBS Pacific cod stock, from 2001–05 (that ranged from 204 to 399 million age-0 fish), which are noticeably below the 30-year average year-class strength (658 million age-0 fish during 1977–2006). However, the 2006 year-class appears to be more than 2.5 times higher than the average recruitment. Although substantially lower than the high levels of the 1980's, the current biomass is still relatively high when compared to the much lower abundance levels of the 1970's. The stock is considered to be fully utilized. Developments in the assessment model include a revised maturity-at-age schedule and the incorporation of new age data into the assessment.

An unidentified octopus rests in a curled up position on the sea floor.

Flatfishes: All flatfish species in the Bering Sea and Aleutian Islands area are underutilized as a result of the requirement in the groundfish FMP to maintain overall groundfish catches within the 2 million t optimum yield cap and the need to prevent excessive bycatch of Pacific halibut and king and Tanner crabs in flatfish trawl fisheries. Yellowfin sole is the most abundant of the flatfish complex, followed by northern rock sole, Alaska plaice, arrowtooth flounder, flathead sole, and Greenland halibut. Greenland halibut, a deep-water flatfish species found on the Continental Slope, is the only flatfish species that is relatively low in historical abundance. The biomass of Greenland halibut increased during the 1970's from the early 1960's level and is currently about 61% of the level expected under no fishing using average recruitment since 1977. Recruitment of young juvenile Greenland halibut appeared to have been poor for about 15 years since the early 1980's after several strong year-classes during the 1970's. Recently, there has been evidence of positive recruitment for Greenland halibut beginning in 2000. The biomass of all the other flatfish species has generally gone through a long period of increases from the late 1960's to the early 1990's, due to recruitment of a succession of strong incoming year-classes. The strength of the year-classes recruiting after 1985 has stabilized, and the biomass of flatfishes is high and stable.

Sablefish: Sablefish (blackcod) is a valuable species caught mostly with longline and pot gear in depths greater than those fished by trawlers. Sablefish are considered to belong to a single stock from the Bering Sea and Aleutian Islands region to the Gulf of Alaska. Sablefish abundance increased during the mid 1960's due to strong year-classes from the 1960's. Abundance subsequently dropped during the 1970's due to heavy fishing; catches peaked at 53,000 t in 1972. The population recovered due to strong year-classes from the late 1970's, and spawning abundance peaked again in 1987. The population then decreased as these strong year-classes died off. Abundance has increased from an all-time low in 2000. The 2000 year-class now appears to be larger than the 1997 year-class and is expected to comprise 18% of the spawning biomass in 2008. Sablefish abundance is now considered moderate, and current spawning biomass is estimated to be 37% of unfished biomass. The stock is fully utilized. Sablefish have been harvested under an IFQ system since 1995, which significantly changed the dynamics of the fishery.

Rockfishes: Rockfishes are assessed and managed in several species groups: Pacific ocean perch, northern rockfish, rougheye and shortraker rockfish, and other rockfishes. The abundance of Pacific ocean perch dropped sharply in the 1960's due to intensive foreign fisheries, and remained low into the early 1980's. In the mid 1980's effort levels were low and have helped rebuild the stock. The Pacific ocean perch stock appears to be recovered and is currently estimated to be at high levels similar to peak levels in the 1960's. Northern rockfish, rougheye rockfish, and shortraker rockfish were previously managed in the "other red rockfishes" species complex, but have now been separated into single-species management groups and have assessment models to help guide management. Northern rockfish were managed as a separate species beginning in 2002. Shortraker rockfish and rougheye rockfish were managed as separate species beginning in 2004. The trend in survey biomass for each of these three species is highly variable. However, model estimates of abundance show an increasing trend since 1980 for northern rockfish, a declining trend for rougheye rockfish, and a stable trend for shortraker rockfish. The "other rockfishes" species group is composed largely of shortspine thornyhead and dusky rockfish. Based on bottom trawl survey information, shortspine thornyhead and dusky rockfish biomass appears to be increasing since 1997. Yields of rockfishes are established based on their longevity and productivity; hence, recommended exploitation rates are low relative to other groundfish species.

Atka mackerel: The Atka mackerel stock is centered mainly in the Aleutian Islands region. Total biomass built up steadily from a biomass of 279,000 t in 1977 to a peak of 677,000 t in 1992 due to particularly strong recruitment from the 1988 year-class. From 1992 to about 1996, the resource declined rather rapidly due to more moderate recruitment from incoming year-classes. From 1996 to 2000, the population trend was fairly stable with several above-average year-classes contributing to the population. After 2000, biomass increased rapidly, reaching a peak of nearly 750,000 t in 2004 due to several back-to-back strong year-classes, and particularly strong recruitment from the 1999 year-class. The biomass is now in the 500,000 t range and is expected to decrease in the near future as recent strong year-classes pass through the population. The stock is fully utilized.

Other Species: The Other Species complex is made up of sharks, skates, sculpins, and squids and octopuses. In response to a developing fishery in the Gulf of Alaska (GOA), the GOA FMP was amended to remove skates from the Other Species category. A similar FMP amendment was initiated by the North Pacific Fishery Management Council in 1999 to remove both skates and sharks from the Other Species category in the Bering Sea and Aleutian Islands area to increase the level of management attention and control for these potentially vulnerable species groups; this action is still in the process of revision and review. Additional FMP amendments are being proposed to split the Other Species category into component groups in both the BSAI and GOA.

Most of the species in this complex are expected to be underutilized and below their MSY. No targeted fisheries for any species in this category exist at this time; their current yields are all taken as bycatch amounts to other target groundfish fishing operations. In recent years, the species that make up this category have received special attention as data on the individual species have been accumulated and are being analyzed. Biomass levels are being estimated for the individual species, and management of the complex by species or major taxonomic groups is being evaluated.

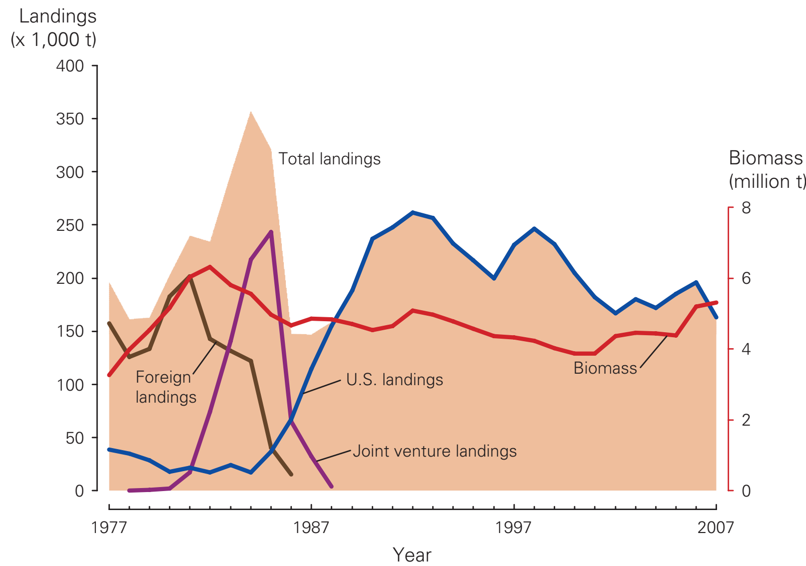

Figure 19-3
Gulf of Alaska groundfish landings and biomass in metric tons (t), 1977–2007.

Gulf of Alaska Groundfishes

Groundfish abundance in the Gulf of Alaska has increased since 1977, peaking at 6.3 million t in 1982 and most recently in 2007 at 5.3 million t, primarily due to increasing arrowtooth flounder biomass. Abundance since 1986 has remained relatively stable, fluctuating between about 4 and 5 million t. The recent average yield (2004–06) for groundfish in the Gulf of Alaska was just over 188,000 t (Table 19-2). This is substantially lower than the current yield of 480,271 t due to underutilization of some groundfish species (particularly flatfish species) that cannot be fully harvested without exceeding the bycatch limits for Pacific halibut set by the NPFMC. The MSY for GOA groundfishes is higher than the current yield at just over 600,000 t. Gulf of Alaska groundfish catches have ranged from a low of 146,703 t in 1987 to a high of 356,659 t in 1984 (Figure 19-3). Recent groundfish catches have been dominated by walleye pollock as well as flatfish, Pacific cod, and rockfish. Groundfish catches since 1989 have fluctuated around 200,000 t.

Walleye pollock: Pollock abundance in the Gulf of Alaska increased dramatically during the 1970's, peaked in the early 1980's, and subsequently declined. Current abundance is estimated to be at the lowest levels in the time series. The 2007 winter Shelikof Strait hydroacoustic survey was 38% lower than the 2006 estimate and is the lowest biomass estimate observed from this region. Estimated harvest rates have never exceeded 15%, suggesting that the extreme variation in pollock abundance is primarily a result of environmental forcing. Pollock abundance may also be negatively impacted by increases in piscivorous fish species in the Gulf of Alaska. The 1999 and 2000 year-classes are the most recent confirmed strong year-classes. Currently, the 2004 and 2005 year-classes appear to be above average, but levels are highly uncertain. Pollock are carefully managed due to concerns about the impact of fisheries on endangered and threatened Steller sea lions; pollock are a major prey item of Steller sea lions in the Gulf of Alaska. Sea lion protection measures include closed areas around rookeries and haul-outs, apportionment of the western central Gulf of Alaska pollock total allowable catch among 3 years and 4 seasons, and the use of more conservative harvest policy to determine the acceptable biological catch (ABC). Pollock in this area are considered fully utilized.

Pacific cod: The trawl survey biomass estimates of Pacific cod peaked in 1990 at about 350,000 t and are presently about 230,000 t based on the most recent trawl survey biomass estimate. The Pacific cod stock is considered healthy but declining and is fully utilized. Assessment modeling of Pacific cod in this region has improved with the addition of age composition data, improved estimates of growth and maturity, and acknowledgements of uncertainties on assumed natural mortality and survey catchability. Additionally, ecosystem analysis of the role Pacific cod plays in the environment has been expanded.

V. O'Connell, ADFG; OAR/NURP

Yelloweye rockfish.

Flatfishes: Flatfishes in the Gulf of Alaska are in general very abundant, largely due to great increases in arrowtooth flounder biomass. Arrowtooth flounder continues to dominate this group (and leads all groundfish based on the 2007 survey biomass estimates for the western and central GOA. Flathead sole, rex sole, and arrowtooth flounder are managed as separate categories, while the rest of the flatfishes are managed as deepwater and shallow water groups. Flatfishes are underutilized due to halibut bycatch considerations.

Sablefish: Sablefish in the Gulf of Alaska are part of a single stock throughout the Gulf, Bering Sea, and Aleutian Islands. For more information on the Alaska sablefish stock, see the sablefish section under Bering Sea and Aleutian Islands Groundfish.

Rockfishes: For management purposes, rockfishes in the Gulf of Alaska are divided into four assemblages or species groups: slope rockfishes, pelagic shelf rockfishes, thornyheads, and demersal shelf rockfishes. The slope rockfishes comprise the largest biomass component of Gulf of Alaska rockfishes. Within this group, Pacific ocean perch, shortraker and rougheye rockfish, and northern rockfish are managed as separate categories along with an "other slope rockfishes" category that aggregates the less abundant species. Slope rockfishes, particularly Pacific ocean perch, were intensively exploited by foreign fleets in the 1960's. Since the 1990's, Pacific ocean perch has rebounded from the heavy exploitation due to apparently favorable recruitment conditions. Their abundance is at moderately high levels compared to the low abundance levels of the 1980's, and is increasing. Pacific ocean perch are fully utilized. As with Pacific ocean perch, the northern rockfish and rougheye rockfish assessments are now based on age-structured models. Thornyheads are highly valued and believed to be at above-average levels of abundance, based on stable to increasing survey trends.

Ivan Loyola, IPHC

The crew of the F/V *Clyde* pose with a large Pacific halibut caught in the Aleutian Islands while on an International Pacific Halibut Commission stock assessment survey.

In the pelagic shelf rockfishes group, dusky rockfish is the dominant species and is now assessed with an age-structured model. The abundance estimate for the dusky rockfish is variable but appears to be at above-average levels (due to low to moderate fishing pressure). Assessments results for dusky rockfish indicate a stable to increasing trend. Other species in the pelagic shelf group have more uncertain estimates of abundance because their occurrence is relatively rare.

Demersal shelf rockfish assessment and management focuses primarily on yelloweye rockfish; the six other species in this group are much less abundant. Traditional population assessment methods (e.g. bottom trawl surveys) are considered problematic for these species due to their affinity for rough terrain. They are currently assessed using submersible line-transect methods. Available information suggests that abundance is stable for this species group, but overall, the trend is uncertain.

Rockfish stocks in general appear to be in good condition due to favorable conditions and precautionary management practices.

Atka mackerel: The Atka mackerel stock occurs mainly in the Aleutian Islands region; its abundance in the Gulf of Alaska is much lower and highly variable. The resource supported a large foreign fishery in the Gulf through the mid 1980's but disappeared thereafter. Fisheries targeting the species resumed in the Gulf in 1990 as the population increased. The absolute abundance of the stock has been difficult to estimate by trawl gear since it is a shallow, schooling species that tends to reside on rough and rocky bottoms. Due to extreme variance in survey catches, it has been concluded that stock abundance cannot be reliably determined from trawl survey data. Because there is no reliable estimate of Atka mackerel biomass and this species has exhibited vulnerability to fishing pressure in the past, Atka mackerel are currently managed as a bycatch-only species. Quota levels are set at low levels that preclude a directed fishery but accommodate bycatch needs in other fisheries.

ISSUES AND PROGRESS

Transboundary Stocks and Jurisdiction

Some of the U.S.-origin eastern Bering Sea walleye pollock migrate into the Russian zone of the northern Bering Sea, intermingle with Russian stocks, and are subject to Russian exploitation. Such exploitation is of concern to the United States as it could impact U.S. stocks and management. While this transboundary issue is a subject of continuing U.S.-Russian scientific studies and discussions, a coordinated exploitation and man-

School of yellowtail rockfish.

agement scheme has not yet been reached. At this time, the United States can only indirectly consider the possible impact of Russian fishing on the U.S. stocks in setting domestic exploitation strategies.

A former unregulated pollock fishery that occurred in the Donut Hole area of the central Bering Sea has come under regulation since the implementation of the Convention on the Conservation and Management of Pollock Resources in the Central Bering Sea in 1997. Under this Convention, signed by the Russian Federation, Japan, Poland, China, the Republic of Korea, and the United States, a central Bering Sea walleye pollock fishery has not been authorized because of low biomass of the Aleutian Basin stock. In fact, the moratorium on pollock fishing in the central Bering Sea was voluntarily imposed beginning in 1993 as negotiations on the Convention were proceeding. Parties to the convention meet annually to discuss current conditions and experimental fishing guidelines (if agreed), and exchange relevant scientific reports.

Bycatch

Pacific halibut, king, Tanner, and snow crabs, salmon, herring, and shrimp all fall under the "prohibited species" category for groundfish fisheries. When taken incidentally in the groundfish fisheries their numbers are reported and counted against cap levels that are set in regulation. Some species are returned immediately to the sea, whereas other species are landed and given to food banks or other non-profit programs. The cap levels for incidental take restrict a number of directed fisheries. For example, the Pacific halibut cap constrains Bering Sea flatfish fisheries. As such, the prohibited species regulations affect the allocation of directed fishery quotas. Since bycatch limits of prohibited (and other managed) species are strictly followed, directed groundfish fisheries could be closed before the entire available groundfish quota is taken.

The NPFMC also has an incentive program to control bycatch whereby bycatch rates are established for the fleet and regulated by individual vessels. It is designed to give a vessel more control over its own fishing strategy by holding it directly accountable for its bycatch rates.

Multispecies Interactions

Marine mammal interactions with fish and fisheries are a great concern to Alaska fishery resource management. Fisheries compete for prey items that marine mammals and other species, including seabirds, depend on for food in the marine ecosystem. The impact of fish removals on Steller sea lions has been implicated as an important factor in the decline of sea lion populations. The Steller sea lion is listed as threatened (eastern Pacific population) and endangered (western U.S. Pacific population) under the Endangered Species Act. Since sea lions feed on walleye pollock, Atka mackerel, and Pacific cod, these groundfish fisheries have been regulated to reduce impact on them. In November 2000, the National Marine Fisheries Service issued a biological opinion under the Section 7 Consultation of the Endangered Species Act that the Bering Sea and Aleutian Islands and the Gulf of Alaska walleye pollock fisheries are likely to jeopardize the continued existence of the western population of Steller sea lions and adversely modify its critical habitat (NMFS, 1998). As a result of this jeopardy determination, NMFS has proposed some reasonable and prudent alternatives to disperse the intensity of pollock, Atka mackerel, and Pacific cod fisheries in the critical habitat of sea lions and to enact additional prohibitions, including 10–20 n.mi. no-trawl zones around sea lion rookeries and haul-out areas.

Allocation Issues

As the domestic groundfish fisheries are now fully developed and capitalized, emerging allocation issues between user groups are important management problems. The NPFMC has been addressing problems as they arise and developing FMP amendments to mitigate them. Recent amendments have made explicit allocations to inshore and offshore sectors of the industry as well as specific percentage allocations of target and bycatch amounts to specific gear types. Industry-sponsored regulation (The American Fisheries Act) has developed a successful cooperative system for the Bering Sea pollock fishery. In 1995, NMFS promulgated regulations to implement an IFQ program for sablefish and Pacific halibut. Under this program, vessel owners are allocated transferable quota shares of sablefish and Pacific halibut that resulted in more efficient use of the resources than under an open-access system.

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Alaska Shellfish Fisheries

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INTRODUCTION

Alaska's major shellfish fisheries developed in the 1960's in the Gulf of Alaska and then later expanded to the Bering Sea and Aleutian Islands region. Shellfish landings in 2006 generated an estimated ex-vessel value of over $153 million. King and snow crabs account for a majority of this value (about $127 million); Tanner crab contributed little to the total value due to low harvest limits while the stock was rebuilding. Other miscellaneous invertebrate fishery resources include shrimp and sea snails. Recent shrimp harvests continue to be low due to depressed stock abundance levels, and there has been no reported harvest of sea snails since 1997. Landings of non-crab invertebrates in Alaska added about $13.7 million to ex-vessel revenue in 2006.

The State of Alaska Department of Fish and Game (ADFG) is the primary management authority for a majority of Alaska shellfish resources. Although a Federal fishery management plan (FMP) exists for crab stocks in the Bering Sea and Aleutian Islands, the North Pacific Fisheries Management Council has deferred management authority to ADFG. Crab fisheries in the Gulf of Alaska, as well as shrimp and other miscellaneous invertebrate resources in Alaska, are also managed by ADFG.

SPECIES AND STATUS

Crabs

The fleet fishing for Alaskan crabs is comprised of 200–250 vessels, many of which are based in the Pacific Northwest. Crabs are captured with baited pots, and most of the catch is landed in Dutch Harbor, Alaska. Quotas, seasons, and size and sex limits restrict catches, with landings limited to large male crabs. Seasonal closures are set to avoid fishing during times when crabs are molting or mating,

Photo above:
Red king crabs.

Table 20-1

Productivity in metric tons (t) and status of Alaska shellfish fisheries resources.

A. Zuyev, Murmansk Marine Biol. Inst.

AFSC, RACE Division

Top photo: close-up of a large male red king crab. Lower photo: Alaskan pink shrimp.

Species/stock	Recent average yield (RAY)[1]	Current yield (CY)	Sustainable yield (MSY)	Stock level relative to B_{MSY}	Harvest rate	Stock status
King crabs[2]						
Blue king crab						
Pribilof Islands	0	0	1,179	Unknown	Not overfishing	Overfished
Saint Lawrence Island	0	0	45	Unknown	Not overfishing	Undefined
Saint Matthews Island	0	0	1,995	Unknown	Not overfishing	Rebuilding
Golden (brown) king crab						
Aleutian Islands	2,435	2,495	6,803	Unknown	Unknown	Undefined
Northern District	0	0	136	Unknown	Unknown	Undefined
Pribilof Islands	32	0	136	Unknown	Unknown	Undefined
Red king crab						
Aleutian Islands, Adak	0	0	680	Unknown	Unknown	Undefined
Aleutian Islands, Dutch Harbor	0	0	Unknown	Unknown	Not overfishing	Undefined
Bristol Bay	7,895	8,303	7,125	Unknown	Not overfishing	Not overfished
Norton Sound	175	204	227	Unknown	Unknown	Undefined
Pribilof Islands	0	0	590	Unknown	Not overfishing	Not overfished
Scarlet king crab						
Aleutian Islands	0	0	0	Unknown	Unknown	Undefined
Eastern Bering Sea	0	0	0	Unknown	Unknown	Undefined
Subtotal, king crab	10,537	11,002	18,916			
Snow and Tanner crabs						
Grooved Tanner crab[3]						
Eastern Aleutian Islands	0	0	91	Unknown	Unknown	Undefined
Eastern Bering Sea	0	0	680	Unknown	Unknown	Undefined
Western Aleutian Islands	0	0	816	Unknown	Not overfishing	Undefined
Snow crab	12,976	16,774	125,397	Below	Not overfishing	Rebuilding
Southern Tanner crab[3]						
Adak (western Aleutians)	41	41	181	Unknown	Not overfishing	Undefined
Eastern Aleutian Islands	Unknown	Unknown	317	Unknown	Not overfishing	Undefined
Eastern Bering Sea	464	962	25,805	Unknown	Not overfishing	Not overfished
Gulf of Alaska[4]	1,230	1,561	Unknown	Unknown		
Triangle Tanner crab[3]						
Eastern Bering Sea	0	0	136	Unknown	Unknown	Undefined
Eastern Aleutian Islands	0	0	454	Unknown	Unknown	Undefined
Subtotal, snow and Tanner crab	14,711	19,338	155,438			
Other shellfishes						
Sea snails[4]	0	0	3,062	Unknown		
Shrimp[4]	853	513	14,722	Below		
Subtotal, other shellfish	853	513	17,784			
Total	26,101	30,853	192,138			

[1] 2004–06 average.

[2] Stock level determinations are not available for individual stocks; collectively, the stock level of king crabs is below B_{MSY}.

[3] Stock level determinations are not available for individual stocks; collectively, the stock level of Tanner crabs is below B_{MSY}.

[4] Harvest rate and stock status are not available for this stock.

and during soft-shell periods. These regulations are in place both to protect the crab resource and to maintain product quality.

Three king crab species (red, blue, and golden or brown), snow crab, and southern Tanner crab have traditionally been harvested commercially off Alaska. Exploratory fisheries on deep-water stocks of scarlet king crab, grooved Tanner crab, and triangle Tanner crab have occurred sporadically, producing minor landings to date. Yield values from these fisheries are presented in Table 20-1. Information on current and maximum sustainable yields is not available for king and Tanner crabs; values presented in Table 20-1 were derived from historical data. Stock status is determined by comparison of the short-term average catches against sustainable production. Alaska crab resources are fully utilized.

The recent average yields for king (10,537 metric tons [t]), snow (12,976 t) and southern Tanner (1,735 t) crabs are all below their respective sustainable yields. Harvest of snow crab has been lower than the sustainable yield since 2000 due to low abundance and lower harvest rates established under a rebuilding plan.

The ex-vessel value in 2006 was about $84.5 million for king crabs, $6.7 million for Tanner crabs, and $42.9 million for snow crabs (ADFG, 2007). Landings in 2006 were: king crab (11,003 t), Southern Tanner crab (1,564 t), and snow crab (16,774 t). Almost all this production came from the Bering Sea, which contributes a majority of king crab landings and all snow crab landings. Snow crab dominates the total crab landings, accounting for 54% of the catch; however, king crabs comprise 55% of the ex-vessel value.

Catch and abundance trends (Rugolo et al., 2007) for king crabs are shown in Figure 20-1. After a peak in 1964–66, declines were evident. Until 1967, Japanese and Russian fisheries dominated Bering Sea landings, but those fisheries were phased out by 1974. In the Bering Sea, domestic catches peaked at 74,000 t in 1980 and then dropped precipitously in 1981. Since then, catches have remained low. Gulf of Alaska catches peaked in 1965, varied at a relatively low level for a decade, and then dropped lower still in 1983. Almost all Gulf of Alaska king crab fisheries have been closed since 1983.

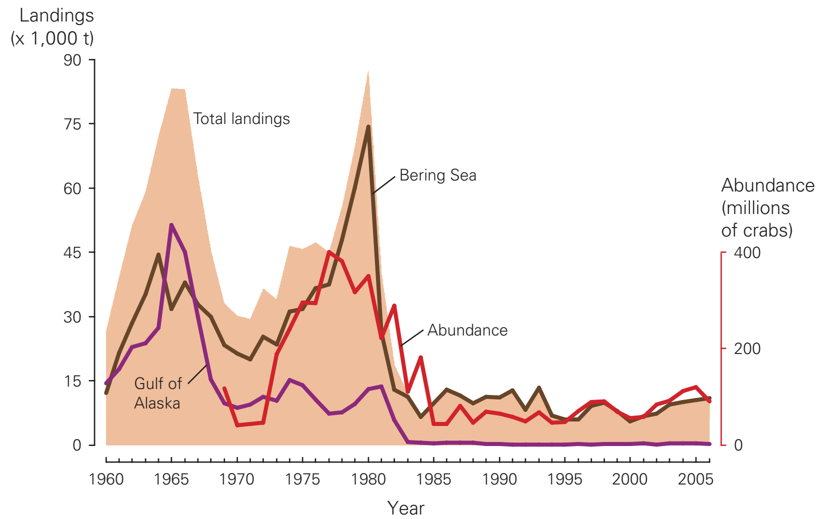

Figure 20-1

King crab landings in metric tons (t) for the Gulf of Alaska and Bering Sea, 1960–2006. Abundance trends are for Bering Sea red, Pribilof Island blue, and Saint Matthews Island blue king crab stocks combined.

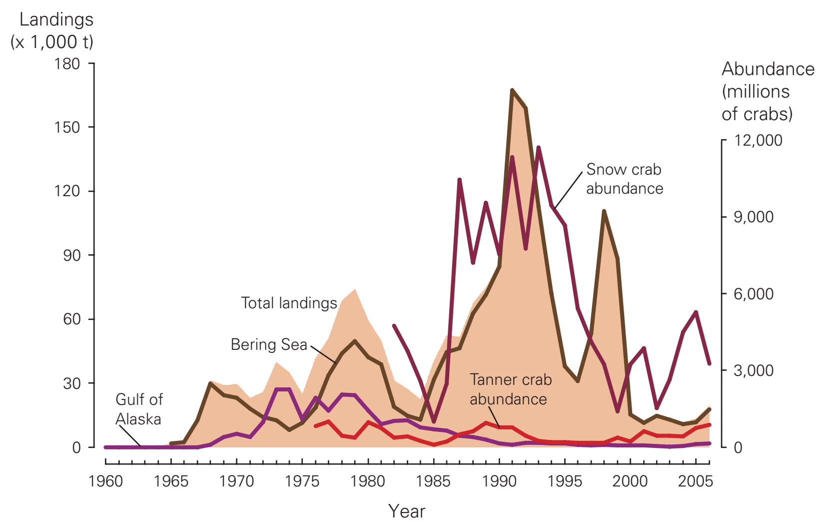

Figure 20-2

Southern Tanner and snow crab landings in metric tons (t) and abundance in individuals for the Gulf of Alaska and Bering Sea, 1960–2006.

Southern Tanner and snow crab trends (Rugolo et al., 2007) are shown in Figure 20-2. The 1965–75 period was a developmental phase for this fishery. During 1975–85, the catch peaked at about 75,000 t in 1979 and then declined thereafter. The catch began to increase again beginning in 1984, reaching an all-time high of 168,000 t in 1991. Landings again decreased until 1997 when the Tanner crab fishery was closed. Abundance trends for the Bering Sea indicate that the Tanner crab stock declined from a relatively high level in the late 1970's to a

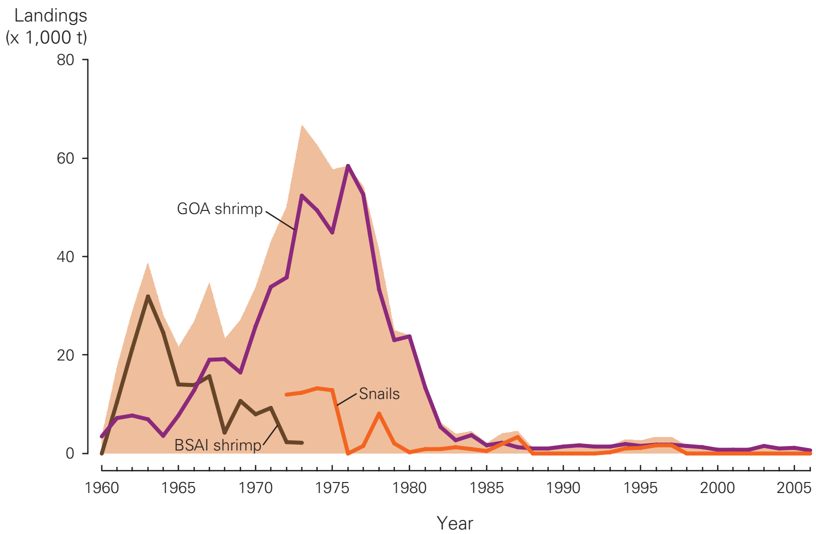

Figure 20-3
Shrimp and snail landings in metric tons (t) for the Gulf of Alaska (GOA) and Bering Sea and Aleutian Islands (BSAI), 1960–2006.

low in 1985. The stock recovered and then declined again subsequent to 1989. Tanner crab abundance has increased in the last two years and is now above the B_{MSY} level. Similarly, snow crab reached a low in 1985 but then sharply rebounded and produced high catches in the 1990's. The stock then declined and reached low levels in 1999. The catch of snow crab has decreased in recent years due to low stock abundance.

Shrimp and Sea Snail

Pink shrimp are the most important of the five species making up Alaskan shrimp landings. The domestic shrimp fishery in western Alaskan waters is currently at a low level; in the Bering Sea, shrimp abundance is too low to support a commercial fishery. The western Gulf of Alaska has been the main area of operation. During the 1970's, when the fishery was more productive, 50–100 vessels trawled for shrimp at Kodiak Island and along the Alaska Peninsula.

Shrimp landings in the western Gulf during 1960–90 rose steadily to about 58,000 t in 1976 and then declined precipitously (Figure 20-3). Since 1988, negligible amounts have been landed, almost all of it coming from Southeast Alaska. Ex-vessel revenue from the western shrimp fisheries averaged $4 million annually, and yielded peak revenue of $14 million in 1977. Bering Sea shrimp catches by Russia and Japan peaked at 32,000 t in 1963, declining gradually thereafter, until the fishery ended in 1973. As with crabs, the sustainable yields of shrimp stocks in Alaska are not well understood, and they have been equated to average catches. Shrimp are managed by regulating catch levels according to stock abundance. In addition, spring "egg hatch" closures are used to protect breeding stocks.

The Japanese pot fishery for snails, conducted from about 1972 until 1987, peaked at about 13,000 t in 1974. Annual catches averaged about 4,800 t during the period of the fishery. The snail stocks of the Bering Sea are underutilized, with no reported catch since 1997. Recent average yield and current yield equal the 2004–06 average catch, and the maximum sustainable yield equals the 1972–97 average.

ISSUES AND PROGRESS

Bycatch and Multispecies Interactions

In general, crab and shrimp resources are depressed throughout Alaska. However, several stocks have recently increased under rebuilding plans where directed fisheries were closed. Eastern Bering Sea Tanner crab has increased to above the B_{MSY} level in 2006 with the fishery closed since the 1996–97 season. Snow crab and St. Matthews Island blue king crab are showing signs of increases as well. Although the Bristol Bay red king crab stock is still well below the high levels that occurred in the 1970's, the stock has increased from the low levels of the mid 1980's. The bycatch of crabs in pot fisheries is an issue, due to uncertainty in the mortality of discarded crab. Bycatch in groundfish trawl fisheries is regulated with caps and/or closed areas for most stocks.

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Marine Mammals of the Alaska Region

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Photo above: Humpback whale, Chatham Strait, Alaska.

INTRODUCTION

The Alaska Region has 42 stocks of 25 species of marine mammals. The U.S. Fish and Wildlife Service manages three of these species (sea otter, polar bear, and walrus), while the National Marine Fisheries Service (NMFS) manages the remaining cetacean and pinniped stocks. Fourteen of the 42 stocks in Alaska have been classified as strategic stocks, as defined by criteria provided in the 1994 Amendments to the Marine Mammal Protection Act (MMPA). These include northern fur seal, Cook Inlet beluga, and AT1 Transient killer whale (listed as depleted under the MMPA); sperm whale, western North Pacific and central North Pacific humpback whales, fin whale, North Pacific right whale, and bowhead whale (all listed as endangered under the Endangered Species Act [ESA] of 1973); Bering Sea, Gulf of Alaska, and Southeast Alaska harbor porpoise (abundance estimates are old and there is a lack of information about fisheries mortality); and western U.S. (listed as endangered under the ESA) and eastern U.S. stocks of Steller sea lion (listed as threatened under the ESA). In the Alaska Region, six stocks are believed to be increasing, two are stable or slightly increasing, three are stable, six are decreasing, and the abundance trends for the remaining 25 stocks are unknown.

Twenty-three stocks of marine mammals are subject to subsistence harvest in Alaska. While most marine mammal stocks are assessed under the authority of Section 117 of the MMPA, NMFS has determined that management of stocks subject to subsistence harvests without significant commercial takes should be developed through the co-management process described in Section 119 of

Table 21-1

Status of marine mammal stocks in the Alaska Region.

Species/stock	Minimum population estimate (N_{min})[1]	Potential biological removal level (PBR)[2]	Annual fisheries-caused mortality[3]	Annual subsistence mortality[4]	Total annual human-caused mortality[5]	Strategic status[6]	MMPA/ESA status[7]	Trend[8]
Seals and sea lions								
Bearded seal (Alaska)	Unknown	Unknown	0.68	6,788	6,788.68	No		U
Harbor seal								
Bering Sea[9]	20,109	603	1.3	174.3	176.2	No		D
Gulf of Alaska[9]	44,453	1,334	24	795	820	No		D
Southeast Alaska[9]	108,670	3,260	0	1,092	1,094	No		U
Northern fur seal (eastern Pacific)	709,881	15,262	0.78	702	704	Yes	D	D
Ribbon seal (Alaska)	Unknown	Unknown	0.8	193	193.8	No		U
Ringed seal (Alaska)	Unknown	Unknown	0.71	9,567	9,567.71	No		U
Spotted seal (Alaska)	Unknown	Unknown	0.88	5,265	5,265.88	No		U
Steller sea lion								
Eastern U.S.	44,584	2,006	1.4	9	15.8	Yes	T	I
Western U.S.	38,988	234	24.6	198	223.6	Yes	E	S
Whales and porpoises								
Baird's beaked whale (Alaska)	Unknown	Unknown	0	0	0	No		U
Beluga whale								
Beaufort Sea	32,453	324	0	152	152	No		U
Bristol Bay	1,619	32	0	19	19	No		S/I
Cook Inlet[10]	264	Undet.	0	1	1	Yes	D	D
Eastern Bering Sea	14,898	298	0	209	209	No		U
Eastern Chukchi Sea	3,710	74	0	65	65	No		S
Bowhead whale (western Arctic)	9,472	95	0.2	46	46.2	Yes	E	I
Cuvier's beaked whale (Alaska)	Unknown	Unknown	0	0	0	No		U
Dall's porpoise (Alaska)[10]	Unknown	Undet.	29.9	0	29.9	No		U
Fin whale (northeast Pacific)	5,700	11.4	0	0	0	Yes	E	I
Gray whale (E. North Pacific)	17,752	417	6.7	122	130	No		I
Harbor porpoise								
Bering Sea	54,492	545	0.35	0	0.35	Yes		U
Gulf of Alaska	34,740	347	68	0	70	Yes		U
Southeast Alaska[11]	13,713	137	0	0	0	Yes		U
Humpback whale								
Central North Pacific	3,698	12.9	3.2	0	5	Yes	E	I
Western North Pacific	367	1.3	0.2	0	0.2	Yes	E	U
Killer whale								
E. North Pacific Northern resident	1,123	11.2	1.5	0	1.5	No		U
E. North Pacific transient	216	2.16	0	0	0	No		I
Gulf, Aleutian, Bering Sea transient	314	3.1	0.4	0	0.4	No		U
AT1 transient	7	0	0	0	0	Yes	D	D
West Coast transient	314	3.1	0	0	0	No		U
Minke whale (Alaska)	Unknown	Unknown	0.32	0	0.32	No		U
North Pacific right whale (E. North Pacific)	Unknown	Unknown	0	0	0	Yes	E	U

the MMPA. The process includes a sound research and management program to identify and address uncertainties concerning the stocks. At this time, the management of most of the stocks that are subject to subsistence harvest is being accomplished under co-management agreements.

Table 21-1 presents a summary of the status of stocks for the marine mammals in the Alaska region. Important population parameters for the stocks and their status under protected species laws are included. These include stock identification, minimum population estimates (N_{min}), potential biological removal levels (PBR), current human-related mortality (divided into fisheries-related, subsistence, and other removals), population status, and current population trend. A narrative for selected stocks follows.

Table 21-1

Continued from previous page.

Species/stock	Minimum population estimate (N_{min})[1]	Potential biological removal level (PBR)[2]	Annual fisheries-caused mortality[3]	Annual subsistence mortality[4]	Total annual human-caused mortality[5]	Strategic status[6]	MMPA/ ESA status[7]	Trend[8]
Pacific white-sided dolphin (N. Pacific)[10]	Unknown	Undet.	0	0	0	No		U
Sperm whale (North Pacific)	Unknown	Unknown	0.5	0	0.5	Yes	E	U
Stejneger's beaked whale (Alaska)	Unknown	Unknown	0	0	0	No		U
Other marine mammals[12]								
Polar bear								
Alaska: Chukchi & Bering Seas	Unknown	Unknown	0	44.8	44.8	No		U
Alaska: Southern Beaufort Sea[13]	1,973	88	0	32.2	54.8	No		S
Sea otter[9]								
South Central Alaska	13,955	1,396	0	297	297	No		S/I
Southeast Alaska	9,266	927	0	301	301	No		U
Southwest Alaska	33,203	830	0.2	97	99.4	No		D
Walrus (Alaska)	Unknown	Unknown	1.2	5,789	5,794	No		U

[1]A conservative estimate of abundance used to estimate PBR; provides reasonable assurance that the stock size is equal to or greater than the estimate.

[2]The maximum number of animals, not including natural mortalities, that may be removed from a stock while allowing that stock to reach or stay at its optimum sustainable population level (50–100% of its carrying capacity); calculated as the product of N_{min}, one-half of R_{max} (the maximum productivity rate), and F_r (the recovery factor).

[3]An estimate of the total number of annual mortalities and serious injuries (likely to result in death) caused by commercial fisheries.

[4]An estimate of the total number of annual mortalities and serious injuries (likely to result in death) caused by subsistence hunting.

[5]An estimate of the total number of annual mortalities and serious injuries (likely to result in death) caused by humans; includes other removals, such as ship strikes, strandings, orphaned animals collected for public display, mortalities associated with research activities, take by foreign countries, and mortalities associated with activities authorized through incidental take regulations.

[6]As defined in the Marine Mammal Protection Act (MMPA) Amendments of 1994, any marine mammal stock 1) for which the level of direct human-caused mortality exceeds the PBR level; 2) which is declining and likely to be listed as threatened under the Endangered Species Act (ESA); or 3) which is listed as threatened or endangered under the ESA or as depleted under the MMPA.

[7]As defined in the MMPA, any species that is listed as threatened (T) or endangered (E) under the ESA is also considered to be a depleted (D) stock.

[8]Trends: I=increasing; S/I=stable/increasing; S=stable; D=decreasing; U=unknown.

[9]Recent changes in the abundance estimates do not indicate a major population increase. Instead, these increases are due to new analytical methods that take environmental covariates into account and thus provide an improved estimate of harbor seal abundance.

[10]Undetermined PBR indicates data are available to calculate a PBR level, but a determination has been made that calculating a PBR level using those data is inappropriate.

[11]No or minimal take reported by fisheries observers; however, observer coverage was minimal or nonexistent.

[12]These species are under the jurisdiction of the U.S. Fish and Wildlife Service, and are not included in the stock status tables of the National Overview.

[13]The PBR level for the Southern Beaufort Sea stock of polar bears assumes a bias of 2 males for every 1 female in the harvest; no more than 30 females may be harvested annually.

STELLER SEA LION: EASTERN AND WESTERN U.S. STOCKS

Stock Definition and Geographic Range

Steller sea lions occur along the North Pacific rim from northern Japan to California, with historic centers of abundance and distribution in the Gulf of Alaska and Aleutian Islands. The current center of abundance has shifted eastward

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Steller sea lion rookery at Seal Rock in Prince William Sound, Alaska.

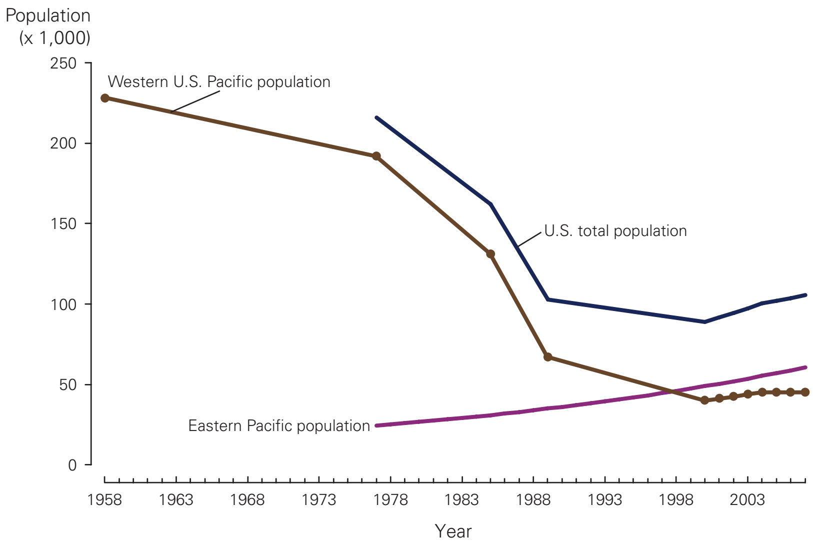

Figure 21-1

Estimated population size of Steller sea lions (adults, juveniles, and pups) of the two stocks off the United States and Canada, 1958–2007. Numbers from 1977–2007 for the Eastern U.S. stock represent a 3.1% annual growth, based on an average count of 52,000 from the 2002 survey (midpoint of 46,000–58,000; Pitcher et al., 2007). Points from 1958–1989 for the Western U.S. stock represent individual surveys. Numbers from 2000–04 show 2.9% annual growth, with numbers stable at 45,000 between 2004–07 (Fritz and Stinchcomb, 2005; NMFS, 2008).

Steller sea lions hauled out to rest, sleep, and socialize on Shakun Rock, Alaska.

to Southeast Alaska and British Columbia because of proportional declines in the western portion of the range. The species is not known to migrate, but individuals disperse widely outside of the breeding season (late May–early July), potentially intermixing with animals from other areas. Two separate stocks of Steller sea lions are recognized within U.S. waters: an eastern U.S. stock, which includes animals east of Cape Suckling, Alaska (144°W), and in Canada; and a western U.S. stock, which includes animals from Cape Suckling westward.

Population Size and Current Trends

Western U.S. stock: The western U.S. stock is distributed across the western Gulf of Alaska, the Aleutian Islands, and the U.S. portion of the Bering Sea. The most recent population estimate for this stock is 38,988 Steller sea lions, based on aerial surveys of non-pups in 2004 and aerial and ground surveys of pups in 2004 and 2005. This estimate has not been corrected for animals not seen during the surveys (i.e. in the water or out of the survey area), so it should be considered a minimum population size. The first reported trend counts of Steller sea lions in Alaska during 1956–60 indicated that there were at least 140,000 sea lions in the Gulf of Alaska and Aleutian Islands. Subsequent surveys indicated a major population decrease, first detected in the eastern Aleutian Islands in the mid 1970's, spreading eastward to the Kodiak Island area during the late 1970's and early 1980's, and then westward to the central and western Aleutian Islands during the early and mid 1980's. The greatest declines since the 1970's occurred in the eastern Aleutian Islands and western Gulf of Alaska, but declines also occurred in the central Gulf of Alaska and central Aleutian Islands. More recently, counts of Steller sea lions at trend sites for the western U.S. Pacific stock showed a 3.1% average annual decline from 1991 to 2004. During 2000–04, counts increased 5.5%, the first region-wide increase for the western stock since standardized surveys began in the 1970's. Surveys conducted in 2006 and 2007 did not encompass the entire western U.S. stock; as a result, abundance trends for the western U.S. stock as a whole through 2007 are not available. However, available data for sub-areas indicate that the western U.S. stock remained largely unchanged between 2004 and 2007 throughout much of its range in Alaska (Cape St. Elias to Tanaga Island, 145°–178° W).

Eastern U.S. stock: The Steller sea lion eastern U.S. stock covers Southeast Alaska, British Columbia, Washington, Oregon, and California. The current minimum population estimate is 44,584 animals (uncorrected) based on aerial surveys in 2002–05. Trend counts for the eastern U.S. stock indicate a growth rate of about 3.1% since the 1970's (Figure 21-1). Counts of adult and juvenile sea lions in Oregon have shown a gradual increase from 1,486 in 1976 to 4,169 in 2002. Counts in California declined by over 50%, from 5,000–7,000 in 1927–47 to 1,500–2,000 during 1980–2004. Limited information suggests that counts in northern California appear to be stable, while in central California, a steady decline in ground counts at Año Nuevo started around 1970, resulting in an 85% reduction in the breeding population by 1987 and a 5% annual decline in pup counts since 1990. Overall, counts of non-pups in California and Oregon have been relatively stable since the 1980's. In Southeast Alaska, counts of non-pups at trend sites increased by 56% between 1979 and 2002. During 1979–2005, counts of pups on the three largest rookeries in Southeast Alaska increased by 148%. In British Columbia, counts of non-pups increased at a rate of 3.2% annually during 1971–2002.

Stock Status

The PBR has been estimated at 234 animals for the western U.S. stock of Steller sea lions and 2,006 for the eastern U.S. stock. The estimated annual level of total human-caused mortality and serious injury was 223.6 animals for the western U.S. stock and 15.8 animals for the eastern U.S. stock. Although the annual human-caused mortality and serious injury does not exceed the PBR level, both stocks of Steller sea lions are classified as strategic stocks under the MMPA because the western U.S. stock is listed as endangered and the eastern U.S. stock is listed as threatened under the ESA.

Issues

The unprecedented decline in the western U.S. stock of Steller sea lion caused a change in the ESA listing status of the stock from threatened to endangered in 1997. The population decline documented in 1990, when it was first listed as threatened, continued until at least 2000. Increasing annual counts of Steller sea lions at census sites since 2000 suggest a change in trend over portions of the range, but data are insufficient to confirm that the decline has stopped. Many theories, including overfishing of sea lion prey species, environmental change, disease, and increased killer whale predation have been suggested as possible causes, but it is not clear what factor or factors are the most important causes of the decline. However, predation by killer whales, environmental variability, and competition for fish, perhaps with commercial fisheries, have been identified as potentially high threats to recovery.

Management actions implemented by NMFS since 1990 to reduce interactions between humans and Steller sea lions include setting no-entry buffer zones around rookeries, a prohibition on groundfish trawling within 10–20 nautical miles of certain rookeries, and the spatial and temporal allocation of Gulf of Alaska walleye pollock catch. More recent modifications began in 1999 and continued into 2002, including reductions in fishery removals of Atka mackerel in areas designated as Steller sea lion critical habitat; further temporal and spatial dispersion of the pollock, cod, and mackerel fisheries; and expansion of the number and extent of protective zones around sea lion rookeries and haul-outs. Area-specific management measures including restrictions and closures designed to reduce direct and indirect interactions between Steller sea lions and the groundfish fisheries were developed by a committee formed from the fishing industry, the Alaska community, environmental groups, and NMFS. A revised Recovery Plan for both stocks of Steller sea lion was released in March 2008 (NMFS, 2008).

Figure 21-2
Distribution of eastern North Pacific right whales during the 1800's (yellow area) and sightings of right whales reported between 1979 and 2005 (red stars), as determined by whaling catch and sighting records. The blue box shows the location of focused right whale surveys in 1997–2000, 2002, and 2004.

EASTERN NORTH PACIFIC RIGHT WHALE

Stock Definition and Geographic Range

In April 2008, North Pacific right whales were listed as endangered under the Endangered Species Act as a separate species from North Atlantic right whales. Two stocks are found in the North Pacific: one in the Sea of Okhotsk and the other in the eastern North Pacific (Brownell et al., 2001). Migratory patterns of the North Pacific stocks are unknown, although researchers believe that the whales spend summers on high-latitude feeding grounds and migrate to more temperate waters during the winter (Clapham et al., 2004). Calving areas for these stocks are unknown. Recent sightings of eastern North Pacific right whales (Figure 21-2) have been reported as far south as Baja California, Mexico, as

Right whale sighted in the Bering Sea, Alaska, in September 2004.

far west as Hawaii in the central North Pacific, and as far north as the sub-Arctic waters of the Bering Sea in the summer (Brownell et al., 2001). Aerial and vessel surveys for right whales have occurred in a portion of Bristol Bay in the eastern Bering Sea where whales have been observed each summer since 1996 (Figure 21-2; LeDuc et al., 2001; Wade et al., 2006; National Marine Fisheries Service, unpublished data[1]). Right whale calls obtained from yearlong deployments of autonomous recorders confirmed their presence in this region from late May to early November (Munger et al., 2003).

Commercial whaling records indicate that right whales historically ranged across the entire North Pacific north of 35°N and occasionally as far south as 20°N (Brownell et al., 2001). In the eastern North Pacific, commercial whalers focused on concentrations of animals found in the Gulf of Alaska, eastern Aleutian Islands, and Bering Sea (Shelden et al., 2005), though whales were observed and killed as far south as the Hawaiian Islands (Figure 21-2). Right whales are large, slow-swimming, and float when killed, making them an easy and profitable species for whalers. By the time the modern whale fishery (with harpoon cannons and steam-powered catcher boats) began in the late 1800's, right whales were rarely encountered in the North Pacific.

[1]National Marine Fisheries Service, National Marine Mammal Laboratory, 7600 Sand Point Way NE, Seattle, WA 98115.

Population Size and Current Trend

The pre-exploitation size of this stock exceeded 11,000 animals and was perhaps twice that number (Scarff, 2001). Estimates of current abundance range from 100 to 500 for the entire North Pacific; however, no quantitative data exist to confirm these estimates (Brownell et al., 2001). The few sightings reported in the eastern North Pacific since the late 1960's were primarily sightings of single whales or small groups of 4–6 animals (Brownell et al., 2001). At this time, it is not possible to produce a reliable estimate of minimum abundance or population trend for this stock. The portion of the eastern North Pacific stock found during summer in the Bering Sea has been studied since 1997 and as of 2004, a total of 23 individuals have been identified from genotyping of biopsy samples (16 males and 7 females; Wade et al., 2006). This includes two male calves accompanied by females that shared at least one allele for each microsatellite marker, as well as sharing a mitochondrial haplotype (Wade et al., 2006). In 2004, the number of females detected in this region rose from one whale biopsied in 2002 to seven, including the female from 2002 (Wade et al., 2006). There is some suggestion of site fidelity among right whales found in the Bering Sea. Of the whales observed between 1997 and 2004, at least five were photographed and five were biopsied over multiple years. This mark-recapture success rate is consistent with a very small population size (Brownell et al., 2001). Dedicated ship-based surveys conducted in the Bering Sea in August 2007 using line-transect methods and passive acoustic monitoring failed to find a single right whale. Additional and considerably expanded effort (shipboard, aerial, acoustic, and oceanographic) is planned for July and August 2008.

Stock Status

The North Pacific right whale is listed as endangered under the ESA, and is therefore designated as depleted under the MMPA, and the eastern North Pacific stock is classified as an MMPA strategic stock. The abundance of this stock is considered to represent only a small fraction of its pre-commercial whaling abundance (i.e. the stock is well below its Optimum Sustainable Population [OSP] size), but reliable estimates of minimum population size and PBR are not available. Between 1835 and 1909, an estimated 15,374 right whales were taken from the North Pacific by American-registered whaling vessels, with most of those animals taken prior to 1875. Total whaling mortality may have been in the range of 26,500–37,000 animals when including struck-but-lost whales and non-American whalers (Scarff, 2001). In addition, 28 right whales were killed between 1911 and 1938 in waters off Alaska and British Columbia, Canada (Reeves et al., 1985). A prohibition on the catching of right whales established in 1935 provided some protection for the species until the U.S.S.R. began widespread illegal whaling in the post-war period. Soviet pelagic whalers illegally killed at least 372 right whales in Alaskan waters from 1963 to 1967, which severely depleted what remained of the slowly recovering North Pacific right whale population and may explain why little recovery has been observed to date (Brownell et al., 2001).

The current estimates of annual human-caused mortality and serious injury appear to be minimal for this stock. Although gillnets were implicated in the death of a right whale off the Kamchatka Peninsula (Russia) in October 1989, no other incidental takes of right whales are known to have occurred in the North Pacific (Brownell et al., 2001). Evidence of entanglements or ship strikes (such as scarring) has not been observed in photographs taken for identification purposes (W. Perryman, personal communication[2]). Any right whale mortality incidental to the commercial fisheries would be considered significant.

Issues

Because of the critically small size of the eastern North Pacific right whale stock, determining seasonal distribution and habitat use is imperative to adequately manage this stock. Some studies on the distribution of the species have already been conducted. Short- and long-term passive acoustic monitoring have been used during dedicated surveys to locate right whales and to determine length of habitat occupation, respectively. Deployment of autonomous acoustic recorders to detect right whale calls year-round was initiated in the southeastern Bering Sea and Gulf of Alaska in 2000 (Munger et al., 2003; Mellinger et al., 2004; Moore et al., 2006). Results of these acoustic data collected from 2000 to 2006 indicate that at least a few right whales continue to occupy middle-shelf habitats in the southeastern Bering Sea from late May through November, and in one year as late as December (Munger, 2007). Acoustic recorders deployed along the Bering Sea slope in April 2004, which marked the first attempt to monitor this region for right whales over the course of a year, detected right whale calls south of the Pribilof Islands on only one day in June 2005 (Munger, 2007). Right whale calls have also been recorded in August and September from instruments deployed in the Gulf of Alaska in the vicinity of the 1998 (Waite et al., 2003), 2004 (K. Hough, personal communication[3]), and 2005 (P. Wade, personal communication[4]) sightings near Kodiak Island, as well as waters southwest of there (ca. 53°N, 157°W) in a region where right whales have not been encountered since the 19th century (Mellinger et al., 2004). Funding for deployments in 2007 was not available, but deployments in the Bering Sea are planned for 2008.

Data are also needed to provide reliable estimates of abundance, or at least to establish the minimum population size. Genetic analysis and photo-identification are techniques that have been used successfully to determine population abundance, viability, movement patterns, and survival in other cetacean populations. For example, mark-recapture analyses of photographs taken in the North Atlantic has led to a minimum population estimate of 291 right whales (Waring et al., 2002). Furthermore, genetic analysis of North Atlantic right whales suggests that inbreeding depression is slowing the recovery of this stock, compared to South Atlantic right whales which exhibit greater genetic diversity (NMFS, 2002). Further analysis of the photographs and genetic samples obtained thus far may provide preliminary estimates of abundance and viability.

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[2]W. Perryman, Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037.

[3]K. Hough, NOAA, 1801 Fairview Avenue E, Seattle, WA 98102.

[4]P. Wade, National Marine Mammal Laboratory, 7600 Sand Point Way NE, Seattle, WA 98115.

HARBOR SEALS

Stock Definition and Geographic Range

Harbor seals are distributed continuously along the Alaskan coast from southernmost Southeast Alaska, throughout the Gulf of Alaska and Aleutian Islands, and as far north as Cape Newenham and the Pribilof Islands in the Bering Sea. They haul out on offshore rocks and reefs, nearshore beaches and tidal flats, and drifting ice calved from glaciers in glacial fjords. Harbor seals are generally non-migratory, with local movements associated with such factors as tides, weather, season, food availability, and reproduction (Scheffer and Slipp, 1944; Fisher, 1952; Bigg, 1969, 1981). Individual seals seem to have a very small home range, rarely moving more that 200 km from a central haul-out site (Lowry et al., 2001), though some long-distance movements of tagged animals have been recorded (Pitcher and McAllister 1981; Lowry et al., 2001; Small et al., 2001). The stock structure of Alaskan harbor seals is unclear and much research, including mitochondrial DNA studies, is underway (O'Corry-Crowe et al., 2003). Currently three stocks (or management units) are recognized by NMFS: 1) Southeast Alaska, 2) Gulf of Alaska (including the Aleutian Islands), and 3) Bering Sea.

Population Size and Current Trend

The population size of harbor seals in Alaska is estimated using aerial surveys to count seals during their annual molt (August–September), the time of year when the largest number of seals are hauled out on land and visible to observers. The state is divided into five survey regions for census purposes: 1) southern Southeast Alaska (from the Canadian border to Frederick Sound); 2) northern Southeast Alaska (Frederick Sound to Kayak Island); 3) Gulf of Alaska (from Prince William Sound to the Shumigan Islands); 4) the Aleutian Islands; and 5) the north side of the Alaska Peninsula, including Bristol Bay. One region is surveyed each year, and the entire state is surveyed on a 5-year cycle.

To derive an accurate estimate of population size from these surveys, a method was developed to address the influence of external conditions on the number of seals hauled out on shore, and counted, during the surveys. Many factors influence the propensity of seals to haul out, including tides, weather, time of day, and date in the seals' annual life history cycle. A statistical model defining the relationship between these factors and the number of seals hauled out was developed for each survey region. Based on those models, the survey counts for each year were adjusted to the number of seals that would have been ashore during a hypothetical survey conducted under ideal conditions for hauling out (Boveng et al., 2003). In a separate analysis of radio-tagged seals, a similar statistical model was used to estimate the proportion of seals that were hauled out under those ideal conditions (Simpkins et al., 2003). The results from these two analyses were combined for each region to estimate the population size of harbor seals in Alaska.

Combining the most recent population estimates for the three Alaska stocks, the total population size of harbor seals in Alaska is estimated to be 180,017 (Table 21-2), based on surveys in 1996–2000 that had incomplete coverage of terrestrial sites in Prince William Sound and of glacial sites in the Gulf of Alaska and the Southeast Alaska regions. The population estimates for the Gulf of Alaska (45,975) and Southeast Alaska stocks (112,391) include survey estimates from glacial sites where seals haul out on ice calved from glaciers. These sites are difficult to survey using standard aerial survey techniques, and photogrammetric techniques are being developed and used to provide more accurate estimates of population sizes at glacial sites. Current estimates probably

Table 21-2

Population estimates for harbor seal stocks in Alaska.

Stock	Year	Population size (N)[1]	CV (N)[2]	N_{min}[3]
Gulf of Alaska		45,975	0.04	44,453
Aleutian Is. region	1999	9,993	0.06	
All other regions	1996	35,982	0.05	
Southeast Alaska		112,391	0.04	108,670
N. SE AK region	1997	32,454	0.06	
S. SE AK region	1998	79,937	0.05	
Bering Sea	2000	21,651	0.1	20,109
Total		180,017	0.03	

[1]Population sizes are based on survey data from the years indicated (Angliss and Outlaw, 2007).

[2]Coefficient of variation for the population estimates.

[3]Conservative estimate of abundance calculated based on each population estimate and its coefficient of variation (Wade and Angliss, 1997).

underestimate the actual number of seals at these sites. The Bering Sea stock is estimated at 21,651 seals.

Minimum population estimates (N_{min}) are calculated for management purposes based on each population estimate and its coefficient of variation (CV; Wade and Angliss, 1997). N_{min} is 44,453 for the Gulf of Alaska stock; 108,670 for the Southeast Alaska stock; and 19,907 for the Bering Sea stock (Table 21-1). Because the Pribilof Islands are not included in the aerial surveys used to estimate the population size of the Bering Sea stock, the maximum count of 202 seals from the Pribilof Islands in 1995 is added to the estimate for this stock (Jemison, 1996), and N_{min} becomes 20,109 harbor seals. The N_{min} estimates for the Gulf of Alaska and Southeast Alaska stocks may be underestimates because survey counts from the glacial sites within those regions are probably underestimated.

Population trends vary within and between the three stocks. Population abundance has declined substantially in some areas of the Gulf of Alaska since the 1970's (including up to an 85% decline from 1976–1988 at Tugidak Island, near Kodiak Island, which was formerly one of the largest harbor seal haul-out sites in the world). Recent trends vary geographically within the Gulf of Alaska. Harbor seal abundance is increasing in the Kodiak Island archipelago (6.6% annually during 1993–2001; Small et al., 2003) and Tugidak Island (7% annual increase during 1992–2001; Small, 1996; Withrow et al., 2002) and decreasing in Prince William Sound (–3.3% annually during 1990–99; VerHoef and Frost, 2003). Despite some positive signs of growth in some areas, the overall Gulf of Alaska stock size likely remains small compared to its size in the 1970's and 1980's.

Population trends in Southeast Alaska also vary geographically. Harbor seal abundance near Ketchikan has increased (5.6% annually during 1994–1998; Small et al., 2003), while seal populations near Sitka showed no detectable trend during 1995–2001 (Small et al., 2003), and seal abundance in Glacier Bay National Park showed a sharp decline of 63–75% from 1992 to 2002 (Mathews and Pendleton, 2006).

Harbor seal abundance in the Bering Sea is thought to have declined substantially between the 1970's and 1990's. Counts of harbor seals along the north side of the Alaska Peninsula in 1995 were less than 42% of the 1975 census, though the 1975 counts were not adjusted for the effects of covariates (environmental conditions, time of day, survey date, etc.; Withrow and Loughlin, 1996). The Bristol Bay population has remained stable since 1990. In recent years, the Bering Sea stock size seems to have stabilized (no detectable trend during 1998–2001; Small et al., 2003).


Dave Withrow, NMML/AFSC

Mother harbor seal and pup on an ice floe calved from the LeConte Glacier near Petersburg, Alaska. Many harbor seals in Alaska have their young on ice floes calved from tidewater glaciers, which provide a relatively safe location to pup and molt.

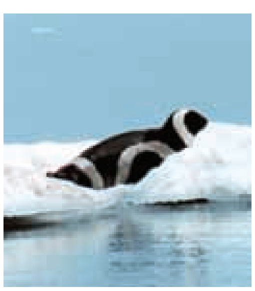
Stock Status

Harbor seals are not listed as threatened or endangered under the ESA nor depleted under the MMPA. PBR levels were estimated for each stock based on N_{min}, maximum net productivity rate for harbor seals, and a recovery factor set at 0.5 for pinniped stocks of unknown status (Bering Sea and Gulf of Alaska) and 1.0 for stable or increasing stocks (Southeast Alaska; Wade and Angliss, 1997). A reliable estimate of the annual rate of mortality incidental to commercial fisheries is unavailable. Based on abundance and mortality data from the mid 1990's, the estimated annual level of total human-caused mortality is 820 for the Gulf of Alaska stock, 1,094 for the southeast Alaska stock, and 176.2 for the Bering Sea stock (Table 21-1). All of these mortality levels are below estimated PBR levels for each stock, and none of the three stocks is currently defined as strategic. The status of the stocks relative to their OSP sizes is unknown.

Issues

The stock structure of harbor seals in Alaska likely will be revised in the near future. Genetics data, information about animal movements, and contrasting population trends within the current three stocks suggest that the stocks be further subdivided. Reviews of genetic and trend data are underway to determine the number of stocks, as well as the geographic boundaries between them (O'Corry-Crowe et al., 2003). As discussed above, subsistence harvest and fishery bycatch mortality levels appear to be sustainable, based on the current three stocks and data from the mid 1990's, though good fishery bycatch estimates are not available and revised stock assessments have been delayed pending new stock boundaries. If stocks are redefined, however, both harvest and bycatch numbers will need to be re-evaluated relative to the new stock boundaries.

Potential impacts of industrial activities are a concern in some regions. Exploration and development of oil reserves and the potential for oil spills during production or transport of oil are important issues, particularly in the aftermath of the Exxon Valdez oil spill in Prince William Sound, Alaska (e.g. Hoover-Miller et al., 2001). Potential impacts of the cruise ship industry on seals have recently become a concern, especially in glacial fjords that are popular tourist destinations (Jansen et al., 2003).



Captain Budd Christman, NOAA Corps

Male ribbon seal at the end of molt season on an ice floe in the Bering Sea.

ARCTIC ICE SEALS: BEARDED SEAL, RIBBON SEAL, RINGED SEAL, AND SPOTTED SEAL

Stock Definition and Geographic Range

Four species of phocid seals are commonly associated with sea ice in Alaska and are collectively known as Arctic ice seals: bearded seals, ribbon seals, ringed seals, and spotted seals. These seal species all haul out on sea ice to rest, give birth, and molt, and are therefore particularly sensitive to changes in the environment that affect the timing and extent of sea ice formation and breakup.

Bearded seals have a circumpolar distribution from approximately 45° to 85°N. In Alaska waters they are distributed over the shallow (less than 200 m) Continental Shelf of the Bering, Chukchi, and Beaufort Seas. Bearded seals generally prefer pack ice habitats with well-developed lead systems (Burns, 1981a). Some migrate through the Bering Strait from April to June and spend the summer along the ice edge in the Chukchi Sea, while others appear to remain in open water areas of the Bering and Chukchi Seas during this time.

Ribbon seals inhabit the North Pacific Ocean and southern parts of the Arctic Ocean. In Alaska waters, they range northward from Bristol Bay in the Bering Sea to the Chukchi and western Beaufort Seas. Ribbon seals are usually found in the loose ice of the ice front zone near the ice edge, and rarely along the coast or on fast ice (Burns, 1981b). From March to May they inhabit the Bering Sea ice front and are most abundant in the central and western Bering Sea. Little is known about ribbon seal distribution during the rest of the year. Some animals are thought to migrate north through the Bering Strait into the Chukchi Sea (Kelly, 1988), while others may remain in the central Bering Sea (Burns, 1981b).

Ringed seals have a circumpolar distribution from approximately 35°N to the North Pole. In Alaska waters, and depending on ice cover, they are found throughout the Beaufort, Chukchi, and Bering Seas as far south as Bristol Bay in the southern Bering Sea. Ringed seals prefer areas with high ice cover, either in fast ice along coastal areas, or in the interior ice pack, away from the ice edge (Burns et al., 1981). Because ringed seals are believed to remain associated with ice throughout the spring and summer, their seasonal distribution is constrained by the seasonal advance and retreat of sea ice in the Bering Sea.

Spotted seals are distributed along the Continental Shelf of the Beaufort, Chukchi, Bering, and Okhotsk Seas south to the northern Yellow Sea and western Sea of Japan. In Alaska waters, they are known to occur as far south as the Pribilof Islands, Bristol Bay, and the eastern Aleutian Islands. Spotted seals migrate south from the

Chukchi Sea through the Bering Strait in October and November ahead of the advancing sea ice, and overwinter in the Bering Sea in the pack ice over the Continental Shelf (Lowry et al., 1998, 2000). During spring, they are distributed mainly in the ice front (Burns et al., 1981) and move to coastal habitats after the sea ice retreats. Spotted seals are often mistaken for North Pacific harbor seals, as there is little morphological difference between the two species and their geographic ranges overlap in the southern Bering Sea. However, only the spotted seal is regularly associated with pack ice.

A lack of significant genetic, phenotypic, and population response data precludes subdividing the stocks of bearded, ribbon, ringed, and spotted seals. Therefore, in U.S. waters, only the Alaska stocks are recognized.

National Marine Mammal Laboratory

A juvenile ribbon seal with the NOAA Ship *Oscar Dyson* seen in the background. The *Dyson*, the first of four technologically advanced survey vessels being added to the NOAA fleet, was in the Bering Sea conducting research on ice seal breeding ecology as part of the National Marine Mammal Laboratory's Polar Ecosystems Program.

Population Size and Current Trend

Reliable estimates for the current minimum population size, abundance, and trend of the Alaska stocks of bearded, ribbon, ringed, and spotted seals are unavailable. However, crude estimates are available from the historical literature. Early estimates of the Bering–Chukchi Sea population of bearded seals range from 250,000 to 300,000 (Burns, 1981a). Burns (1981b) estimated the worldwide population of ribbon seals at 240,000 in the mid 1970's, with an estimate of 90,000–100,000 for the Bering Sea. A similarly rough estimate for the number of ringed seals in Alaska is 3.3–3.6 million (Frost et al., 1988), based on aerial surveys conducted in the Chukchi and Beaufort Seas during 1985–87. A more accurate estimate of the density of bearded seals in the Chukchi Sea, based on aerial surveys and haul-out behavior studies conducted in 1999 and 2000, resulted in an average density of 0.07 seals/km^2 and 0.14 seals/km^2, respectively, with consistently high densities along the coast to the south of Kivalina (Bengtson et al., 2005). The same surveys produced ringed seal abundance estimates, corrected for seals in the water, of 252,488 and 208,857 for 1999 and 2000, respectively. Similar surveys, flown in 1996–99 in the Alaska Beaufort Sea, produced observed ringed seal densities of 0.81–1.17 km^2, resulting in an estimate of 18,000 seals hauled out in the surveyed area of the Beaufort Sea. Combining this estimate with the average abundance estimate of 230,673 from the Chukchi Sea (Bengtson et al., 2005) gives a total of approximately 249,000 ringed seals. This total is a minimum population estimate, as it does not include the whole geographic range of the ringed seal stock.

The worldwide population of spotted seals was estimated to be 335,000–450,000, with an estimate for the Bering Sea of 200,000–450,000 (Burns, 1973). Aerial surveys conducted in 1992–93 produced a maximum count of 4,145 spotted seals hauled out on the ice in the Bering Sea in spring and along the western Alaska coast during summer (Rugh et al., 1995). The proportion of time that spotted seals haul out averages about 6.8% (CV = 8.85; Lowry et al., 1994); applying this correction factor to the maximum count of 4,145 results in an estimate of 59,214 seals.

Stock Status

Bearded, ribbon, ringed, and spotted seals are not listed as threatened or endangered under the ESA, nor as depleted under the MMPA. Current and reliable estimates of the minimum population size, total abundance, PBR, and human-caused injury or mortality are not available. Because current information is insufficient to evaluate whether subsistence hunting is adversely affecting these stocks, and because of minimal evidence of interactions with U.S. fisheries, the Alaska stocks

Lisa Hiruki-Raring, NMML/AFSC

Ringed seal near Kotzebue, Alaska, instrumented with a satellite-linked time–depth recorder to evaluate the amount of time that seals spend basking on the surface of the ice.

of bearded, ribbon, ringed, and spotted seals are not classified as strategic stocks.

Issues

Arctic ice seals are a critical component of the Alaska Native subsistence harvest. All four species are hunted for subsistence purposes, but bearded and ringed seals in particular are targeted, with an average of 6,788 and 9,567 taken each year, respectively (ADFG, 2000a,b). There is significant annual variation in harvest numbers; however, the effect of the subsistence hunt on ice seal populations cannot be assessed, because there are no current and reliable population dynamics and ecological data for any of the four species of Arctic ice seals. Abundance, population discreteness, annual survival, and reproductive rates (together with information on food habits, seasonal movements, distribution, and habitat requirements for breeding, foraging, and molting) are all unknown, but are essential to making sound management and conservation decisions. Current knowledge of vital rates in all four species of Arctic ice seals is insufficient to allow for the timely detection of changes in population trends. Without reliable estimates of the abundance of these species, PBR levels cannot be calculated and any impacts of human activities on the populations cannot be assessed.

Ecological data are particularly important with regard to the effect of global climate change and the resulting changes to Arctic ice habitats. A reduction or change in ice cover would directly affect the survival of all four species of ice seals, since they depend on seasonal ice for breeding and haul-out substrate. Evidence indicates that the Arctic climate is changing significantly and that one result of the change is a reduction in the extent of sea ice in at least some regions of the Arctic (ACIA, 2004; Johannessen et al., 2004). All four species of ice seals will be vulnerable to reductions in sea ice, as they are dependent on sea ice for at least part of their life history. There are insufficient data to make reliable predictions on the effects of Arctic climate change on ice seal populations.

Oil and gas exploration and development overlaps with both the summer and winter ranges of ringed seals in the Alaska Beaufort Sea. There has been concern that oil and gas exploration could result in changes in ringed seal distribution. However, aerial surveys conducted for 3 years both before and after industry activities indicate that local seal densities in the spring were not significantly different after industry activity (Moulton et al., 2002).

The effects of interactions with commercial fisheries (both direct, such as entanglement in nets, and indirect, such as competition for food resources) are not well known. However, given that there is little overlap between the distribution of commercial fisheries and the distribution of Arctic ice seals, it is possible that commercial fishery impacts may be minor.

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Marine Mammals of the Pacific Region and Hawaii

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Photo above:
A killer whale breaks the ocean surface. The Southern Resident stock of killer whales is listed as Endangered under the ESA.

INTRODUCTION

The Pacific region has 64 stocks of at least 39 species of marine mammals. All species are protected under the Marine Mammal Protection Act (MMPA), and threatened and endangered species are also protected under the Endangered Species Act (ESA). The U.S. Fish and Wildlife Service is responsible for managing two stocks of sea otters (central California and Washington), while the National Marine Fisheries Service (NMFS) has management authority for cetacean and pinniped stocks. Of the 64 marine mammal stocks found in the Pacific region, 13 stocks are listed under the ESA (2 threatened, 11 endangered), and 16 stocks are strategic under the MMPA. In the eastern Pacific Ocean (i.e. waters off Washington, Oregon, California, and northern Mexico), the strategic stocks of marine mammals include endangered sperm, humpback, blue, fin, sei, and southern resident killer whales; short-finned pilot whales; long-beaked common dolphins; and threatened Guadalupe fur seals and California sea otters. Strategic stocks in Hawaiian waters include endangered sperm, blue, fin, and sei whales; false killer whales (Hawaii stock); and endangered Hawaiian monk seals. Fourteen stocks have known population trends: seven are increasing, one is stable/increasing, five are stable, and one is declining; the trends for the remaining 50 stocks are unknown. The status of marine mammal stocks in the Pacific region is summarized in Table 22-1. Seven marine mammal stocks are highlighted in this chapter: the Hawaiian monk seal, the Pacific Islands Stock Complex of false killer whales, the eastern North Pacific stocks of humpback and blue whales, and three stocks of

Table 22-1

Status of marine mammal stocks in the Pacific region.

Species/stock	Minimum population estimate (N_{min})[1]	Potential biological removal level (PBR)[2]	Annual fisheries-caused mortality[3]	Total annual human-caused mortality[4]	Strategic status[5]	MMPA/ESA status[6]	Trend[7]
Seals and sea lions							
California sea lion (U.S.)	141,842	8,511	≥ 159	≥ 232	No		I
Guadalupe fur seal	3,028	91	0.0	0.0	Yes	T	I
Harbor seal							
California	31,600	1,896	389	≥389	No		S
Oregon & Washington Coast	22,380	1,343	≥ 13	≥ 15.2	No		S
Washington Inland Waters	12,844	771	≥ 30	≥ 34	No		S
Hawaiian monk seal	1,214	Undet.	Unknown	Unknown	Yes	E	D
Northern elephant seal (California Breeding)	74,913	4,382	≥ 8.8	≥ 10.4	No		I
Northern fur seal (San Miguel Island)	5,096	219	≥ 1.0	≥ 1.0	No		U
Whales and porpoises							
Baird's beaked whale (CA / OR / WA)	203	2.0	0	0.2	No		U
Blainville's beaked whale (Hawaii)	1,204	9.6	0.8	0.8	No		U
Blue whale							
Eastern North Pacific	1,005	1.0	0	0.6	Yes	E	U
Western North Pacific	Unknown	Undet.	Unknown	Unknown	Yes	E	U
Bottlenose dolphin							
California Coastal	290	2.4	0.4	0.4	No		S
CA / OR / WA Offshore	2,295	23	0.2	0.2	No		U
Hawaii	2,046	20	≥ 0.2	≥ 0.2	No		U
Brydes whale							
Eastern Tropical Pacific	Unknown	Undet.	0	0	No		U
Hawaii	373	3.7	Unknown	Unknown	No		U
Common dolphin (CA / OR / WA)	392,687	3,927	59	59	No		U
Cuvier's beaked whale							
CA / OR / WA	1,234	10	0	≥ 0.2	No		U
Hawaii	6,919	69	Unknown	Unknown	No		U
Dall's porpoise (CA / OR / WA)	43,425	347	1.8	1.4	No		U
Dwarf sperm whale							
CA / OR / WA	Unknown	Undet.	0	0	No		U
Hawaii	11,555	116	Unknown	Unknown	No		U
False killer whale							
Hawaii	249	2.4	4.9	4.9	Yes		U
Palmyra Atoll	806	7.7	1.9	1.9	No		U
Fin whale							
CA / OR / WA	2,760	16	0	1.4	Yes	E	U
Hawaii	101	0.2	Unknown	Unknown	Yes	E	U
Fraser's dolphin (Hawaii)	7,917	79	Unknown	Unknown	No		U
Harbor porpoise							
Morro Bay	1,206	10	4.5	4.5	No		I
Monterey Bay	1,149	10	9.5	9.5	No		S
Northern California / Southern Oregon	12,940	259	≥ 0	≥ 0	No		U
Oregon / Washington Coast	27,705	277	0.6	0.6	No		U
San Francisco–Russian River	6,254	63	≥ 0.8	≥ 0.8	No		S/I
Washington Inland Waters	7,841	63	15.2	15.4	No		U
Humpback whale (CA / OR / WA)	1,236	2.5	≥ 1.8	≥ 2.2	Yes	E	I
Killer whale							
Eastern North Pacific Offshore	331	3.3	0	0	No		U
Eastern North Pacific Southern Resident	89	0.18	0	0.2	Yes	E	U
Hawaii	250	2.5	Unknown	Unknown	No		U
Long-beaked common dolphin (California)	1,152	11	12.5	12.5	Yes		U
Longman's beaked whale (Hawaii)	371	3.7	Unknown	Unknown	No		U
Melon-headed whale (Hawaii)	1,386	14	Unknown	Unknown	No		U
Mesoplodont beaked whales (CA / OR / WA)	576	5.7	0	0	No		U

Table 22-1

Continued from the previous page.

Species/stock	Minimum population estimate (N_{min})[1]	Potential biological removal level (PBR)[2]	Annual fisheries-caused mortality[3]	Total annual human-caused mortality[4]	Strategic status[5]	MMPA/ ESA status[6]	Trend[7]
Minke whale							
CA / OR / WA	544	5.4	0	0	No		U
Hawaii	Unknown	Undet.	Unknown	Unknown	No		U
Northern right whale dolphin (CA / OR / WA)	11,754	113	18	18	No		U
Pacific white-sided dolphin (CA / OR / WA)	39,822	382	5.4	5.4	No		U
Pantropical spotted dolphin (Hawaii)	7,362	74	$\geq$ 0.8	$\geq$ 0.8	No		U
Pygmy killer whale (Hawaii)	382	3.8	Unknown	Unknown	No		U
Pygmy sperm whale							
CA / OR / WA	Unknown	Undet.	0	0.2	No		U
Hawaii	4,082	41	Unknown	Unknown	No		U
Risso's dolphin							
CA / OR / WA	9,947	80	6.6	6.6	No		U
Hawaii	1,426	14	Unknown	Unknown	No		U
Rough-toothed dolphin (Hawaii)	13,184	132	Unknown	Unknown	No		U
Sei whale							
Eastern North Pacific	27	0.005	0	0	Yes	E	U
Hawaii	37	0.1	Unknown	Unknown	Yes	E	U
Short-finned pilot whale							
CA / OR / WA	123	0.98	1.0	1.0	Yes		U
Hawaii	5,986	60	0.8	0.8	No		U
Sperm whale							
CA / OR / WA	1,719	3.4	0.2	0.2	Yes	E	U
Hawaii	5,531	11	0.0	0.0	Yes	E	U
Spinner dolphin (Hawaii)	1,691	17	0	0	No		U
Striped dolphin							
CA / OR / WA	16,737	167	0	0	No		U
Hawaii	7,078	71	Unknown	Unknown	No		U
Other marine mammals[8]							
Sea otter							
California	2,376	7	Unknown	Unknown	Yes	T	I
Washington[9]	790	8	Unknown	Unknown	No		I

[1] N_{min} is a conservative estimate of abundance used to estimate PBR; it provides reasonable assurance that the stock size is equal to or greater than the estimate.

[2] The maximum number of animals, not including natural mortalities, that may be removed from a stock while allowing that stock to reach or stay at its optimum sustainable population level (50–100% of its carrying capacity); calculated as the product of N_{min}, one-half of R_{max} (the maximum productivity rate), and F_r (the recovery factor). Undet. = undetermined.

[3] An estimate of the total number of annual mortalities and serious injuries (likely to result in death) caused by commercial fisheries; represents injuries/mortalities occurring only within the U.S. Exclusive Economic Zone.

[4] An estimate of the total number of annual mortalities and serious injuries (likely to result in death) caused by humans; includes other sources of mortality, such as ship strikes, strandings, orphaned animals collected for public display, mortalities associated with research activities, take by foreign countries, and mortalities associated with activities authorized through incidental take regulations.

[5] As defined in the Marine Mammal Protection Act (MMPA) Amendments of 1994, any marine mammal stock 1) for which the level of direct human-caused mortality exceeds the PBR level; 2) which is declining and likely to be listed as threatened under the Endangered Species Act (ESA); or 3) which is listed as threatened or endangered under the ESA or as depleted under the MMPA.

[6] As defined in the MMPA, any species that is listed as threatened (T) or endangered (E) under the ESA is also considered to be a depleted (D) stock.

[7] Trends: I=increasing; S/I=stable/increasing; S=stable; D=decreasing; U=unknown.

[8] These species are under the jurisdiction of the U.S. Fish and Wildlife Service, and are not included in the stock-status tables of the National Overview.

[9] There is no formal Federal ESA designation for the northern sea otter, but this stock is legally designated as endangered by the State of Washington (Washington Administrative Code 232-12-014).

Charles Littnan, NMFS

Juvenile monk seal.

harbor porpoise in central California. Additional details and information about all 62 stocks managed by NMFS in the Pacific region can be found in the MMPA stock assessment reports (Carretta et al., 2007).

HAWAIIAN MONK SEAL

Stock Definition and Geographic Range

Hawaiian monk seals are distributed throughout the Northwestern Hawaiian Islands (NWHI) in six main reproductive subpopulations at French Frigate Shoals, Laysan Island, Lisianski Island, Pearl and Hermes Reef, Midway Atoll, and Kure Atoll. Additional populations with limited reproduction are found at Necker and Nihoa Islands, and a small but apparently growing number of seals occur throughout the main Hawaiian Islands (MHI).

Genetic variation among NWHI monk seals appears low and may reflect both a long-term history of low population levels and more recent declines due to human influences. On average, 10–15% of the seals migrate among the NWHI subpopulations (Johnson and Kridler, 1983; Harting, 2002). These subpopulations are therefore not demographically isolated, although the different island subpopulations have exhibited considerable independence. For example, abundance at French Frigate Shoals grew rapidly from the 1950's to the 1980's, while other subpopulations rapidly declined. NWHI and MHI seals have not been compared genetically, but observed interchange of individuals among the regions is extremely rare, suggesting that these may be more appropriately designated as separate stocks. Further evaluation of a separate MHI stock will be pursued following genetic stock structure analysis (currently underway) and additional studies of MHI monk seals. In the meantime, while research and recovery activities may focus on the problems of single island/atoll subpopulations, the species is managed as a single stock.

Population Size and Current Trend

The total Hawaiian monk seal abundance in 2007 was estimated at 1,247; this estimate is the sum of estimated abundance at the six main NWHI subpopulations, an extrapolation of counts at Necker and Nihoa Islands, and a minimum abundance estimate for the MHI. A total of 1,072 seals (including pups) were estimated for the main reproductive subpopulations in 2005. Estimates for Necker and Nihoa Islands (± standard deviation) were 48.5 (± 19.9) and 51.7 (± 22.1), respectively. The total number of individually identifiable seals in the MHI was 77 for 2005, and is the current best minimum abundance estimate for this area. The minimum population estimate (N_{min}) for the entire Hawaiian monk seal population in 2007 was 1,214 seals.

Total mean non-pup beach counts at the six main reproductive NWHI subpopulations in 2005 were 67% lower than in 1958. From 1998 (the first year for which a reliable total abundance estimate has been obtained) through 2005, abundance has declined at 3.8% per year; this is the best estimate of current population trend.

Natural sources of mortality which may impede the recovery of Hawaiian monk seals include food limitation, shark predation, single- and multiple-male aggression, and disease/parasitism. Various measures to detect and mitigate male aggression have been developed and successfully applied. Shark-related injury and mortality incidents occur throughout the monk seal's range, but shark predation on monk seal pups has emerged as a serious threat since the late 1990's. Various mitigation measures are ongoing to address this problem.

An Unusual Mortality Event (UME) contingency plan has recently been published for the monk seal (Yochem et al., 2004). While disease effects on monk seal demographic trends are uncertain, there is concern that diseases of livestock, feral animals, pets, or humans could be transferred to native monk seals in the MHI and potentially spread to the core population in the NWHI. Recent diagnoses confirm that in 2003 and 2004, two deaths of free-ranging monk seals were associated with diseases not previously found in the species: leptospirosis and toxoplasmosis. *Leptospira* bacteria are found in many of Hawaii's streams and estuaries and are associated with livestock and rodents. Cats, domestic and feral, are a common source of toxoplasma parasites.

Human-induced mortality has caused two major declines of the Hawaiian monk seal (Ragen, 1999). Sealers, surviving sailors of wrecked ships, guano gatherers, and feather hunters decimated this species in the 1800's (Dill and Bryan, 1912; Wetmore, 1925; Clapp and Woodward, 1972). A 1958 survey indicated at least a partial recovery of the species during the first half of this century (Rice, 1960); however, subsequent surveys documented a second major decline beginning in 1958 (or earlier), during which several populations (Kure Atoll, Midway Atoll, and Pearl and Hermes Reef) decreased by 80–100%. The causes of this second decline have not been fully explained, but population trends at some sites appear to have been determined by the pattern of human disturbance (Kenyon, 1972; Gerrodette and Gilmartin, 1990; Ragen, 1999). Such disturbances have caused pregnant females to abandon prime pupping habitat and nursing females to abandon their pups, thereby increasing juvenile mortality. Currently, human activity in the NWHI is highly restricted and human disturbance of seals has become relatively rare. In contrast, a small number of seals coexist with 1.2 million residents and over 6 million tourists each year in the MHI, where disturbance of seals is a concern.

Fishery interactions with monk seals include operations/gear conflict, seal consumption of discarded fish, and competition for prey. Entanglement of monk seals in discarded fishing gear, which is believed to originate outside the Hawaiian Archipelago, is a source of mortality and injury throughout the seal's range. The NWHI lobster fishery has been closed since 2000 due to uncertainty in stock assessments, removing a potential source of interactions with monk seals. The NWHI bottomfish fishery, which has been reported to interact with monk seals, will close no later than 2011 in accordance with President Bush's establishment of the Papahānaumokuākea Marine National Monument in 2006. Interactions between the pelagic longline fishery and monk seals apparently ceased in 1991 after NMFS established a permanent Protected Species Zone extending 50 nautical miles (n.mi.) around the NWHI and the corridors between the islands. Interactions between nearshore fisheries and monk seals also occur in the MHI, mostly involving hookings of seals. A total of 32 seals were observed with embedded hooks in the MHI during 1990–2005, and the frequency of such hookings appears to be on the rise.

In addition to disturbance and nearshore fishery interactions, monk seals face other challenges in the MHI. These include exposure to feral and domestic animals, which represent potential disease vectors. Additionally, vessel traffic around the populated islands carries the potential for collisions with seals and impacts from oil spills. Thus, issues surrounding the presence of monk seals in the MHI will likely become an increasing focus for management and recovery of this species.

Stock Status

In 1976, the Hawaiian monk seal was designated as endangered under the ESA and depleted under the MMPA. The species is well below its optimum sustainable population (OSP) and therefore is characterized as a strategic stock under the MMPA. According to the methodology specified in the 1994 Amendments to the MMPA and guidelines subsequently developed by NMFS, potential biological removal (PBR) for the monk seal is undetermined. The original 1983 Recovery Plan for the Hawaiian monk seal was revised in 2007.


J. P. McVey, NOAA Sea Grant

Hawaiian monk seal, Laysan Island, Hawaii.

False killer whales and dolphins seen from the bow of a NOAA Research Vessel.

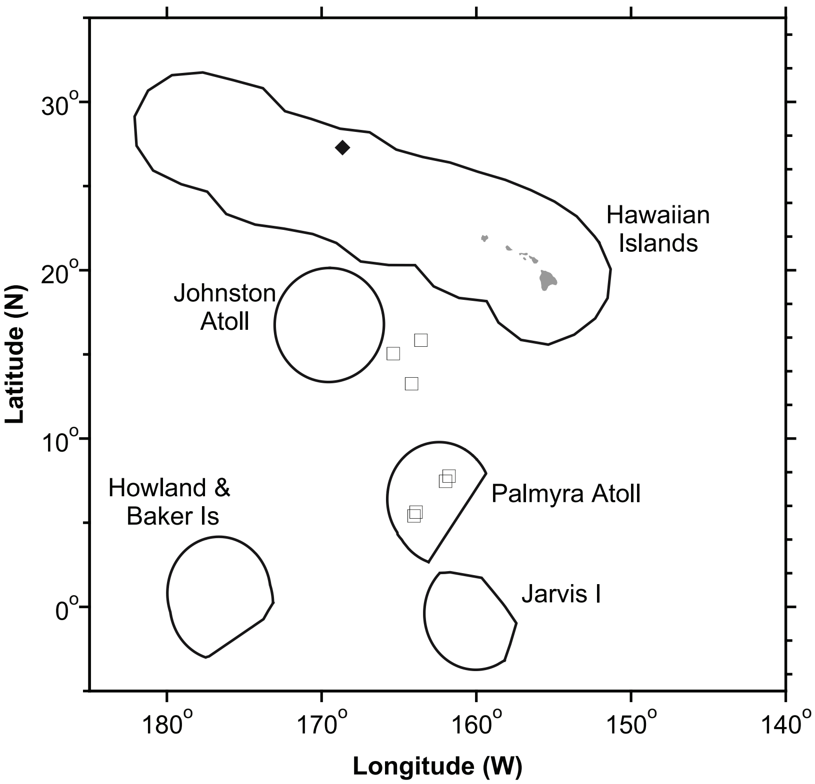

Figure 22-1
False killer whale sighting locations during standardized shipboard surveys of the Hawaiian U.S. EEZ (2002, black diamond), the Palmyra U.S. EEZ (2005, open squares), and pelagic waters of the central Pacific south of the Hawaiian Islands (2005, open squares). Outer lines represent approximate boundary of U.S. EEZs.

FALSE KILLER WHALE: PACIFIC ISLANDS STOCK COMPLEX

Stock Definition and Geographic Range

False killer whales are found worldwide in tropical and warm-temperate waters. In the North Pacific, this species is well known from southern Japan, Hawaii, and the eastern tropical Pacific. Most knowledge about this species comes from outside of Hawaiian waters, although there are six stranding records from Hawaiian waters (Nitta, 1991; Maldini et al., 2005) and two sightings of false killer whales were made during a 2002 shipboard survey of U.S. waters surrounding the Hawaiian Islands (Figure 22-1; Barlow, 2006). Smaller-scale surveys conducted in the MHI show that false killer whales are also commonly encountered in nearshore waters (Mobley et al., 2000; Mobley, 2001, 2002, 2003, 2004; Baird et al., 2005).

Genetic analyses of tissue samples collected near the main Hawaiian Islands indicate that Hawaiian false killer whales are reproductively isolated from false killer whales found in the eastern tropical Pacific Ocean (Chivers et al., 2007); however, the offshore range of this Hawaiian population is unknown. Fishery interactions demonstrate that this species also occurs in U.S. territorial waters around Palmyra Atoll (Table 22-2; Figure 22-2), but it is not known whether these animals are part of the Hawaiian stock or whether they represent a separate stock of false killer whales. Recent surveys have confirmed the presence of false killer whales in the U.S. Exclusive Economic Zone (EEZ) waters of American Samoa and Johnston Atoll. For the MMPA stock assessment reports, there are currently two Pacific Island Region management stocks: 1) the Hawaiian stock, which includes animals found within the EEZ of the Hawaiian Islands; and 2) the Palmyra stock, which includes false killer whales found in the EEZ of Palmyra Atoll.

Population Size and Current Trend

Population estimates for this species have been made from shipboard surveys in Japan and the eastern tropical Pacific, but genetic evidence suggests that false killer whales around Hawaii form a distinct population. A recent mark–recapture

		Outside of U.S. EEZ			Hawaiian Island EEZ			Palmyra Island EEZ		
Year	% observer coverage	Obs.	Est.	Mean annual takes	Obs.	Est.	Mean annual takes	Obs.	Est.	Mean annual takes
2001	23.0	2	11 (0.71)		0	0 (-)		1	4 (1.00)	
2002	24.8	3	12 (0.58)		0	0 (-)		2	5 (0.71)	
2003	21.9	0	0 (-)	7.7 (0.34)	2	8 (0.68)	4.9 (0.41)	0	0 (-)	1.9 (0.59)
2004	25.4	3	12 (0.58)		3	13 (0.58)		0	0 (-)	
2005	34.2	1	4 (1.00)		1	3 (1.00)		0	0 (-)	

Table 22-2
Summary of available information on observed (Obs.) and estimated (Est.) incidental mortality and serious injury of false killer whales (Hawaiian stock) in commercial fisheries, by EEZ region. Data is based on observer data from the Hawaii-based longline fishery. Mean annual take estimates are based on 2001–05 data; the coefficient of variation (CV) is in parentheses. The minimum total annual take within U.S. EEZ waters is estimated to be 6.8 (CV = 0.34).

photo-identification study of false killer whales in the inshore waters of the main Hawaiian Islands produced an estimate of 123 individuals (CV = 0.72; Baird et al., 2005). Analyses of a 2002 shipboard line-transect survey of the entire Hawaiian EEZ (Hawaiian Islands Cetacean and Ecosystem Assessment Survey or HICEAS) resulted in an abundance estimate of 236 (CV = 1.13) false killer whales (Barlow, 2006). A re-analysis of the HICEAS data using improved methods and incorporating additional sighting information obtained during line-transect surveys south of the Hawaiian EEZ during 2005 resulted in a revised estimate of 484 (CV = 0.93) false killer whales within the Hawaiian Islands EEZ (Barlow and Rankin, 2007). This is the best available abundance estimate for false killer whales within the Hawaiian Islands EEZ.

Recent line-transect surveys in the Palmyra EEZ produced an estimate of 1,329 (CV = 0.65) false killer whales (Barlow and Rankin, 2007). This is the best available abundance estimate for false killer whales within the Palmyra Atoll EEZ.

Information on the current population trend of false killer whales is not available for either Hawaii or Palmyra Atoll.

Stock Status

Information on fishery-related mortality of cetaceans in Hawaiian waters is limited, but the types of gear used in Hawaiian fisheries (including gillnets, traps, and longlines) are responsible for marine mammal mortality and serious injury in other fisheries throughout U.S. waters. Gillnets appear to capture marine mammals wherever they are used, and float lines from lobster traps and longlines occasionally entangle whales. Interactions with cetaceans have been reported for all Hawaiian pelagic fisheries, and false killer whales have been identified in fishermen's logs and NMFS observer catches from pelagic longlines (Nitta and Henderson, 1993).

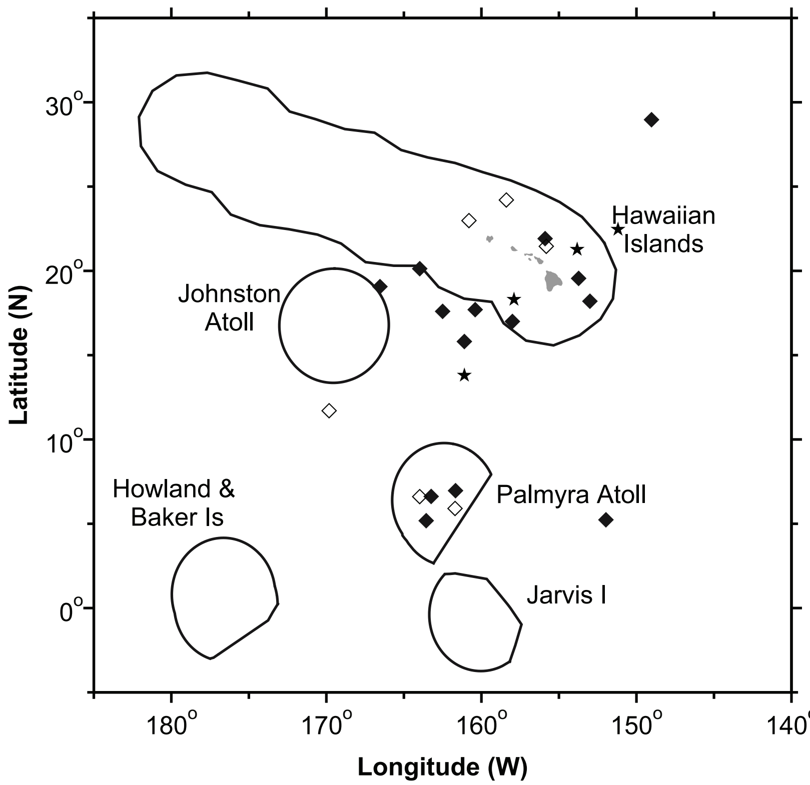

Figure 22-2
Locations of observed false killer whale takes (filled symbols) and possible takes of this species (open symbols) in the Hawaii-based longline fishery, 2001–05. Stars are locations of genetic samples from fishery-caught false killer whales. Solid lines represent the U.S. EEZ.

Between 1994 and 2005, 20 false killer whales were observed hooked in the Hawaii-based longline fishery, with approximately 4–34% of all effort observed (Forney and Kobayashi, 2007; Figure 22-2). The average interaction rate of false killer whales was 0.81 animals per 1,000 sets. All false killer whales caught were considered seriously injured, based on the nature of the interactions (Forney

Humpback whale breaching, Hawaiian Islands Humpback Whale National Marine Sanctuary.

and Kobayashi, 2005). Average 5-year estimates of mortality and serious injury for 2001–05 are 7.7 (CV = 0.34) false killer whales per year outside of the U.S. EEZ, 4.9 (CV = 0.41) false killer whales within the Hawaiian Islands EEZ, and 1.9 (CV = 0.59) false killer whales within the Palmyra Atoll EEZ (Table 22-2). Total U.S. EEZ mortality and serious injury for all areas combined averaged 6.8 (CV = 0.34) false killer whales per year between 2001 and 2005.

False killer whales are not listed as threatened or endangered under the ESA or as depleted under the MMPA. Because the rate of mortality and serious injury to false killer whales within the Hawaiian Islands EEZ (4.9 animals per year) exceeds the PBR (PBR = 2.4) under the MMPA, this stock is considered a strategic stock under the 1994 amendments to the MMPA. The total fishery mortality and serious injury for Hawaiian false killer whales cannot be considered to be insignificant and approaching zero, because it exceeds the PBR. The rate of mortality and serious injury to false killer whales within the Palmyra Atoll EEZ in the Hawaii-based longline fishery (1.9 animals per year) does not exceed the PBR (7.7) for this stock and thus, this stock is not considered strategic. The total fishery mortality and serious injury for the Palmyra stock is greater than 10% of the PBR and, therefore, cannot be considered insignificant and approaching zero.

HUMPBACK WHALE: CALIFORNIA/ OREGON/WASHINGTON STOCK

Stock Definition and Geographic Range

Within the North Pacific, at least three separate stocks of humpback whales migrate between their winter/spring calving and mating areas and their summer/fall feeding areas: 1) the California/ Oregon/Washington stock (CA/OR/WA stock, also called the eastern North Pacific stock), which includes whales that migrate from Mexico and Central America to feeding grounds off the U.S. west coast and southern British Columbia in summer/fall (Figure 22-3); 2) the Central North Pacific stock, which includes whales that migrate from the Hawaiian Islands to northern British Columbia, Southeast Alaska, and Prince William Sound west to Kodiak; and 3) the Western North Pacific stock, which includes whales that migrate from islands in the western Pacific to feeding areas off Russia, along the Aleutian Islands, and in the Bering Sea. Winter/spring populations of humpback whales also occur in Mexico's offshore islands, but the summer/fall feeding destination of these whales is not well known. Although this structure represents the predominant migration pathways, some individual whales migrate from Mexico to the Gulf of Alaska and others migrate from Japan to British Columbia. In general, interchange occurs (at low levels) between breeding areas, but fidelity is extremely high among the feeding areas.

Significant genetic differences exist between the California and Alaska feeding groups based on analyses of mitochondrial DNA and nuclear DNA. The genetic exchange rate between the California and Alaska groups is estimated to be less than one female per generation. The two breeding areas (Hawaii and coastal Mexico) showed fewer genetic differences than did the corresponding feeding areas. The observed movement of individually identified whales between Hawaii and Mexico substantiates these findings.

Population Size and Current Trend

Based on whaling statistics, the pre-1905 population of humpback whales in the North Pacific was estimated to be 15,000, but whaling reduced this population to approximately 1,200 by 1966. The entire North Pacific total now almost certainly exceeds 6,000 humpback whales. For the CA/OR/WA stock, the more recent abundance estimate is 1,300–1,400 whales based on ship surveys in 1996 and 2001 and on mark–recapture studies in 2002 and 2003. Ship surveys provide some indication that humpback whales increased in abundance in California coastal waters between 1979–80 and 1991 and between 1991 and 1996; however, estimates declined between 1996 and 2001. Mark–recapture population estimates increased steadily from 1988–90 to 1997–98 at about 8% per year. The CA/OR/WA stock appears to have declined in abundance between 1998 and 1999, but the most recent mark–recapture estimate shows that growth may have resumed. Population estimates for the entire North Pacific have also increased substantially, from 1,200 whales in 1966 to between 6,000 and 10,000 whales circa 1992. Although these estimates are based on different methods and the earlier estimate is extremely uncertain, the population growth rate implied by these estimates (6–8%) is consistent with the recently observed growth rate of the CA/OR/WA stock. The best estimate of humpback whale abundance in the CA/OR/WA region is the average of the 2001–05 line-transect estimate (1,401 animals) and the 2002/2003 mark–recapture estimate (1,391 animals) or 1,396 whales.

Stock Status

Humpback whales in the North Pacific were estimated to have been reduced to 13% of carrying capacity (K) by commercial whaling. The initial abundance has never been estimated separately for the CA/OR/WA stock, but this stock was also depleted (probably twice) by whaling. Both the central and eastern stocks have been recovering since the end of commercial whaling in 1964, and recent population growth rates have been 6–8% annually. Humpback whales are formally listed as endangered under the ESA, and consequently the California/Mexico stock is automatically considered as a depleted and strategic stock under the MMPA. The estimated annual mortality and injury due to entanglement (1.8 per year), ship strikes (0.2 per year), and other anthropogenic sources (0.2 per year) is less than the potential biological removal (PBR = 2.5) estimated for U.S. waters.

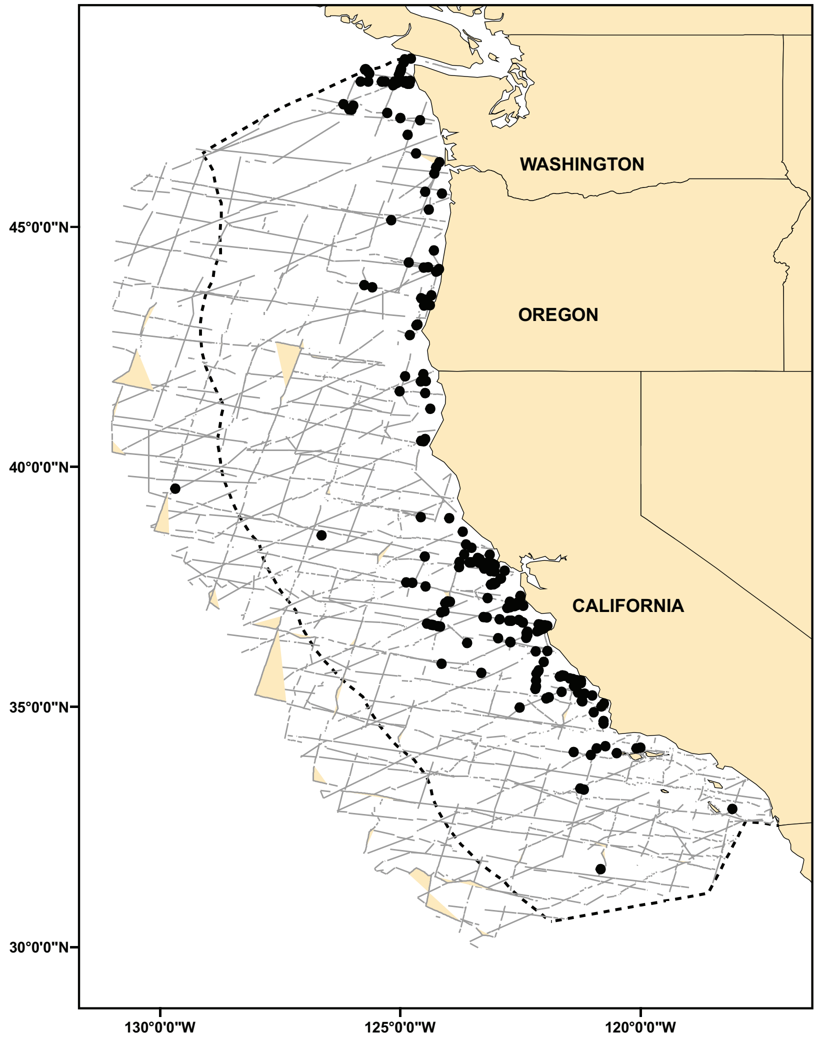

Figure 22-3
Humpback whale sightings based on shipboard surveys off California, Oregon, and Washington, 1991–2005. Dashed line represents the U.S. EEZ; thin lines indicate completed transect effort of all surveys combined.

BLUE WHALE: EASTERN NORTH PACIFIC STOCK

Stock Definition and Geographic Range

The North Pacific contains at least two stocks of blue whales that are distinguishable based on stable differences in call characteristics. Up to five stocks

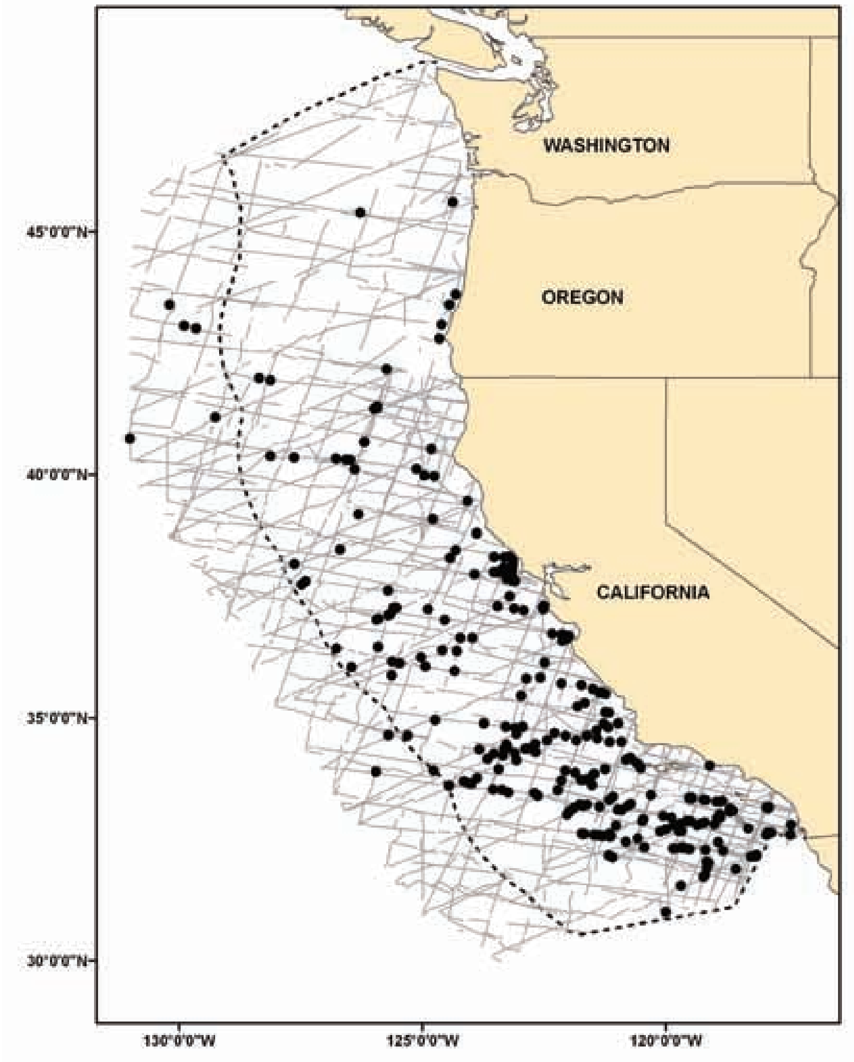

Figure 22-4

Blue whale sighting locations based on aerial and summer/autumn shipboard surveys off California, Oregon, and Washington, 1999–2005. Dashed line represents the U.S. EEZ; thin lines represent completed transect effort for all surveys combined.

SWFSC Protected Resources Division

Aerial photo of a blue whale with her calf in the eastern tropical Pacific Ocean.

have been proposed for the North Pacific. This section covers the Eastern North Pacific stock that feeds primarily in California waters in summer/fall (from June to November) and migrates south to reproductive areas off Mexico and as far south as the Costa Rica Dome (10°N) in winter/spring. Blue whales have been seen and heard off Oregon with increasing frequency since 2000 (Figure 22-4). In 2004, blue whales were seen in the northern Gulf of Alaska for the first time in approximately two decades. One of those whales was identified by photographers as a whale that was previously seen off southern California in the 1990's. In recent years, acoustic researchers have documented Eastern North Pacific blue whale calls in the Gulf of Alaska. It is not known whether blue whales are now rediscovering this historical feeding area or whether they have continued to use this area in small numbers that escaped the notice of whale biologists.

Population Size and Current Trend

The size of the feeding stock of blue whales in California was estimated recently using both line-transect methods and mark–recapture methods. The line-transect estimates of 800 whales were based on ship surveys off California, Oregon, and Washington in 2001 and 2005. The mark-recapture estimates were based on photographs of individual whales taken off California in 2000–02, and averaged 1,567 individuals. The best current estimate of blue whale abundance is the average of the line-transect and mark–recapture estimates, or approximately 1,186 blue whales off the U.S. West Coast.

There is some indication that blue whales have increased in abundance in California coastal waters between 1979–80 and 1991, and between 1991 and 1996. This may be due to an increase in the blue whale stock as a whole, but could also be the result of increased use of California waters as a feeding area. Although the population in the North Pacific is expected to have grown since being given protected status in 1966, the possibility of continued unauthorized takes after blue whales were protected and the existence of incidental ship strikes make this uncertain.

Stock Status

Previously, blue whales in the entire North Pacific were estimated to be at 33% (1,600) of historic carrying capacity (4,900). The initial abundance has never been estimated separately for the eastern stock, but this stock was almost certainly depleted by whaling. Blue whales are formally listed as endangered under the ESA, and consequently the eastern North Pacific stock is automatically considered as a depleted and strategic stock under the MMPA. There were no observed fishery entanglements during the period of 1998–2002, and the total estimated human-caused mortality and serious injury due to ship strikes (0.6 per year) is less than the potential biological removal (PBR = 1.0) calculated for this stock.

HARBOR PORPOISE: CENTRAL CALIFORNIA STOCKS

Stock Definition and Geographic Range

In the Pacific, harbor porpoises are found in coastal and inland waters from Point Conception, California, north to Alaska and west to the Kamchatka Peninsula (in eastern Russia) and Japan (Gaskin, 1984). Most harbor porpoise along the California coast are found in waters less than 60 m deep (Barlow, 1988; Carretta et al., 2001). In contrast to harbor porpoises on the U.S. East Coast, which exhibit seasonal migrations between the Carolinas and the Gulf of Maine (Polacheck et al., 1995), U.S. West Coast harbor porpoises appear to have limited geographic movement. Along the California coast, harbor porpoise were previously divided into two stocks (central California and northern California) based on regional differences in pollutant levels and other evidence of limited movement in this region (Calambokidis and Barlow, 1991). Recent molecular genetic evidence has revealed further population subdivision within this region (Chivers et al., 2002), and four harbor porpoise stocks are now recognized off California (Figure 22-5). This stock structure includes three stocks in central California (Morro Bay, Monterey Bay, and San Francisco–Russian River; Table 22-3), and a Northern California/Southern Oregon stock. Harbor porpoise stock boundaries may be further refined as additional genetic samples are analyzed in this region.

Small-scale movements of harbor porpoises along the California coast in response to changing oceanographic conditions, such as El Niño, have been suggested by Forney (1999), who found that porpoise abundance off central California was negatively correlated with higher than normal sea surface temperatures.

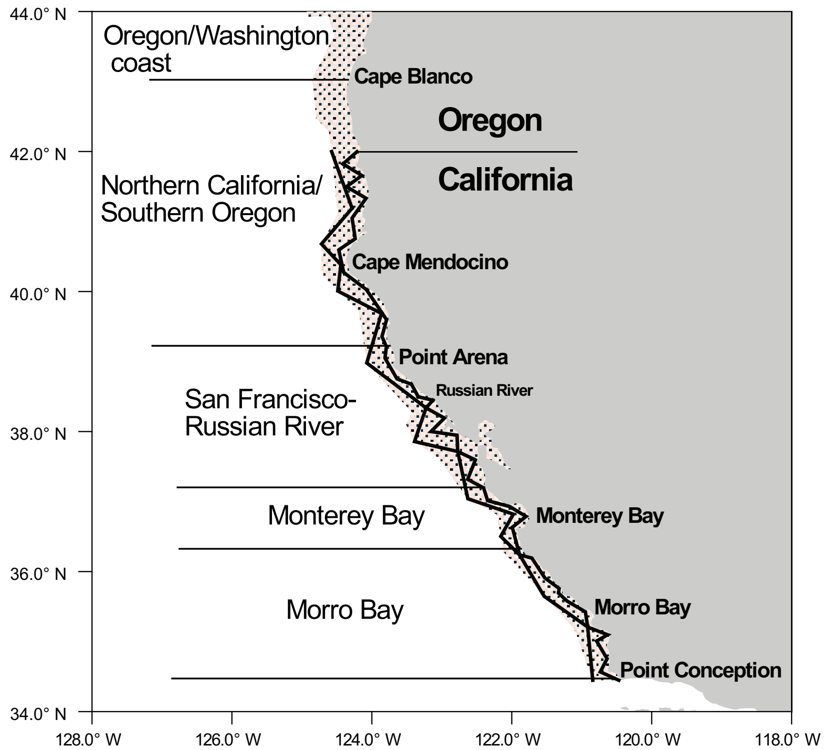

Figure 22-5

Harbor porpoise stocks and boundaries in California and southern Oregon. Stippled area shows approximate harbor porpoise habitat between 0–200 m depths. The thick solid line represents survey transects flown during 1989–2002 aerial surveys. Survey coverage north of the California/Oregon border has been completed by the National Marine Mammal Laboratory.

Stock	Population size	Lower 95% confidence interval	Upper 95% confidence interval	Coefficient of variation
Morro Bay	1,656	730	3,183	0.39
Monterey Bay	1,149	675	3,353	0.42
San Francisco–Russian River	8,521	4,151	17,145	0.38

Table 22-3

Estimated population sizes for harbor porpoise stocks in central California based on 1999 and 2002 aerial surveys.

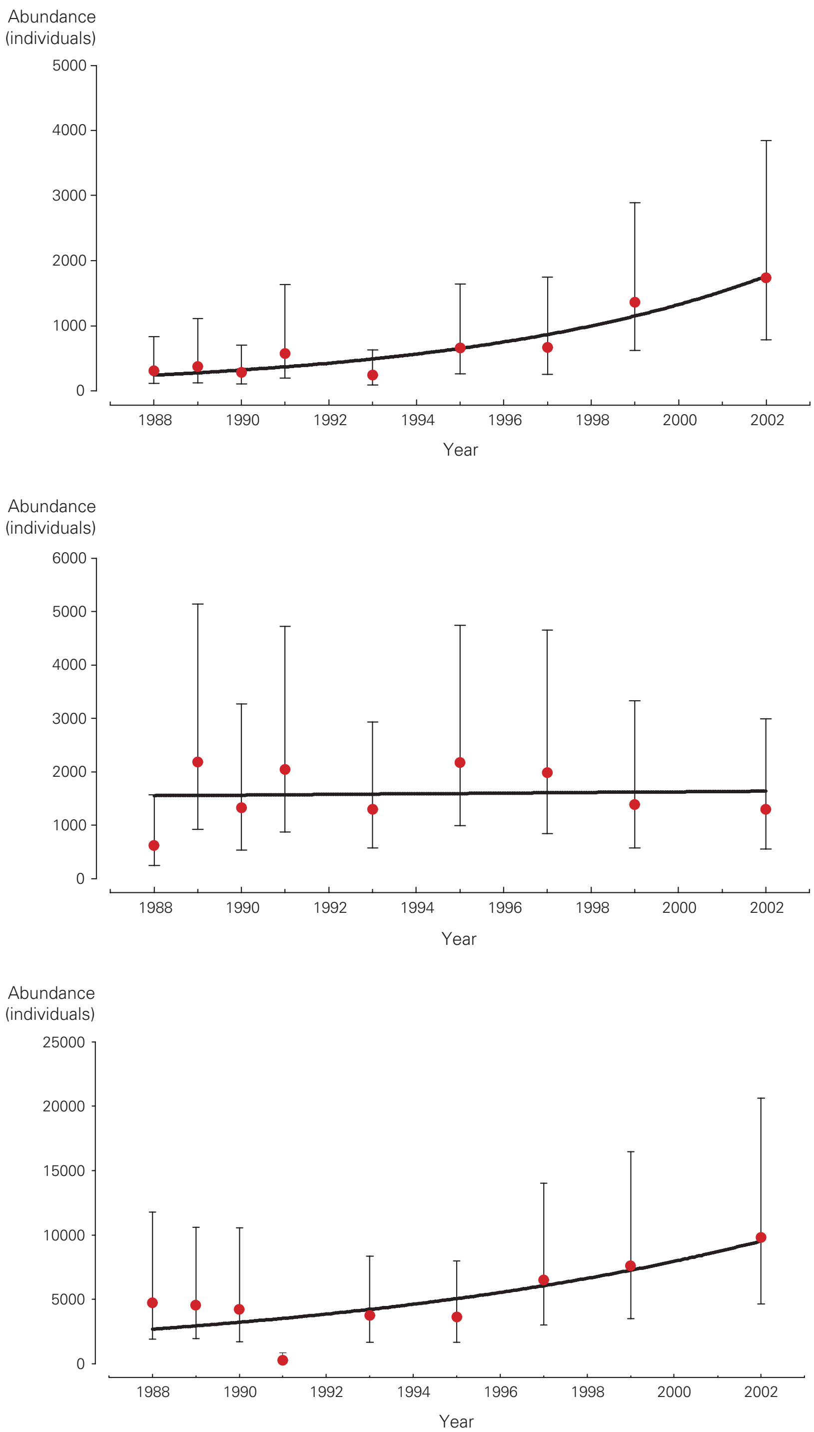

Figure 22-6

Aerial survey estimates of abundance for central California stocks of harbor porpoise, 1988–2002. Error bars represent the lower and upper 95% confidence intervals. Solid lines represent linear regressions on the natural logarithm of abundance over time. Top, Morro Bay stock (slope of regression is statistically significant, $p < 0.002$); middle, Monterey Bay stock (slope of regression is not statistically significant, $p = 0.64$); bottom, San Francisco–Russian River stock (slope of regression is not statistically significant, $p = 0.24$).

Population Size and Current Trend

The most recent estimates of population size for the three central California porpoise stocks are based on pooled data from aerial surveys conducted in 1999 and 2002 (Carretta and Forney, 2004; Table 22-3). A new series of aerial surveys was conducted between 2003 and 2007 to provide updates on the abundance of these stocks. Data from these surveys are currently being analyzed.

Morro Bay Stock: Abundance estimates from a series of nine aerial surveys conducted between 1988 and 2002 suggested that the Morro Bay population of harbor porpoise was increasing. The first five aerial surveys conducted between 1988 and 1993 yielded abundance estimates between 100 and 500 animals. Aerial surveys conducted between 1995 and 2002 yielded abundance estimates between 600 and 1,700 animals. Based on just the 1999–2002 aerial surveys, which were conducted under the best conditions, the abundance estimate is 1,656 animals. The slope of a linear regression on the natural logarithm of abundance from 1988 to 2002 is significantly different from zero ($p < 0.002$, Figure 22-6), indicating population growth.

Monterey Bay Stock: Harbor porpoise in Monterey Bay do not show any trend in abundance over the period of 1988–2002. The slope of a linear regression on the natural logarithm of abundance from 1988 to 2002 is not significantly different from zero ($p = 0.64$, Figure 22-6). Based on just the 1999–2002 aerial surveys, which were conducted under the best conditions, the abundance estimate is 1,613 animals.

San Francisco–Russian River Stock: Abundance of the San Francisco-Russian River stock of harbor porpoise appeared to be stable or declining between 1988–1991, and the slope of a linear regression on the natural logarithm of abundance from 1988 to 2002 is not significantly different from zero ($p = 0.24$, Figure 22-6). Based on just the 1999–2002 aerial surveys, which were conducted under the best conditions, the abundance estimate is 6,254 animals.

Stock Status

Harbor porpoise in California waters are not listed as threatened or endangered under the ESA or as depleted under the MMPA. In the early 1980's, harbor porpoise mortality in set gillnets off central California was estimated at more than 200 animals annually (Diamond and Hanan, 1986). In the mid-to-late 1990's, estimates of harbor porpoise mortality in Monterey Bay ranged from 40 to 130 animals annually (Forney et al., 2001). A ban on all gillnets in central California waters shallower than 110 m took effect in September 2002; this ban is expected to effectively reduce fishery-caused harbor porpoise mortality in this region to near zero. The current mean annual human-caused mortality (take) for the three central California stocks is less than the potential biological removal, and none of the stocks is considered strategic under the MMPA. The average annual mortality for each stock compared to PBR is given in Table 22-4.

Stock	PBR	Mean annual takes
Morro Bay	10	4.5 (0.97)
Monterey Bay	10	9.5 (0.66)
San Francisco–Russian River	63	0.8 (NA)

Table 22-4
Potential biological removal (PBR) and mean annual mortality and serious injury of harbor porpoise for the period 1998–2002, with the coefficient of variation in parentheses.

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Marine Mammals of the Atlantic Region and the Gulf of Mexico

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Photo above: Oceanic bottlenose dolphins in the Gulf of Mexico.

INTRODUCTION

The Atlantic region, including the Gulf of Mexico, has at least 94 stocks of 39 species of marine mammals. The U.S. Fish and Wildlife Service has management authority for two stocks of the endangered West Indian manatee, while the National Marine Fisheries Service (NMFS) has responsibility for management of the remaining cetacean and pinniped stocks.

According to criteria provided by the 1994 Amendments to the Marine Mammal Protection Act (MMPA), there are 53 strategic stocks in the Atlantic region, including several stocks classified as threatened or endangered under the Endangered Species Act (ESA; Table 23-1). In the western North Atlantic, the strategic[1] stocks include endangered right, humpback, fin, sei, blue, and sperm (two stocks) whales; endangered West Indian manatee (two stocks); western North Atlantic coastal bottlenose dolphin (depleted under the MMPA); stocks where estimated mortality exceeds their potential for biological removal (PBR): harbor porpoise;

[1]Under the Marine Mammal Protection Act, a strategic stock is defined as a marine mammal stock that 1) has a level of direct human-caused mortality exceeding the potential biological removal; 2) based on the best available scientific information is declining and is likely to be listed as a threatened species under the ESA within the foreseeable future; or 3) is listed as a threatened or endangered species under the ESA, or is designated as depleted under the MMPA.

Table 23-1

Status of marine mammal stocks in the Atlantic region, including the Gulf of Mexico.

Species/stock	Minimum population estimate (N_{min})[1]	Potential biological removal level (PBR)[2]	Annual fisheries-caused mortality[3]	Total annual human-caused mortality[4]	Strategic status[5]	MMPA/ ESA status[6]	Trend[7]
Seals and sea lions							
Grey seal (W. North Atlantic)	Unknown	Unknown	304	445	No		I
Harbor seal (W. North Atlantic)[8]	91,546	2,746	882	893	No		I
Harp seal (NW North Atlantic)[8]	Unknown	Unknown	73	447,442	No		I
Hooded seal (NW North Atlantic)	Unknown	Unknown	25	5,199	No		U
Whales and porpoises							
Atlantic spotted dolphin							
N. Gulf of Mexico	22,626	226	0	0	No		U
W. North Atlantic	36,235	362	6	6	No		U
Atlantic white-sided dolphin (W. North Atlantic)	50,883	509	357	357	No		U
Blainville's beaked whale (N. Gulf of Mexico)[9]	24	0.2	0	0	Yes		U
Blue whale (W. North Atlantic)	Unknown	Unknown	0	0.2	Yes	E	U
Bottlenose dolphin							
Gulf of Mexico bay, sound, and estuary[10]	Unknown	Unknown	Unknown	Unknown	Yes		U
N. Gulf of Mexico oceanic	2,641	26	Unknown	Unknown	No		U
N. Gulf of Mexico Continental Shelf	17,084	270	0	0	No		U
N. Gulf of Mexico coastal stocks[11]							
Eastern	Unknown	Unknown	Unknown	Unknown	Yes		U
Northern	Unknown	Unknown	Unknown	Unknown	Yes		U
Western	Unknown	Unknown	Unknown	Unknown	Yes		U
W. North Atlantic offshore	70,775	566	Unknown	Unknown	No		U
W. North Atlantic coastal	Unknown	Unknown	Unknown	Unknown	Yes	D	U
Brydes whale (N. Gulf of Mexico)	5	0.1	0	0	No		U
Clymene dolphin							
N. Gulf of Mexico	4,901	49	0	0	No		U
W. North Atlantic	Unknown	Unknown	0	0	No		U
Common dolphin (W. North Atlantic)	99,975	1,000	151	151	No		U
Cuvier's beaked whale							
N. Gulf of Mexico	39	0.4	0	0	Yes		U
W. North Atlantic[12]	2,154	17	1	1	Yes		U
Dwarf sperm whale[13]							
N. Gulf of Mexico	340	3.4	0	0	No		U
W. North Atlantic	285	2	0	0	No		U
False killer whale (N. Gulf of Mexico)	501	5	0	0	No		U
Fin whale (W. North Atlantic)	1,678	3.4	0.8	2.8	Yes	E	U
Fraser's dolphin							
N. Gulf of Mexico	Unknown	Unknown	0	0	No		U
W. North Atlantic	Unknown	Unknown	0	0	No		U
Gervais' beaked whale (N. Gulf of Mexico)[9]	24	0.2	0	0	Yes		U
Harbor porpoise (Gulf of Maine / Bay of Fundy)	60,970	610	652	734	Yes		U
Humpback whale (Gulf of Maine)	549	1.1	2.8	4.2	Yes	E	U
Killer whale							
N. Gulf of Mexico	28	0.3	0	0	No		U
W. North Atlantic	Unknown	Unknown	0	0	No		U
Long-finned pilot whale (W. North Atlantic)[14]	24,866	249	163	163	No		U
Melon-headed whale							
N. Gulf of Mexico	1,293	13	0	0	No		U
W. North Atlantic	Unknown	Unknown	0	0	No		U
Mesoplodont beaked whales (W. N. Atlantic)[12]	2,154	17	1	1	Yes		U
Minke whale (Canadian East Coast)	1,899	19	2.2	2.6	No		U
North Atlantic right whale (Western)	313	0	1.4	3.2	Yes	E	U
Northern bottlenose whale (W. North Atlantic)	Unknown	Unknown	0	0	No		U
Pantropical spotted dolphin							
N. Gulf of Mexico	29,311	293	0	0	No		U

Table 23-1

Continued from previous page.

Species/stock	Minimum population estimate (N_{min})[1]	Potential biological removal level (PBR)[2]	Annual fisheries-caused mortality[3]	Total annual human-caused mortality[4]	Strategic status[5]	MMPA/ ESA status[6]	Trend[7]
Pantropical spotted dolphin (continued)							
W. North Atlantic	3,010	30	6	6	No		U
Pygmy killer whale							
N. Gulf of Mexico	203	2	0	0	No		U
W. North Atlantic	Unknown	Unknown	0	0	No		U
Pygmy sperm whale[13]							
N. Gulf of Mexico	340	3.4	0	0	No		U
W. North Atlantic	285	2	0	0	Yes		U
Risso's dolphin							
N. Gulf of Mexico	1.271	13	0	0	No		U
W. North Atlantic	12,920	129	40	40	No		U
Rough-toothed dolphin (N. Gulf of Mexico)	2,034	20	0	0	No		U
Sei whale (Nova Scotia)	128	0.3	0	0.4	Yes	E	U
Short-finned pilot whale							
N. Gulf of Mexico	542	5.4	0	0	No		U
W. North Atlantic[14]	24,866	249	163	163	No		U
Sperm whale							
N. Gulf of Mexico	1,409	2.8	0	0	Yes	E	U
North Atlantic	3,539	7.1	0	0.2	Yes	E	U
Spinner dolphin							
N. Gulf of Mexico	1,356	14	0	0	No		U
W. North Atlantic	Unknown	Unknown	0	0	No		U
Striped dolphin							
N. Gulf of Mexico	2,266	23	0	0	No		U
W. North Atlantic	68,558	686	0	0	No		U
White-beaked dolphin (W. North Atlantic)	1,023	10	0	0	No		U
Other marine mammals							
West Indian manatee[15]							
Florida	1,822	3.6	Unknown	> PBR	Yes	E	D
Antillean	86	0.172	Unknown	Unknown	Yes	E	D

[1]N_{min} is a conservative estimate of abundance used to estimate PBR; it provides reasonable assurance that the stock size is equal to or greater than the estimate.

[2]The maximum number of animals, not including natural mortalities, that may be removed from a stock while allowing that stock to reach or stay at its optimum sustainable population level (50–100% of its carrying capacity); it is calculated as the product of N_{min}, one-half of R_{max} (the maximum productivity rate), and F_r (the recovery factor).

[3]An estimate of the total number of annual mortalities and serious injuries (likely to result in death) caused by commercial fisheries.

[4]An estimate of the total number of annual mortalities and serious injuries (likely to result in death) caused by humans; it includes other sources of mortality, such as ship strikes, strandings, orphaned animals collected for public display, mortalities associated with research activities, takes by foreign countries, and mortalities associated with activities authorized through incidental take regulations.

[5]As defined in the Marine Mammal Protection Act (MMPA) Amendments of 1994, any marine mammal stock 1) for which the level of direct human-caused mortality exceeds the PBR level; 2) which is declining and likely to be listed as threatened under the Endangered Species Act (ESA); or 3) which is listed as threatened or endangered under the ESA or as depleted under the MMPA.

[6]As defined in the MMPA, any species that is listed as threatened or endangered under the ESA is also considered to be a depleted stock.

[7]Trends: I=increasing; S/I=stable/increasing; S=stable; D=decreasing; U=unknown.

[8]Annual mortality includes Canadian fishery bycatch data and NW Atlantic commercial hunt statistics.

[9]This is a combined abundance estimate for Blainville's beaked whale and Gervais' beaked whale.

[10]Represents at least 33 individually recognized stocks of bottlenose dolphin in U.S. Gulf of Mexico bays, sounds, and other estuaries. These stocks are combined in a single report in U.S. Atlantic Stock Assessment Reports (e.g. Waring et al., 2007).

[11]Represents three individually recognized stocks of bottlenose dolphin in U.S. Gulf of Mexico coastal waters. These stocks are combined in a single report in U.S. Atlantic Stock Assessment Reports.

[12]The abundance estimate may include both Cuvier's beaked whale and mesoplodont beaked whales.

[13]The abundance estimate may include both dwarf and pygmy sperm whales.

[14]The estimates may include both short-finned and long-finned pilot whales.

[15]This species is under the jurisdiction of the U.S. Fish and Wildlife Service, and is not included in the stock-status tables of the National Overview.

NEFSC Protected Species Branch

Pilot whale.

and stocks designated as strategic based on Atlantic Scientific Review Group recommendations: pygmy sperm whale in the western North Atlantic, bottlenose dolphins (33 bay, sound, and estuarine stocks and 3 coastal stocks) in the Gulf of Mexico, Blainville's beaked whale, Cuvier's beaked whale (2 stocks), Gervais' beaked whale, and mesoplodont beaked whales.

Recent assessments indicate that of the 94 Atlantic marine mammal stocks, 3 are increasing (gray, harbor, and harp seals), 2 are decreasing (Florida and Antillean stocks of West Indian manatee), and trends for the remaining 89 stocks are unknown (Table 23-1). The four marine mammal stocks highlighted in this unit are representative of the scientific and management issues for Atlantic and Gulf of Mexico regions.

BOTTLENOSE DOLPHIN: NORTHERN GULF OF MEXICO OCEANIC STOCK

Stock Definition and Geographic Range

Based on research currently being conducted on bottlenose dolphins in the Gulf of Mexico and the western North Atlantic Ocean, stock structure is uncertain but appears to be complex. The multidisciplinary research programs conducted over the last three and a half decades (e.g. Wells, 1994) are beginning to shed light on stock structures of bottlenose dolphins, though additional analyses are needed before they can be elaborated on in the Gulf of Mexico. As additional research is completed, it may be necessary to revise the stock structure of bottlenose dolphins in the Gulf of Mexico.

Thirty-eight stocks have been provisionally identified for Gulf of Mexico bottlenose dolphins (Waring et al., 2007). These stocks are comprised of both long-term resident and nonresident (e.g. migratory) stocks; the former are more susceptible to human impacts. Stock sizes are generally small, ranging from about 30 to 1,500 animals. Seasonal movements of dolphins provide opportunities for genetic exchange between individual stocks, complicating the identification of stocks, especially in coastal and inshore waters. Gulf of Mexico stock structure includes 33 bay, sound, and estuarine stocks located in inshore habitats; 3 Gulf of Mexico coastal stocks covering nearshore waters; a Continental Shelf stock; and an oceanic stock in waters from the 200 m isobath to the seaward extent of the U.S. Exclusive Economic Zone (EEZ).

Both coastal/nearshore and offshore ecotypes of bottlenose dolphins (Hersh and Duffield, 1990) occur in the Gulf of Mexico (LeDuc and Curry, 1997). The offshore and nearshore ecotypes are genetically distinct using both mitochondrial and nuclear markers (Hoelzel et al., 1998). In the northwestern Atlantic, Torres et al. (2003) found a statistically significant break in the distribution of the ecotypes at 34 km from shore. The offshore ecotype was found exclusively seaward of 34 km and in waters deeper than 34 m. Within 7.5 km of shore, all animals were of the coastal ecotype. If the distribution of ecotypes found by Torres et al. (2003) is similar in the northern Gulf of Mexico, the oceanic stock consists of the offshore ecotype.

Population Size and Current Trend

During summer 2003 and spring 2004, line-transect surveys dedicated to estimating the abundance of oceanic cetaceans were conducted in the northern Gulf of Mexico. During each year, a grid of uniformly-spaced transect lines from a random start were surveyed from the 200-m isobath to the seaward extent of the U.S. EEZ using NOAA Ship *Gordon Gunter* (Mullin, 2007). The


SEFSC/NMFS

Gulf of Mexico oceanic bottlenose dolphin.

estimate of abundance for bottlenose dolphins in oceanic waters, pooled from 2003 to 2004, was 3,708 (CV=0.42) (Mullin, 2007), which is the best available abundance estimate for this species in the northern Gulf of Mexico. However, population data are insufficient to determine trends for this stock.

Stock Status

The level of past or current, direct, human-caused mortality of bottlenose dolphins in the Gulf of Mexico is unknown; however, interactions between bottlenose dolphins and fisheries have been observed in the Gulf of Mexico. Pelagic swordfish, tunas, and billfish are the targets of the pelagic longline fishery operating in the U.S. Gulf of Mexico. There were no reports of mortality or serious injury to bottlenose dolphins in the Gulf of Mexico by this fishery during 1998–2006 (Yeung, 1999, 2001; Garrison, 2003, 2005; Garrison and Richards, 2004; Fairfield-Walsh and Garrison, 2006). However, fishery interactions have previously been reported to occur between bottlenose dolphins and the pelagic longline fishery in the Gulf of Mexico (NMFS, unpublished data[2]), with annual fishery-related mortality and serious injury to bottlenose dolphins estimated to be 2.8 per year (CV=0.74) during 1992–93 (Waring et al., 2007). This could include bottlenose dolphins from the Continental Shelf and oceanic stocks. One animal was hooked in the mouth and released by the pelagic longline fishery in 1998 (Yeung, 1999).

There have been no reports of incidental mortality or injury associated with the shrimp trawl fishery in this area. A trawl fishery for butterfish was monitored by NMFS observers for a short period in the 1980's, with no records of incidental take of marine mammals (Burn and Scott, 1988; NMFS unpublished data[2]), although an experimental set by NMFS resulted in the death of two bottlenose dolphins (Burn and Scott, 1988). There are no other data available with regard to this fishery.

The use of explosives to remove oil rigs in portions of the Continental Shelf in the western Gulf of Mexico has the potential to cause serious injury or mortality to marine mammals. These activities have been closely monitored by NMFS observers since 1987 (Gitschlag and Herczeg, 1994). There have been no reports of either serious injury or mortality to bottlenose dolphins in the oceanic Gulf of Mexico (NMFS unpublished data[2]).

The status of bottlenose dolphins, relative to the optimal sustainable population (OSP), in the U.S. Gulf of Mexico oceanic waters is unknown. Although the total fishery-related mortality and serious injury for this stock is unknown, it is assumed to be less than 10% of the calculated PBR and (from a population perspective) insignificant and approaching zero. Because bottlenose dolphins are not listed as threatened or endangered under the ESA and the annual fishery-related mortality and serious injury has not exceeded the PBR, this is not considered a strategic stock.

NORTH ATLANTIC RIGHT WHALE: NORTH ATLANTIC STOCKS

Stock Definition and Geographic Range

The right whale is a slow-swimming animal that frequents coastal and shelf habitats. It feeds in temperate or high latitudes in summer, and calves in warmer water in winter. The North Atlantic population is generally thought to consist of two relatively discrete stocks in the eastern and western portions of this ocean basin, although the eastern population is functionally extinct.

Historically, right whales were found in coastal waters throughout the North Atlantic in a range that extended from Florida (and perhaps further south) to Greenland in the west, and from western Africa to Norway in the east. However, intensive exploitation has greatly reduced the range of this animal. In the western North Atlantic, the remaining population is largely confined to U.S. and Canadian waters, spending summers feeding in the Gulf of Maine and on the Scotian Shelf. In winter, pregnant females migrate to give birth in the coastal waters of Georgia and Florida (Kraus et al., 1986; Winn et al., 1986); although other whales are also found there at this time, the whereabouts of a substantial portion of the population in winter remains unknown. The Bay of Fundy constitutes a major summer feeding area for the


SEFSC/NMFS

Gulf of Mexico oceanic bottlenose dolphin.

[2]National Marine Fisheries Service, SEFSC, Mississippi Laboratory, 3209 Frederic St., Pascagoula, MS 39567.

North Atlantic right whales.

population, although recent genetic studies suggest the existence of a second, unidentified feeding area (Schaeff et al., 1993).

The western North Atlantic stock has been the subject of a long-term study since the 1970's, and much of its biology and behavior is reasonably well understood (see Kraus and Rolland, 2007). Most of the population has been biopsy sampled, and genetic analyses are ongoing (Schaeff et al., 1993, 1997; Brown et al., 1994; Rosenbaum et al., 1997, 2000; Frasier et al., 2007).

Population Size and Current Trend

No consistent, statistically based population estimates are available for the western North Atlantic population. However, considerable effort has been spent recording re-sighting histories of individual whales using photo-identification techniques[3] so that a reasonable and consistently calculable population index, minimum number alive (MNA), is available. In 1992, the western North Atlantic MNA was estimated to be 295 individuals (Knowlton et al., 1994), and an updated census yielded an MNA estimate of 291 animals in 1998 (Kraus et al., 2001). A review of the photo-ID recapture database on 30 June 2007 indicated that 325 individually recognized whales in the catalog were known to be alive during 2003. This index, while known to be biased low, can be used to track population trends more precisely than is possible for other large whale stocks. An International Whaling Commission (IWC) workshop on status and trends of western North Atlantic right whales (IWC, 2001) concluded that the population was in decline during the 1990's. However, over the 14-year period of 1990–2003, the MNA increased by a mean growth rate of 1.8%, despite losses exceeding gains during some years in the 1990's.

In the eastern North Atlantic stock, only a handful of individuals are assumed to exist. Rare sightings have been made of single individuals in European waters (Brown, 1986), but it is unclear whether these represent a tiny residual population or individuals who have wandered in from the western North Atlantic. However, in recent years, re-sightings of two photographically identified individuals have been made off Iceland and arctic Norway and in the old Cape Farewell whaling ground east of Greenland (Jacobsen et al., 2004; Frasier et al., 2007).

Stock Status

The North Atlantic right whale is critically endangered throughout its range (Brownell et al., 1986; Clapham et al., 1999). Given the various threats described below, this species is among the most threatened of all large whales and further conservation action is urgently required to avoid extinction.

Right whales suffer significant anthropogenic mortality. The principal anthropogenic factors preventing recovery and growth of the population are ship strikes and entanglements in fishing gear. From 2001 to 2005, the average reported mortality and serious injury to right whales was 3.2 animals per year (1.4 from fishery interactions and 1.8 from ship strikes). During this period, 7 of 16 records of mortality or serious injury (including records from both U.S. and Canadian waters) involved entanglements or fishery interactions. Sources of ship strikes are generally unknown, though many of the right whale's major habitats in the western

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[3]Individual right whales can be identified from photographs using the pattern of callosities on the head and any prominent scarring (Kraus et al., 1986).

North Atlantic are adjacent to, or even straddle, major shipping lanes. Given the population's dependence upon nearshore habitat during much of its life cycle, intensive coastal development poses additional threats to recovery.

Awareness and mitigation programs for reducing right whale anthropogenic injury and mortality have been established in both the southeastern and northeastern United States. A Recovery Plan was implemented in 1991, and a revised plan was published in 2004. Additionally, a Mandatory Ship Reporting System was implemented in 1999 covering right whale critical habitat areas in the southeastern United States and in the Great South Channel/Cape Cod Bay/Massachusetts Bay areas. This system requires vessels over 300 tons to report information on their identity, location, course, and speed. In return, the vessels receive information on right whale occurrence and on measures to avoid collisions with the whales. Research is ongoing to test compliance with suggested speed restrictions in areas where right whales have been reported.

Studies showing relatively low genetic diversity in the western North Atlantic population (Schaeff et al., 1993, 1997) suggest that inbreeding may be inhibiting recovery. This topic has been investigated using DNA extracted from historic baleen and bone samples (Rosenbaum et al., 1997, 2000). Findings suggest that the eastern and western North Atlantic populations were not genetically distinct (Rosenbaum et al., 2000), but the virtual extirpation of the eastern stock and its lack of recovery in the last hundred years strongly suggests population subdivision over a protracted (but not evolutionary) time scale. Genetic studies concluded that the principal loss of genetic diversity occurred prior to the 18th century (Waldick et al., 2002). However, revised conclusions of species composition in North American Basque whaling archaeological sites (Rastogi et al., 2004) contradict the previously held belief that Basque whaling during the 16th and 17th centuries was principally responsible for the loss of genetic diversity.

This is a strategic stock because the average annual fishery-related mortality and serious injury exceeds PBR and because the North Atlantic right whale is an endangered species (Waring et al., 2007). PBR is usually calculated using the minimum population size, maximum net productivity rate, and a recovery factor. However, given the decline of estimated survival rates for this stock (Caswell et al., 1999; IWC, 2001), the PBR has been set to zero and no mortality or serious injury can be considered insignificant.

NEFSC Protected Species Branch

Pilot whales.

LONG-FINNED PILOT WHALE: WESTERN NORTH ATLANTIC STOCK

Stock Definition and Geographic Range

There are two species of pilot whales in the Western Atlantic—the long-finned and the short-finned pilot whale. The distribution of long-finned pilot whales, a northern species, overlaps with that of the short-finned pilot whales, a predominantly southern species, between 35°30′ N and 38°00′ N (Leatherwood et al., 1976). Most of the pilot whale takes in fishery bycatch are not identified to species, and bycatch does occur in the overlap area. In this summary, therefore, long-finned pilot whales and unidentified pilot whales are considered together.

The long-finned pilot whale is distributed in the northern hemisphere from North Carolina east to North Africa and the Mediterranean and north to Iceland, Greenland, and the Barents Sea (Sergeant, 1962; Leatherwood et al., 1976; Abend,

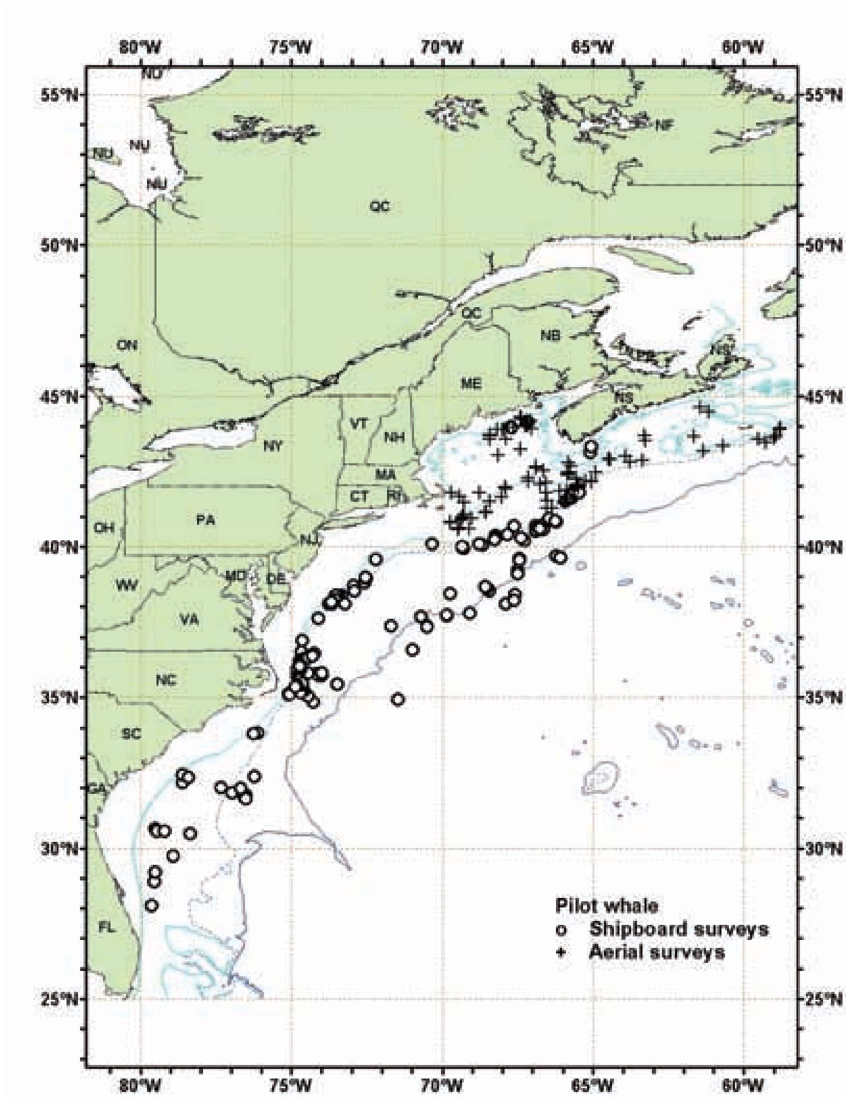

Figure 23-1

Distribution of pilot whale sightings from Northeast Fisheries Science Center and Southeast Fisheries Science Center shipboard and aerial surveys during the summer in 1998–2006. Isobaths are at 100 m and 1,000 m.

1993; Buckland et al., 1993; Abend and Smith, 1999). The stock structure of the North Atlantic population is uncertain (ICES, 1993; Fullard et al., 2000). Morphometric (Bloch and Lastein, 1993) and genetic (Siemann, 1994; Fullard et al., 2000) studies have provided little support for stock structure across the Atlantic. However, Fullard et al. (2000) have proposed a stock structure that is correlated to sea surface temperature: a cold-water population west of the Labrador/North Atlantic current, and a warm-water population that extends across the Atlantic in the Gulf Stream.

In the western North Atlantic, pilot whales are found in winter and early spring principally along the Continental Shelf edge of the northeastern United States (CETAP, 1982; Payne and Heinemann, 1993; Abend and Smith, 1999). In the late spring, they move onto Georges Bank, the Gulf of Maine, and more northern waters, and remain in these areas through late autumn. In general, pilot whales occupy areas of high relief or submerged banks, but are also associated with the Gulf Stream north wall and thermal fronts along the Continental Shelf edge (Waring et al., 1992; NMFS, Unpublished data[4]).

Population Size and Current Trend

The total number of long-finned pilot whales in the Atlantic off the eastern United States and Canadian coasts is unknown. The initial population size was estimated to be between 50,000 and 60,000 individuals in this region (Mitchell, 1974; Mercer, 1975), but no current reliable estimates exist due to the difficulty of distinguishing long- and short-finned pilot whales at sea. The current best estimate for pilot whales (both species combined) in the western North Atlantic is 31,139 (CV = 0.27). This estimate is the result of two line-transect sighting surveys conducted in 2004 (Figure 23-1): one in waters north of Maryland (15,728 animals, CV = 0.34), and one south of Maryland (15,411 animals, CV = 0.43; Mullin and Fulling, 2003). The minimum population size of pilot whales is estimated to be 24,866. Due to changes in survey methodology, earlier abundance estimates should not be used to make comparisons to more current estimates, and no population trends are currently available for this species.

Stock Status

The status of long-finned pilot whales relative to the OSP in the U.S. Atlantic EEZ is unknown, but the stock's abundance may have been affected by reduction in foreign fishing, curtailment of drive fisheries[5] for pilot whales in the western North Atlantic, and increased abundance of pilot whale prey items (Atlantic herring, Atlantic mackerel, and squid). The current and maximum net productivity rates for long-finned pilot whales are also

[4]NMFS, Northeast Fisheries Science Center, 166 Water St., Woods Hole, MA 02543.

[5]Targeted fisheries on whales where groups of whales are herded by motorized boats toward shore for slaughter.

unknown. To calculate PBR, the default value for cetaceans (0.04, based on reproductive life history constraints) was used for the maximum productivity rate. The PBR for western North Atlantic pilot whales is 249 animals per year.

As with the abundance estimates, the total fishery-related mortality and serious injury cannot be estimated separately for the two species of pilot whales in the U.S. Atlantic. The estimated average fishery-related mortality or serious injury of pilot whales during the period 2001–05 was 163 animals per year (CV = 0.09; Table 23-2). Pilot whales have frequently been observed to feed on hooked fish (NMFS, unpublished data[4]), and pelagic longline fisheries accounted for more than half of the estimated annual mortality and serious injury of pilot whales in the western North Atlantic (87 whales per year, including one seriously injured pilot whale in a 2005 experimental fishery; CV = 0.16). Bycatch of pilot whales also occurs in Mid-Atlantic bottom trawls (38 whales per year, CV = 0.15) and northeast bottom trawls (19 whales per year, CV = 0.12), Mid-Atlantic midwater trawls (7 whales per year, CV = 0.34), northeast midwater trawls (1 whale per year, CV = 0.35), and herring midwater trawls (11 whales in 2001). Although no data are available on bycatch of pilot whales in the bluefin tuna purse seine fishery (which has not been observed since 1996), previous interactions have been observed and may continue to be an issue. An unknown number of western North Atlantic pilot whales have also been taken in fisheries operating in the Canadian EEZ (Read, 1994; Hooker et al., 1997).

Another potential human-caused source of mortality is pollution. Bioaccumulation of polychlorinated biphenyls (PCB's) and chlorinated pesticides (DDT, DDE, dieldrin, and others) in whale blubber has been recorded by a number of researchers (Taruski et al., 1975; Muir et al., 1988; Dam and Bloch, 2000; Weisbrod et al., 2000). Elevated levels of toxic metals (mercury, lead, and cadmium) and selenium have also been measured in pilot whales (Nielsen et al., 2000). The population effects of observed tissue contaminant levels remain unknown.

Additionally, strandings (including mass strandings) of pilot whales are another source of mortality, although the role of human activity in such events is unknown (Table 23-3). Two hundred and twenty-one pilot whales were reported stranded between Maine and Florida during 2001–05, including two mass strandings in Massachusetts (57 whales in 2002 and 18 whales in 2005), one in Florida in 2003 (28 whales), and one in North Carolina in 2005 (33 whales; NMFS, unpublished data[4]). Although some of these animals were returned to the water, some studies have indicated that animals returned to the water frequently swim away and strand someplace else (Fehring and Wells, 1976; Irvine et al., 1979; Odell et al., 1980).

Wayne Hoggard, SEFSC

Biopsy sample being collected by NMFS scientists aboard the NOAA Ship *Gordon Gunter*.

The species is not listed as threatened or endangered under the ESA, nor is it classified as depleted under the MMPA. This stock is not a strategic stock because the estimated average human-related mortality is below the PBR for pilot whales. The total U.S. fishery-related mortality and serious injury is not less than 10% of the PBR and therefore cannot be considered to be approaching zero mortality and serious injury rate.

HARBOR SEAL: WESTERN NORTH ATLANTIC STOCK

Stock Definition and Geographic Range

Harbor seals are the most abundant seal species found in U.S. Atlantic waters and the most commonly seen marine mammal in New England coastal waters. In the western North Atlantic, har-

Table 23-2

Summary of the incidental mortality of pilot whales (*Globicephala* spp.) in commercial fisheries.

Fishery	Data type[1]	Year	No. Vessels[2]	Observer coverage[3]	Obs. serious injury[4]	Obs. mortality[4]	Est. serious injury	Est. mortality	Est. combined mortality[5]	Est. CV[6]	Mean annual mortality[7]
Mid-Atlantic bottom trawl	Observer, dealer	2001	Unk.	0.01	0	0	0	39	39	0.31	38 (0.15)
		2002		0.01	0	0	0	38	38	0.36	
		2003		0.01	0	0	0	31	31	0.31	
		2004		0.03	0	0	0	35	35	0.33	
		2005		0.03	0	4	0	31	31	0.31	
Northeast bottom trawl	Observer, dealer	2001	Unk.	0.01	0	0	0	21	21	0.27	19 (0.12)
		2002		0.03	0	0	0	22	22	0.26	
		2003		0.04	0	0	0	20	20	0.26	
		2004		0.05	0	2	0	15	15	0.29	
		2005		0.12	0	4	0	15	15	0.30	
Mid-Atlantic mid-water trawl	Observer, dealer, VTR	2001	23	0	0	0	0	Unk.	Unk.	Unk.	7 (0.34)
		2002	20	0.003	0	0	0	Unk.	Unk.	Unk.	
		2003	23	0.018	0	0	0	3.9	3.9	0.46	
		2004	25	0.064	0	0	0	8.1	8.1	0.38	
		2005	31	0.084	0	0	0	7.5	7.5	0.76	
Northeast mid-water trawl	Observer, dealer, VTR	2001	24	0.001	0	0	0	Unk.	Unk.	Unk.	1 (0.35)
		2002	27	0	0	0	0	Unk.	Unk.	Unk.	
		2003	28	0.031	0	0	0	1.9	1.9	0.56	
		2004	22	0.126	0	1	0	1.4	1.4	0.58	
		2005	25	0.199	0	0	0	1.1	1.1	0.68	
Gulf of Maine / Georges Bank herring mid-water trawl[8]	Observer	2001	10	1	0	11	0	11	11	NA	11 (NA)
Pelagic longline (excluding NED-E)[9]	Observer, logbook	2001	98	0.04	4	1	50	20	70	0.5	86 (0.16)
		2002	87	0.05	4	0	52	2	54	0.46	
		2003	63	0.09	2	0	21	0	21	0.77	
		2004	60	0.09	6	0	74	0	74	0.42	
		2005	60	0.06	9	0	212	0	212	0.21	
Pelagic longline (NED-E area only)[9]	Observer	2001	9	1	0	0	0	0	0	0	0
		2002	14	1	0	0	0	0	0	0	
		2003	11	1	0	0	0	0	0	0	
Pelagic longline experimental fishery[10]	Observer	2005	6	1	1	0	1	0	1	NA	1 (NA)
Total											163 (0.9)

[1]Observer data are used to measure bycatch rates, and are collected within the Northeast Fisheries Science Center Fisheries Observer Program. Logbook data are mandatory, collected by the Southeast Fisheries Science Center, and used to measure total effort for the longline fishery. Dealer data are mandatory, collected by the Northeast Fisheries Science Center, and used to estimate effort.

[2]The number of vessels in the fishery. For the squid trawl fisheries, numbers are based on 2002 permit holders; many trawl vessels participate in multiple fisheries, so numbers are not additive across fisheries. For the herring mid-water trawl fishery, three foreign and seven American vessels participate. For the pelagic longline fishery, numbers are based on vessels reporting effort to the pelagic longline logbook.

[3]Coverage for the trawl fisheries is measured as the number of trips; coverage for the longline fishery is measured as the number of sets.

[4]Recorded by on-board observers.

[5]Includes estimates of mortality and serious injury.

[6]Coefficient of variation for the combined mortality estimates.

[7]The mean of the estimated combined mortality for the years shown, with the coefficient of variation in parentheses.

[8]Includes joint venture (JV) and total allowable level of foreign fishing (TALFF) fishing. During JV operations, nets that are transferred from the domestic vessel to a foreign vessel for processing are observed on board the foreign vessel; nets that are fished by a domestic vessel but not transferred to a foreign vessel are not observed. During TALFF operations, all nets fished by the foreign vessel are observed.

[9]An experimental program to test effects of gear characteristics, environmental factors, and fishing practices on sea turtle bycatch rates in the Northeast Distant (NED-E) water component of the fishery conducted from 1 June 2001 to 31 December 2003. Observer coverage was 100% during this experimental fishery. Summaries are provided for the pelagic longline excluding the NED-E in one row and for only the NED-E in a second row. No mortalities nor serious injuries were observed for pilot whales in the NED-E, though 1 pilot whale was caught alive and released without injury (Garrison, 2003; Garrison and Richards, 2004).

[10]A cooperative research program to test effects of gear characteristics and fishing practices.

NEFSC Protected Species Branch

Pilot whale and calf.

State	2001	2002	2003	2004	2005	State total
Maine	6	2	1	4	2	15
New Hampshire	0	0	0	0	0	0
Massachusetts	3	65	5	1	22	96
Rhode Island	1	1	1	1	0	4
Connecticut	0	0	0	0	0	0
New York	1	0	0	3	1	5
New Jersey	0	0	6	0	2	8
Delaware	0	0	0	0	0	0
Maryland	0	0	0	0	4	4
Virginia	0	0	3	1	4	8
North Carolina	2	0	3	3	38	46
South Carolina[1]	1	0	1	0	0	2
Georgia	0	0	0	0	0	0
Florida	0	0	29	4	0	33
Annual total	14	68	49	17	73	221

[1]Only moderate confidence on species identification for 2003.

Table 23-3

Pilot whale strandings, by state, along the U.S. Atlantic Coast during the years 2001–05. No distinction has been made between short-finned and long-finned pilot whales.

bor seals are common from Labrador to southern New England and New Jersey, and occasionally to the Carolinas (Boulva and McLaren, 1979; Katona et al., 1993; Gilbert and Guldager, 1998). Although the stock structure is unknown, the northwest Atlantic subspecies, *Phoca vitulina concolor*, is believed to represent a single breeding population. Breeding and pupping normally occurs in waters north of the New Hampshire/Maine border, although breeding occurred as far south as Cape Cod in the early part of the twentieth century (Temte et al., 1991; Katona et al., 1993).

Harbor seals are year-round inhabitants of the coastal waters of eastern Canada and Maine (Katona et al., 1993), and are found seasonally along the southern New England and New York coasts from September through late May (Schneider and Payne, 1983; Barlas, 1999). A general southward movement from the Bay of Fundy to southern New England waters occurs in autumn and early winter (Rosenfeld et al., 1988; Whitman and Payne, 1990; Jacobs and Terhune, 2000). A northward movement from southern New England to Maine and eastern Canada occurs prior to the pupping season, which takes place from mid May through June (Richardson, 1976; Kenney, 1994; deHart, 2002). The overall geographic range throughout U.S. Atlantic coast waters has not changed greatly during the last century.

Population Size and Current Trend

Harbor seals, like gray seals, were bounty-hunted in New England waters until the late 1960's. This hunt may have caused the demise of the harbor seal stock in U.S. waters (Katona et al., 1993). However, the number of seals along the New England coast has increased nearly five-fold since the passage of the MMPA in 1972. A 2001 coast-wide aerial summer survey produced a count of 99,340 seals (CV = 0.097; Gilbert et al., 2005). Although this number has been corrected for animals in the water or outside of the survey area, the count is considered to be a minimum population estimate. This number is substantially higher than the last survey count in 1997; the number of pups in 2001 was also much higher than the 1997 count (Gilbert and Guldager, 1998; Gilbert et al., 2005). Increased abundance of seals in the Northeast Region has also been documented during aerial and boat surveys of overwintering haulout sites (Payne and Selzer, 1989; Rough, 1995; Barlas, 1999).

The average increase in uncorrected counts over the 1981–2001 survey period (i.e. 1981, 1982, 1986, 1993, 1997, and 2001 surveys) has been 6.6% (Gilbert et al., 2005). Possible factors contributing to harbor seal population increase include MMPA protection, fishery management regulations designed to rebuild groundfish stocks

Aerial view of harbor seals hauled out on a beach.

(e.g. closed areas and fishing effort reduction), and habitat protection of important haulout sites (e.g. National Park Service and National Wildlife Refuge lands).

Stock Status

Researchers and fishery observers have documented incidental mortality of harbor seals in several fisheries in recent years, particularly within the Gulf of Maine sink gillnet fishery (Waring et al., 2007). Bycatch in several Atlantic Canada and Greenland fisheries was summarized in Read (1994). Estimated average annual fishery-related mortality and serious injury to this stock in U.S. waters during 2001–05 was 882 harbor seals (CV = 0.16).

Shark predation has become an important source of pup mortality at Sable Island, Nova Scotia. Lucas and Stobo (2000) suggest that shark-inflicted mortality in pups, as a proportion of total production, was less than 10% in 1980–93, approximately 25% in 1994–95, and increased to 45% in 1996. Also, shark predation on adults was selective towards mature females. They suggest that predation mortality is likely impacting population growth, and may be contributing to the observed population decline in that area.

Other sources of mortality include human interactions (boat strikes, fishing gear, and deliberate shooting), storms, abandonment of pups by the mother, and disease (Katona et al., 1993; NMFS, unpublished data[4]). Canada's Department of Fisheries and Oceans reports small numbers of harbor seals taken annually in a subsistence hunt (numbers in the 2002–05 period range from 16 in 2004 to 334 in 2002 [DFO, 2006]). Annually, small numbers of harbor seals regularly strand during the winter period in southern New England and Mid-Atlantic regions (NMFS, unpublished data[4]). Reported strandings from 2001 through 2005 were 177 in 2001, 262 in 2002, 377 in 2003, 560 in 2004, and 341 in 2005. Sixty-eight (4.0%) of the seals stranded during this 5-year period showed signs of human interactions. Further, many live stranded animals are euthanized due to poor condition of the animals, although some sick and injured seals are transported to rehabilitation facilities. Stranding data probably underestimate the extent of fishery-related mortality and serious injury because not all animals that die or are seriously injured are washed ashore, and not all animals washed ashore show obvious signs of entanglement or other fishery interactions.

The western North Atlantic harbor seal stock is increasing and is not listed as threatened or endangered under the ESA. The stock is not a strategic stock since the estimated annual level of fishery-related mortality and serious injury in U.S. waters (882 seals) does not exceed PBR (2,746 animals). However, because human-induced mortality and serious injury is greater than 10% of PBR, these losses cannot be considered to be approaching a zero mortality and serious injury rate.

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Sea Turtles

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Unit 24

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Photo above:
Green turtle feeding on sea grass.

INTRODUCTION

Sea turtles are highly migratory and widely distributed throughout the world's oceans. Of the seven species found worldwide, six are found in U.S. waters and include the loggerhead, Kemp's ridley, olive ridley, green, leatherback, and hawksbill turtles. In the Pacific Ocean, all of these species except the Kemp's ridley inhabit either the U.S. coastal and Exclusive Economic Zone (EEZ) or the high seas. Nesting populations of the green and hawksbill occur in the Hawaiian Archipelago, American Samoa, and other U.S. territories (e.g. Guam, Northern Marianas, Palau, Micronesia, Jarvis Island, and Palmyra Atoll). With rare exception, the loggerhead, leatherback, and olive ridley do not nest in U.S. Pacific states or territories. The loggerhead, Kemp's ridley, green, hawksbill, and leatherback are commonly found in U.S. Atlantic waters, while the olive ridley almost exclusively inhabits South Atlantic Ocean waters. Significant nesting assemblages of the loggerhead, leatherback, green, and hawksbill are found in the southeastern United States and the U.S. Caribbean. The current status of U.S. sea turtles, based on research conducted at major nesting beaches, is summarized in Table 24-1.

All six species of sea turtles found in the United States are currently listed either as endangered or threatened under the Endangered Species Act (ESA). The Kemp's ridley, hawksbill, and leatherback are listed as endangered throughout their ranges. The loggerhead is listed as threatened. The green turtle is also listed as threatened, except for breeding populations found in Florida and on the Pacific coast of Mexico, which are listed as endangered. The olive ridley is listed as threatened, except for nesting populations on the Pacific coast of Mexico, which are listed as endangered. The authority to protect and conserve sea turtles in the marine environment is vested in the National Marine Fisheries Service (NMFS), while the U.S.

Table 24-1
Status of principal sea turtle nesting populations in the Atlantic and Pacific regions.

Species	ESA status[1]	Location of principal nesting populations[2]
Atlantic region		
Loggerhead	Threatened	North Carolina, South Carolina, Georgia, Florida
Green[3]	Endangered, threatened	Florida, all other Atlantic populations
Kemp's ridley	Endangered	Mexico
Leatherback	Endangered	Florida, U.S. Virgin Islands, Puerto Rico, Suriname, French Guiana
Hawksbill	Endangered	U.S. Virgin Islands, Puerto Rico
Pacific region		
Loggerhead	Threatened	Japan, Australia
Green[3]	Threatened, endangered	Hawaii, Mexico
Olive ridley[3]	Threatened, endangered	Mexico, Costa Rica
Leatherback	Endangered	Mexico, Central America (including Costa Rica), Irian Jaya, Malaysia
Hawksbill	Endangered	Hawaii

[1]Status under the Endangered Species Act (ESA).
[2]Sea turtles in the U.S. Atlantic and Pacific regions originate from nesting populations in the U.S. and foreign countries.
[3]The ESA status for this species varies for different breeding populations.

Fish and Wildlife Service (USFWS) has jurisdiction for protection of sea turtles, their eggs, and hatchlings on land (nesting beaches).

SPECIES AND STATUS

Sea turtles have complex life histories, but historical data on population sizes are limited or nonexistent. This paucity of long-term abundance and trend data makes it difficult to fully understand current population dynamics. Standardized surveys of selected nesting beaches were implemented in the United States for green turtles (in Hawaii) in 1973 and for other sea turtles in the late 1980's. These surveys, which count the number of nests laid per year, provide an index of the annual adult female population and an indication of whether their relative abundance is declining, stable, or increasing.

Atlantic Region

Loggerhead


Gray's Reef NMS

Loggerhead turtle moving up the beach at night to make a nest and lay eggs.

Genetic research has enhanced our knowledge of sea turtle biology by identifying unique breeding populations. Only two large loggerhead nesting assemblages (e.g. > 10,000 nesting females per year) exist in the world, and are restricted to the southeastern United States and Masirah Island in the Middle Eastern country of Oman. The U.S. and Oman nesting aggregations are similar in size and represent about 35 and 40% of the nests, respectively, for this species. Most nesting in the United States occurs along Florida's east coast, where the mean annual number of nests deposited in south Florida from 1998–2002 was 75,459 nests per year. This number of nests equates to approximately 18,405 females nesting per year (Florida Fish and Wildlife Conservation Commission, unpublished data[1]). The most current analyses show evidence of a declining trend from 1982–2007 in the Florida aggregation. After reaching a high of almost 86,000 nests in Florida during 1998, the number dropped to 45,084 nests in 2007 (Florida Fish and Wildlife Conservation Commission, unpublished data[1]). Four U.S. nesting subpopulations occur: central and southwest Florida; north of Cape Canaveral, Florida (about 7,500 nests in 1998; stable or declining); the Florida Panhandle (about 1,000 nests in 1998); and the islands of the Dry Tortugas near Key West, Florida (about 200 nests per year). Adult and immature turtles from these four subpopulations, as well as a fifth subpopulation that nests along the Yucatán coast of Mexico, mix with each other on

[1]Florida Fish and Wildlife Conservation Commission, 620 S. Meridian St., Tallahassee, FL 32399.

the foraging grounds. Important developmental habitat for juvenile loggerheads consists of inshore bays, sounds, and lagoons along U.S. Gulf and Atlantic coasts from Cape Cod, Massachusetts, to southern Texas.

Kemp's Ridley

The Kemp's ridley inhabits coastal waters throughout the U.S. Atlantic coast and the Gulf of Mexico. The Kemp's ridley is unusual in that it nests almost exclusively along one stretch of beach in the State of Tamaulipas on the Caribbean coast of Mexico. This single population underwent a dramatic decline after 1947, when on a single day an estimated 40,000 Kemp's ridley females were filmed coming ashore to nest. This mass nesting emergence is a phenomenon commonly known as an arribada. The population plummeted to fewer than 1,000 females nesting annually through the early 1980's. Today, under strict protection, the population appears to be in the earliest stages of recovery (Figure 24-1). Nesting, although still rare, has also increased in the United States (primarily Texas), rising from 6 in 1996 to 128 in 2007 (U.S. National Park Service, unpublished data[2]). This increase can be attributed to two primary factors—full protection of nesting females and their nests in Mexico, and the requirement to use turtle excluder devices (TED's) in shrimp trawls both in the United States and Mexico. Significant progress has also been made through collaboration with Mexico and the USFWS to establish and maintain more comprehensive nesting beach surveys for Kemp's ridleys.

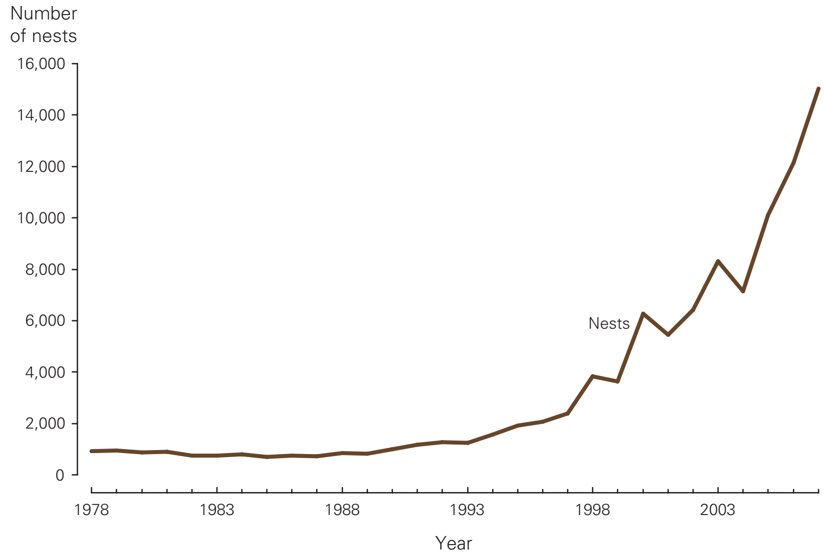

Figure 24-1
Number of Kemp's ridley nests observed annually at nesting sites of Tamaulipas and Veracruz, Mexico, 1978–2007 (Gladys Porter Zoo, 2001; R. Marquez M., unpublished data, SEMARNAP/INP, CRIP-Manzanillo, Program Nacional de Tortugas Marinas, P. Ventanas S/N, A.P. 591, Manzanillo, Colima, Mexico 28200).

Green

Green turtles are found in southeastern U.S. waters around the U.S. Virgin Islands and Puerto Rico, and off the continental United States from Texas to Massachusetts. Important feeding grounds in Florida include the Indian River Lagoon, the southeast Florida coastline, the Florida Keys, Florida Bay, Homosassa, Crystal River, Cedar Key, and St. Joseph Bay. North of Florida, the Pamlico–Albemarle Sound estuarine complex in North Carolina provides important foraging habitat, and green turtles are not uncommon in Connecticut and New York in the Long Island Sound during warmer months. In Texas, Laguna Madre once supported a significant green turtle population that was heavily exploited in the late 19th and early 20th centuries. The primary nesting beaches in the United States are along the east and southwest coasts of Florida; limited nesting also occurs in the U.S. Virgin Islands and Puerto Rico. The nesting population in the southeastern United States appears to be increasing, but is not genetically distinct from other nesting populations. Based on genetic information, subpopulations throughout the North and South Atlantic mix while on the foraging grounds. The number of nests deposited annually in the southeast United States fluctuates greatly, alternating between years of high and low levels of nesting, with an overall dramatic increase in the number of nests in Florida. From 1990–2007, Florida green turtle nests have ranged from 435 to 12,752 (Florida Fish and Wildlife Conservation Commission, unpublished data[1]).

Leatherback

Leatherbacks are capable of tolerating a wide range of water temperatures and are distributed along the entire U.S. East Coast from as far north as the Gulf of Maine, south to Puerto Rico and the

[2]U.S. National Park Service, 1849 C Street NW, Washington, DC 20240.

Leatherback turtle surfacing to breathe.

U.S. Virgin Islands, and into the Gulf of Mexico. They occupy pelagic waters where they feed primarily on jellyfish and salps, but also commonly forage in coastal waters. In the western North Atlantic, waters shared with Canada (including the Gulf of Maine, Scotian Shelf, and Newfoundland) act as important seasonal foraging habitats for leatherbacks. To protect turtles while in these vital habitats, both countries collaborate on the development of an interactive and cooperative research program to address turtle conservation issues.

In the United States, the largest nesting assemblages of leatherbacks are found in the U.S. Virgin Islands, Puerto Rico, and Florida. Nesting in Puerto Rico between 1978–2005 has ranged from 469 to 882 nests, and the population has been growing since 1978 (TEWG, 2007). At the primary nesting beach on St. Croix, nesting has fluctuated from a few hundred nests to a high of 1,008 in 2001 (TEWG, 2007). The Florida nesting population is of growing importance, with between 800 and 900 total nests per year in the 2000's, following nesting totals of fewer than 100 nests per year in the 1980's (Florida Fish and Wildlife Conservation Commission, unpublished data[1]). However, U.S. nesting populations are very small in number compared to major Atlantic nesting grounds.

Hawksbill

The hawksbill is most commonly found in the Caribbean Sea, but also regularly occurs in southern Florida and southern Texas and has occasionally been recorded as far north as Massachusetts. Within the continental United States, a small amount of nesting occurs in Southeast Florida and the Florida Keys. The largest U.S. nesting assemblages of hawksbills are found at Mona Island in Puerto Rico, Buck Island in the U.S. Virgin Islands, and to a lesser extent at other sites in these areas. Approximately 500–1,000 nests are laid on Mona Island each year. The most significant nesting in the Caribbean Sea occurs in Mexico, where about 2,800 females nest in Campeche, Yucatán, and Quintana Roo each year. Hawksbill populations in the Atlantic were greatly depleted during the 20th century as a result of overharvest for trade in products made from their shells.

Pacific Region

Olive Ridley

Olive ridleys are well known for their synchronized mass nesting emergences, a phenomenon commonly known as arribadas. Although non-nesting individuals are occasionally seen in the waters of the southwestern United States, olive ridleys are rare in the Pacific Islands and do not have any nesting sites located on U.S. Pacific coasts. Significant nesting assemblages were once found along the Pacific coast of Mexico, but in recent years the Mexican arribadas have been largely restricted to one site, La Escobilla in the state of Oaxaca. In Costa Rica, a major nesting aggregation is found at Playa Ostional; smaller aggregations also occur in Nicaragua, Guatemala, and Panama. This species continues to be threatened by incidental capture in trawl and longline fisheries.

Loggerhead

Loggerheads originating from Japanese nesting beaches spend much of their early life stages in the central Pacific Ocean. A portion of this subpopulation regularly forages off the Pacific coast of Baja California, Mexico, and occasionally as far north as the waters off southern California. Generally, the loggerheads found foraging off these coasts are immature. A few records exist of loggerheads as far north as Alaska and as far south as Chile; however, these extremes are likely not part of the normal range of the species. Loggerheads have been recorded in waters around the Northern Mariana Islands, American Samoa, and Hawaii, but are uncommon there. Loggerheads occupy both oceanic waters and coastal benthic habitats around continents during their life cycle. In the open ocean they are often associated with convergence zones, oceanic fronts, and boundary currents. Nesting occurs primarily in Japan and Australia. Currently, less than 1,000 female loggerheads nest annually in all of Japan and less than 500 nest annually in eastern Australia, where long-term data on nesting and foraging populations indicate a severe decline. Preliminary genetic analysis indicates that loggerheads inhabiting the eastern and North Pacific originate from the Japanese nesting stock, while animals foraging off of the coast of South America originate from nesting beaches in Australia (Dutton, unpublished data[3]).

Leatherback

The leatherback is a pelagic species that likely occurs near all U.S. Pacific islands and is widely distributed on the high seas. The leatherback is often sighted in coastal waters of the western United States, which provide critical foraging habitat. Principal leatherback nesting populations in the western Pacific occur in the Solomon Islands, Vanuatu, Papua (Indonesia), Papua New Guinea, and historically in peninsular Malaysia. In the eastern Pacific, principal leatherback nesting beaches occur in Mexico and Costa Rica. Leatherbacks are seriously declining at all major nesting beaches throughout the Pacific. The decline is dramatic along the Pacific coasts of Mexico and Costa Rica and coastal Malaysia. The Malaysian nesting population, once one of the largest in the Pacific (e.g. several thousand nesters annually), is essentially extinct, with only two or three females currently nesting each year. From 1984 to 1995, nesting at Mexiquillo, a major nesting beach on the Pacific coast of Mexico, declined at an annual rate of 22%. Similar declines have been reported for major nesting assemblages of leatherbacks in Costa Rica, with counts of nesting females declining from 1,367 in 1988–89 to 49 during the 2004–05 season. The collapse of these nesting populations has likely been caused by a tremendous overharvest of eggs, the direct harvest of adults, and incidental mortality from fishing. Satellite telemetry tracks from six post-nesting leatherbacks tagged at Jamursba-Medi, Papua, Indonesia, indicate that a portion of the western Pacific population utilizes the temperate waters off of North America (Benson et al., 2007). This information is consistent with genetic studies that are currently underway (Dutton et al., 2006).

Hawksbill

The hawksbill is typically more associated with islands than other sea turtle species and is often found foraging on coral reefs. Although not all U.S. flag islands in the western Central Pacific have been surveyed, the hawksbill likely occurs at most of them. The USFWS estimates that probably no more than 35 hawksbills nest in Hawaii each year, primarily along the east coast of the island of Hawaii. The number of hawksbills present in American Samoa and Guam is unknown, but nesting has been observed at Tutuila and the Manu'a Islands in American Samoa. The status of the hawksbill throughout the Pacific is unknown, but continued exploitation of hawksbills for their shells is a conservation concern. The most important conservation achievement for this species in recent years was the decision by Japan to end the import of hawksbill shell. Further declines are possible if this trade is renewed. Additionally, destruction and degradation of coral reefs that hawksbills rely on for food and habitat is a major threat to recovery.

Green

The green turtle is found throughout the North Pacific, occasionally ranging as far north as Eliza Harbor on Admiralty Island, Alaska, and Ucluelet, British Columbia. On the U.S. West Coast, a resident population of green turtles occurs in San

[3]P. H. Dutton, NMFS Southwest Fisheries Science Center, 8604 La Jolla Shores Dr., La Jolla, CA 92037.

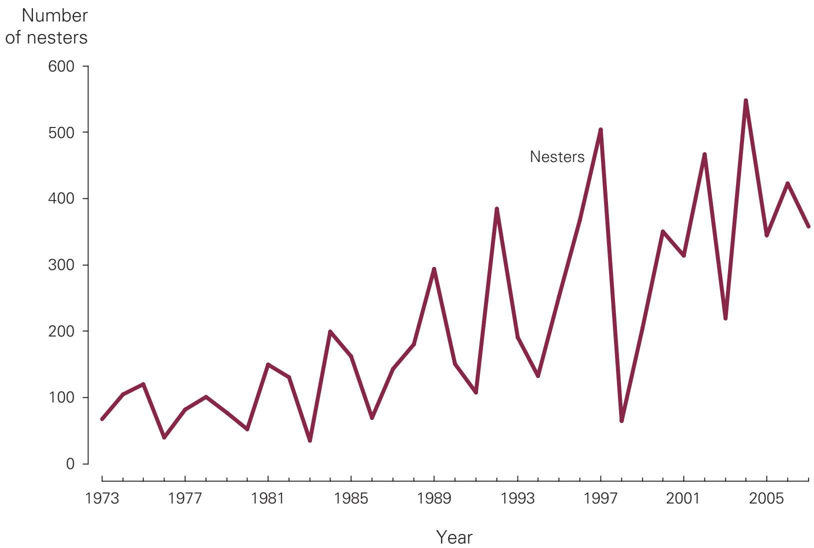

Figure 24-2
Population estimates for nesting green turtles on East Island, French Frigate Shoals, Northwest Hawaiian Islands, 1973–2007.

Diego Bay. In the Central Pacific, green turtles can be found at most tropical islands including the islands in the Hawaiian Archipelago. Ninety to 95% of all nesting and breeding activity occurs in the Northwestern Hawaiian Islands at French Frigate Shoals. At least 50% of these activities take place on East Island, which has been monitored by researchers since 1973 (Figure 24-2). Beach counts of nesting females have increased over the last three decades from a low of 35 individuals in 1983 to a high of 548 in 2004. This increase in Hawaiian green turtle counts is attributed to a reduction in human-caused mortality after the species was listed under the ESA in 1978. In American Samoa, the primary nesting beach is at Rose Atoll where an estimated 15 to 25 females return annually. The number of green turtles in Guam is unknown, and only low nesting activity has been recorded there. Based on limited data, green turtle populations in American Samoa, Guam, Palau, Commonwealth of the Northern Mariana Islands, Federated States of Micronesia, Republic of the Marshall Islands, and the Unincorporated Islands (Wake, Johnston, Kingman, Palmyra, Jarvis, Howland, Baker, and Midway) have declined dramatically, due foremost to the harvest of eggs and adult turtles by humans. Genetic studies to determine the population structure and migratory patterns of green turtles in the Pacific are currently underway.

Significant progress is being made in the monitoring of Hawaiian green turtles by NMFS and USFWS. A 5-year series of saturation surveys completed in 1992 led to the development of rigorous quantitative methods to estimate the nesting population. Progress is also being made in monitoring juvenile and subadult Hawaiian green turtles in their nearshore habitat.

ISSUES

Fisheries Interactions

Sea turtles are threatened by multiple factors, most of which are human-related. A principal concern is their incidental capture in fisheries. Trawl, longline, and gillnet fisheries pose the greatest threats, although turtles are also taken and killed in fixed-gear fisheries, such as pound nets and traps/pots. Trawl fisheries pose a large threat to turtle survival, although much progress has been made towards reducing this source of mortality. Prior to the implementation of TED regulations, the National Academy of Sciences estimated that as many as 44,000 sea turtles, mostly loggerheads and Kemp's ridleys, were killed annually in the Gulf of Mexico and southeastern U.S. Atlantic shrimp trawl fisheries. Currently, TED use is mandated for the shrimp fishery and a portion of the summer flounder trawl fishery. In 2003, regulations were amended to increase the size of the TED escape opening, a change that benefits larger species such as leatherback and adult green and loggerhead turtles.

In the Pacific and Atlantic pelagic longline fisheries for highly migratory species (including tuna, swordfish, and some shark species), the incidental take of sea turtles is monitored through a logbook and observer program. Workshops have been held to formulate research techniques to assess the population-level effects of hooking and entanglement and to identify ways to reduce or mitigate incidental capture in longline fisheries.

NMFS supported a landmark experiment to evaluate the effects of hook and bait types on sea turtle bycatch in pelagic longline fisheries in the eastern Atlantic, known to capture significant numbers of sea turtles. NMFS also conducted fishery-dependent research on the Grand Banks in the North Atlantic to identify gear and fishing method modifications that would reduce or eliminate the bycatch of sea turtles while preserving local longline fisheries. Researchers found that using larger offset circle hooks and substituting mackerel-style bait had the potential to significantly reduce the interaction rate and mortality rate of leatherbacks and loggerheads.

Implementation of U.S. gear modifications, such as those demonstrated in gear experiments in the Atlantic, may have broader implications for sea turtles around the world. If modifications in longline fishing practices demonstrate that target species (e.g. swordfish) can be caught sustainably and with similar catch-per-unit-effort as before, the international community will be more likely to accept the results of such studies and to adopt gear and fishing modifications.

In related research, satellite transmitters have been deployed on sea turtles captured on longline hooks to track post-release movements and better understand the long-term effects on individual animals. Linkages between individual movements and oceanographic processes are also being studied, and computer simulation models are under development to better assess the impacts of Pacific fisheries on these populations.

Significant progress has been made with coastal states to investigate fishery interactions in the Mid-Atlantic and to implement a management response to reduce annual spring mortality of loggerheads and Kemp's ridleys in Virginia and North Carolina waters. A comprehensive NMFS strategy for sea turtle conservation and recovery in Atlantic Ocean and Gulf of Mexico commercial and recreational fisheries addresses incidental capture through a consistent, gear-based approach.

Non-Fisheries Interactions

Propeller strikes and vessel collisions pose significant threats to sea turtles, especially in areas of high human population where recreational boat and commercial traffic is heavy and coastal ports are active. Sea turtles can become entrained and killed in the draghead of hopper dredges used in constructing and maintaining navigation channels. Coastal power plants that draw their cooling water from nearshore and estuarine waters can also entrain sea turtles and cause mortality.

SEFSC Pascagoula Laboratory

Children travel through a makeshift shrimp trawl equipped with a TED. Outreach and education events, such as this one sponsored by the NMFS Pascagoula Laboratory, help teach people about sea turtle conservation.

Habitat Concerns

Coastal development can interfere with or prevent nesting and affect reproductive success. Monitoring and protecting beaches of the southeastern United States and Hawaii is essential to the survival and recovery of sea turtles. Many nesting beaches have already been significantly degraded or destroyed. In particular, nesting habitat is threatened by coastal armoring structures (i.e. rigid shoreline protection) such as sea walls, rock revetments, and sandbag installations. Many miles of once productive nesting beach have been permanently lost to this type of shoreline protection. Additionally, nesting habitat can be negatively impacted by altered beach and sand characteristics resulting from beach nourishment projects. Artificial beachfront lighting, increased human activity in the coastal zone, and beach driving also seriously threaten species' recovery. In light of these issues, conservation and long-term protection of nesting habitats is an urgent and high priority need.

Development in the coastal zone can also degrade the foraging habitat of sea turtles. Important foraging grounds for several species of sea turtles exist along the U.S. East Coast and throughout the Gulf of Mexico near major areas of nearshore and

Ursula Keuper-Bennett/Peter Bennett

Hawaiian green turtle exhibiting the skin, eye, and oral tumors that result from fibropapillomatosis (FP).

offshore oil exploration and production. Offshore oil extraction may result in chronic low-level spills and occasional massive spills, which may imperil important foraging habitat.

Damage and destruction of coral reefs and nearshore hard-bottom habitat is also an important habitat issue facing sea turtles. Many sea turtles rely on coral reefs for food and habitat; degradation of these critical habitats can pose a major threat to turtle species' recovery.

Marine Debris

Ingestion of marine debris can be a serious threat when turtles mistake debris for natural food items. An examination of loggerhead hatchlings' feeding habits in offshore convergence zones revealed a high incidence of tar and plastic in their stomachs. Some types of marine debris, such as oil, may be directly or indirectly toxic through exposure or ingestion. Other hazards, such as discarded or derelict fishing gear, may also entangle and drown turtles.

Disease

A disease known as fibropapillomatosis (FP), originally identified in green turtles but now affecting other species as well, has emerged as a serious threat to the recovery of some populations. The disease is most notably present in green turtles of Hawaii, Australia, Florida, and the Caribbean. FP can be fatal and is commonly expressed as tumors that occur on the skin and eyes. Regional differences in symptoms exist between some affected populations; in Hawaii, green turtles have a high incidence of tumors in the oral cavity, whereas oral tumors have not been found in Florida or other areas. The cause of the disease remains unknown, although a fibropapilloma-associated turtle herpesvirus is consistently present in turtles with FP (Greenblatt et al., 2004).

Recently, FP has been systematically monitored in several locales in Hawaii. At a study site on southern Molokai where tumors were virtually unknown before 1988, the prevalence of tumored green turtles ranged from 42 to 56% during the 1995–97 surveys and declined to 9–15% during the 2005–07 surveys. In Florida, up to 50% of the immature green turtles captured in Indian River Lagoon are infected, and there are similar reports from other sites, including Florida Bay, as well as Puerto Rico and the U.S. Virgin Islands. The disease has also been found to affect loggerheads in Florida Bay.

A multidisciplinary research program is underway to study the cause and effects of FP. The possible etiologies of the disease, including viruses, parasites, and environmental pollutants are also under investigation. Recent studies demonstrated the involvement of both a retrovirus and a herpesvirus. In addition to field and laboratory research, statistical analyses and modeling are underway to link FP incidence and severity to key aspects of green turtle population dynamics and to assess impacts on population recovery.

Progress

In 1998, recovery plans were published for five species of Pacific sea turtles and one regionally distinct and important population (the East Pacific green turtle). U.S. Atlantic recovery plans were completed in the early 1990's; two plans, the loggerhead and Kemp's ridley, are currently under revision. These plans describe and prioritize the actions that are necessary to conserve and recover turtles throughout their ranges. In addition to addressing these issues, research priorities focus on understanding population structure, migratory movements, and life histories, as well as threats to sea turtle recovery.

In the last decade, considerable effort has been expended to elucidate sea turtle management units (stocks) through the use of genetic tools. For all species, scientists have found a high degree of genetic

Caroline Rogers, USGS

Hawksbill turtle.

structuring within ocean basins. It is believed that these genetically distinct stocks arose as a result of genetic isolation facilitated by the species' natal homing behavior. While the animals appear to segregate when nesting, they commingle on foraging grounds, sometimes thousands of miles away from natal beaches (where they hatched).

Additionally, the analyses of genetic material from turtles incidentally taken in various fisheries can tell us which populations are being impacted by fisheries interactions. For example, the Hawaii-based longline fishery interacts with loggerheads originating from Japan, green turtles originating from Hawaii and the eastern Pacific (Mexico or Ecuador), and leatherbacks originating primarily from the far western Pacific rookeries—Papua (Indonesia), Malaysia, and the Solomon Islands—and to a lesser extent from the eastern Pacific—Mexico and Costa Rica. The fishery also interacts with olive ridleys originating from both the eastern Pacific, and the Indian and western Pacific rookeries. Eastern Atlantic and Mediterranean longline fisheries interact with migrating loggerheads from the western Atlantic (primarily the United States).

Genetic analyses also can identify the natal areas of turtles mixing on foraging grounds. Loggerheads inhabiting foraging habitats along the East Coast of the United States originate from the United States, Mexico, and Brazil. Green turtles co-occur from Florida, the Caribbean, and the South Atlantic Ocean (east and west). Leatherbacks caught in the Northeastern Distant Fisheries in the Atlantic originate from the western Atlantic stock (e.g. Caribbean).

Complementing the genetic work, satellite telemetry studies are helping to identify routes of travel and resident foraging grounds of sea turtles. NMFS scientists have successfully used satellite telemetry to study the migratory movements of post-nesting Hawaiian and Florida green turtles; Florida loggerheads; foraging green turtles in San Diego Bay; post-nesting leatherbacks in the western Pacific and St. Croix, U.S. Virgin Islands; and foraging Pacific leatherbacks off central California.

NMFS has conducted considerable research on various kinds of tags to mark and identify sea turtles in order to collect important biological information on life history variables such as growth,

Olive ridley turtle.

survival rates, and age at maturity. A number of studies are also investigating habitat use to further our understanding of the life histories of Kemp's ridleys, loggerheads, and greens. Work at study sites in Florida, North Carolina, the northwestern Gulf of Mexico, and Hawaii will help determine the importance of inshore and nearshore habitats to the survival of these species. Based on this research, critical habitat for the green turtle has been designated for the nearshore foraging grounds off Culebra, Puerto Rico, and for the hawksbill on Mona and Monita Islands, Puerto Rico.

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Part 4
Appendices

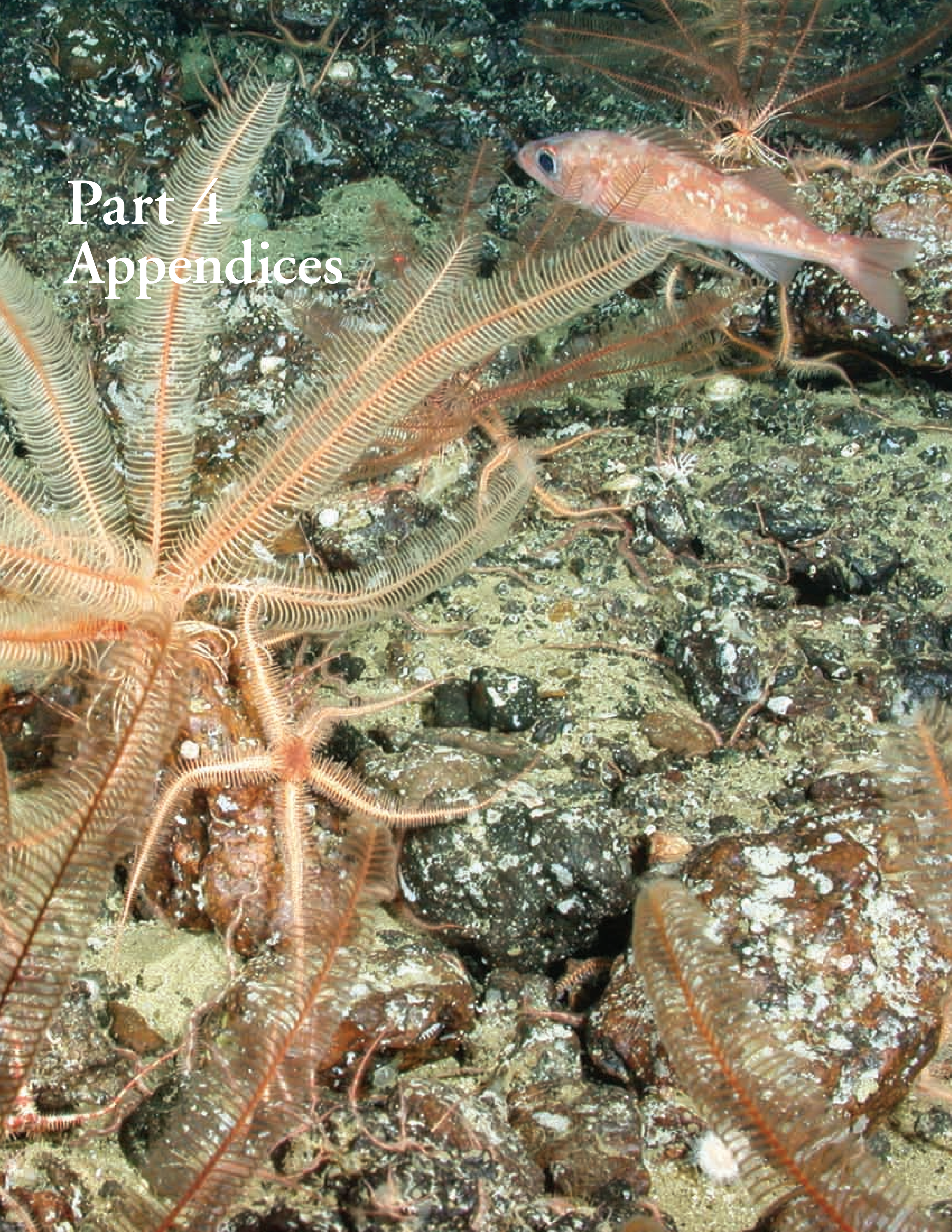

Photo on previous page: Shortbelly rockfish swimming past intact, healthy bottom habitat. Photo courtesy of John Butler, SWFSC.

Appendix 1: Acknowledgements

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Appendix 2: Fishery Management Councils, Their Jurisdictions, and Fishery Management Plans

NEW ENGLAND
FISHERY MANAGEMENT COUNCIL
50 Water Street, Mill 2
Newburyport, MA 01950
Voice (978) 465-0492
Fax (978) 465-3116
http://www.nefmc.org

Jurisdiction
Maine, New Hampshire, Massachusetts, Rhode Island, and Connecticut

Fishery Management Plans
- Atlantic Herring
- Atlantic Salmon
- Atlantic Sea Scallop
- Deep-Sea Red Crab
- Monkfish (joint management with the Mid-Atlantic Fishery Management Council)
- Northeast Multispecies
- Northeast Skate Complex

MID-ATLANTIC
FISHERY MANAGEMENT COUNCIL
Suite 2115 Federal Building
300 S. New Street
Dover, DE 19904
Voice (302) 674-2331
Toll free (877) 446-2362
Fax (302) 674-4136
http://www.mafmc.org
info@mafmc.org

Jurisdiction
New York, New Jersey, Delaware, Pennsylvania, Maryland, Virginia, and North Carolina

Fishery Management Plans
- Atlantic Mackerel, Squid and Butterfish
- Bluefish
- Spiny Dogfish (joint management with the New England Fishery Management Council)
- Summer Flounder, Scup and Black Sea Bass
- Atlantic Surfclam and Ocean Quahog
- Tilefish

SOUTH ATLANTIC
FISHERY MANAGEMENT COUNCIL
4055 Faber Place Drive, Suite 201
North Charleston, SC 29405
Voice (843) 571-4366
Toll free (866) SAFMC-10
Fax (843) 769-4520
http://www.safmc.net
safmc@safmc.net

Jurisdiction
North Carolina, South Carolina, Georgia, and the east coast of Florida

Fishery Management Plans
- Atlantic Coast Red Drum
- Coral, Coral Reefs and Live/Hard Bottom Habitats of the South Atlantic Region

- Dolphin and Wahoo Fishery of the Atlantic
- Golden Crab Fishery of the South Atlantic Region
- Pelagic *Sargassum* Habitat of the South Atlantic Region
- Shrimp Fishery of the South Atlantic Region
- Snapper–Grouper Fishery of the South Atlantic Region

GULF OF MEXICO
FISHERY MANAGEMENT COUNCIL
2203 N Lois Ave, Suite 1100
Tampa, FL 33607
Voice (813) 348-1630
Toll free (888) 833-1844
Fax (813) 348-1711
http://www.gulfcouncil.org
gulfcouncil@gulfcouncil.org

Jurisdiction
Texas, Louisiana, Mississippi, Alabama, and the west coast of Florida

Fishery Management Plans
- Coral and Coral Reefs of the Gulf of Mexico
- Coastal Migratory Pelagic Resources of the Gulf of Mexico and South Atlantic (joint management with the South Atlantic Fishery Management Council)
- Red Drum Fishery of the Gulf of Mexico
- Reef Fish Resources of the Gulf of Mexico
- Shrimp Fishery of the Gulf of Mexico
- Spiny Lobster in the Gulf of Mexico and South Atlantic (joint management with the South Atlantic Fishery Management Council)
- Stone Crab Fishery of the Gulf of Mexico

CARIBBEAN
FISHERY MANAGEMENT COUNCIL
268 Muñoz Rivera Avenue, Suite 1108
San Juan, PR 00918
Voice (787) 766-5926
Fax (787) 766-6239
http://www.caribbeanfmc.com

Jurisdiction
U.S. Virgin Islands and Commonwealth of Puerto Rico

Fishery Management Plans
- Corals and Reef Associated Plants and Invertebrates of Puerto Rico and the U.S. Virgin Islands
- Queen Conch Resources of Puerto Rico and the U.S. Virgin Islands
- Shallow Water Reef Fish Fishery of Puerto Rico and the U.S. Virgin Islands
- Spiny Lobster Fishery of Puerto Rico and the U.S. Virgin Islands

PACIFIC
FISHERY MANAGEMENT COUNCIL
7700 NE Ambassador Place, Suite 101
Portland, OR 97220
Voice (503) 820-2280
Toll free (866) 806-7204
Fax (503) 820-2299
http://www.pcouncil.org

Jurisdiction
California, Oregon, Washington, and Idaho

Fishery Management Plans
- Coastal Pelagic Species
- Pacific Coast Groundfish
- Pacific Coast Salmon
- U.S. West Coast Fisheries for Highly Migratory Species

WESTERN PACIFIC
FISHERY MANAGEMENT COUNCIL
1164 Bishop Street, Suite 1400
Honolulu, HI 96813
Voice (808) 522-8220
Fax (808) 522-8226
http://www.wpcouncil.org
info.wpcouncil@noaa.gov

Jurisdiction
Hawaii, American Samoa, Guam, and Commonwealth of the Northern Marianas Islands

Fishery Management Plans
- Bottomfish and Seamount Groundfish Fisheries of the Western Pacific Region

- Coral Reef Ecosystem of the Western Pacific Region
- Crustacean Fisheries of the Western Pacific Region
- Pelagic Fisheries of the Western Pacific Region
- Precious Coral Fisheries of the Western Pacific Region

NORTH PACIFIC FISHERY MANAGEMENT COUNCIL

605 W 4th Avenue, Suite 306
Anchorage, AK 99501
Voice (907) 271-2809
Fax (907) 271-2817
http://fakr.noaa.gov/npfmc/

Jurisdiction

Alaska

Fishery Management Plans

- Bering Sea/Aleutian Islands King and Tanner Crabs
- Groundfish of the Bering Sea and Aleutian Islands Management Area
- Groundfish of the Gulf of Alaska
- Salmon Fisheries in the EEZ off the Coast of Alaska
- Scallop Fishery off Alaska

OFFICE OF SUSTAINABLE FISHERIES, HIGHLY MIGRATORY SPECIES DIVISION

1315 East-West Highway
Silver Spring, MD 20910
Voice (301) 713-2347
http://www.nmfs.noaa.gov/sfa/hms/

Secretarial Plans

- Consolidated Atlantic Highly Migratory Species

Appendix 3: Principal Facilities of the National Marine Fisheries Service

OFFICE OF THE ASSISTANT ADMINISTRATOR FOR FISHERIES
National Marine Fisheries Service
1315 East-West Highway
Silver Spring, MD 20910
Voice (301) 713-2239
http://www.nmfs.noaa.gov

REGIONAL OFFICES AND FISHERY SCIENCE CENTERS

Northeast Regional Office
55 Great Republic Drive
Gloucester, MA 01930
Voice (978) 281-9300
Fax (978) 281-9333
http://www.nero.noaa.gov/nero/

Northeast Fisheries Science Center
166 Water Street
Woods Hole, MA 02543-1026
Voice (508) 495-2000
Fax (508) 495-2258
http://www.nefsc.noaa.gov/

Woods Hole Laboratory
166 Water Street
Woods Hole, MA 02543
Voice (508) 495-2000
Fax (508) 495-2258
http://www.nefsc.noaa.gov/nefsc/woodshole/

Narragansett Laboratory
28 Tarzwell Drive
Narragansett, RI 02882
Voice (401) 782-3200
http://na.nefsc.noaa.gov/

Milford Laboratory
212 Rogers Avenue
Milford, CT 06460-6499
Voice (203) 882-6500
Fax (203) 882-6570 or –6517
http://mi.nefsc.noaa.gov

James J. Howard Marine Sciences Laboratory
74 Magruder Road, Sandy Hook
Highlands, NJ 07732
Voice (732) 872-3000
http://sh.nefsc.noaa.gov/

National Systematics Laboratory
10th & Constitution Avenue NW
Washington, DC 20560
Voice (202) 357-4990
http://www.nefsc.noaa.gov/nefsc/systematics/

Maine Field Station
17 Godfrey Drive, Suite 1
Orono, ME 04473
Voice (207) 866-7322
Fax (207) 866-7342
http://www.nefsc.noaa.gov/nefsc/orono/

Southeast Regional Office
263 13th Avenue S
St. Petersburg, FL 33701
Voice (727) 824-5301
http://sero.nmfs.noaa.gov/

Southeast Fisheries Science Center
75 Virginia Beach Drive
Miami, FL 33149
Voice (305) 361-4200
http://www.sefsc.noaa.gov

Miami Laboratory
75 Virginia Beach Drive
Miami, FL 33149-1003
Voice (305) 361-4200
http://www.sefsc.noaa.gov/facility.jsp

Mississippi Laboratory
3209 Frederic Street
Pascagoula, MS 39567
Voice (228) 762-4591
http://www.sefsc.noaa.gov

Panama City Laboratory
3500 Delwood Beach Road
Panama City, FL 32408
Voice (850) 234-6541
Fax (850) 235-3559
http://www.sefscpanamalab.noaa.gov/

Galveston Laboratory
4700 Avenue U
Galveston, TX 77551-5997
Voice (409) 766-3500
http://galveston.ssp.nmfs.gov/index.html

Beaufort Laboratory
101 Pivers Island Road
Beaufort, NC 28516-9722
Voice (252) 728-3595
Fax (252) 728-8784
http://www.sefsc.noaa.gov

Southwest Regional Office
501 W. Ocean Boulevard
Long Beach, CA 90802-4213
Voice (562) 980-4000
http://swr.nmfs.noaa.gov/

Southwest Fisheries Science Center
8604 La Jolla Shores Drive
La Jolla, CA 92037-1508
Voice (858) 546-7000
Fax (858) 546-7003
http://swfsc.noaa.gov/

La Jolla Laboratory
8604 La Jolla Shores Drive
La Jolla, CA 92037-1508
Voice (858) 334-2800
Fax (858) 546-7003
http://swfsc.noaa.gov/

Santa Cruz Laboratory
110 Shaffer Road
Santa Cruz, CA 95060
Voice (831) 420-3900
Fax (831) 420-3980
http://swfsc.noaa.gov/

Pacific Grove Laboratory
1352 Lighthouse Avenue
Pacific Grove, CA 93950-2097
Voice (831) 648-8515
Fax (831) 648-8440
http://swfsc.noaa.gov/

Northwest Regional Office
7600 Sand Point Way NE
Seattle, WA 98115-0070
(206) 526-6150
http://www.nwr.noaa.gov/

Northwest Fisheries Science Center
2725 Montlake Boulevard E
Seattle, WA 98112-2097
Voice (206) 860-3200
Fax (206) 860-3217
http://www.nwfsc.noaa.gov/

Manchester Research Station
7305 E Beach Drive
Port Orchard, WA 98366
Voice (206) 842-5434
Fax (206) 842-8364
http://www.nwfsc.noaa.gov/research/facilities/manchester.cfm

Newport Research Station
2032 SE OSU Drive, Building 955
Newport, OR 97365-5275
Voice (541) 867-0500
Fax (541) 867-0505

Pasco Research Station
3305 E Commerce Street
Pasco, WA 99301-5839
Voice (509) 547-7518
Fax (509) 547-4181

Point Adams Research Station
520 Heceta Place
Hammond, OR 97121-0155
Voice (503) 861-1818
Fax (503) 861-2589

Mukilteo Research Station
10 Park Avenue, Building 8
Mukilteo, WA 98275-1618
Voice (425) 347-6935
Fax (425) 347-4072

Alaska Regional Office
P.O. Box 21668
Juneau, AK 99802-1668
Voice (907) 586-7221
Fax (907) 586-7249
http://www.fakr.noaa.gov/
alaska.webmaster@noaa.gov

Alaska Fisheries Science Center
7600 Sand Point Way NE, Building 4
Seattle, WA 98115-0070
Voice (206) 526-4000
Fax (206) 526-4004
http://www.afsc.noaa.gov/
afsc.webmaster@noaa.gov

Seattle Laboratory
7600 Sand Point Way NE, Building 4
Seattle, WA 98115-0070
Voice (206) 526-4000
Fax (206) 526-4004
http://www.afsc.noaa.gov/

National Marine Mammal Laboratory
7600 Sand Point Way NE
Seattle, WA 98115-6349
Voice (206) 526-4045
Fax (206) 526-6615
http://www.afsc.noaa.gov/nmml/

Auke Bay Laboratories
Ted Stevens Marine Research Institute
17109 Pt. Lena Loop Road
Juneau, AK 99801
Voice (907) 789-6000
Fax (907) 789-6094
http://www.afsc.noaa.gov/abl/TSMRI.htm

Kodiak Laboratory
P.O. Box 1638
Kodiak, AK 99615
Voice (907) 481-1700
Fax (907) 481-1781
http://www.afsc.noaa.gov/kodiak/

Little Port Walter Field Station
P.O. Box 253
Sitka, AK 99835
Voice (907) 723-4457
http://www.afsc.noaa.gov/abl/MarSalm/3lpw.
html

Pacific Islands Regional Office
1601 Kapiolani Boulevard, Suite 1110
Honolulu, HI 96814
Voice (808) 944-2200
Fax (808) 973-2941
http://www.fpir.noaa.gov/

Pacific Islands Fisheries Science Center
2570 Dole Street
Honolulu, HI 96822-2396
Voice (808) 983-5300
Fax (808) 983-2902
http://www.pifsc.noaa.gov

Appendix 4: Stock Assessment Principles and Terms

Much of the information in this report comes from the scientific analysis of fisheries data to develop stock assessments. **Stock assessment** is the process of collecting and analyzing demographic information about fish populations to describe the conditions or status of a fish stock. The result of a stock assessment is a report that often includes an estimation of the amount or abundance of the resource, an estimation of the rate at which it is being removed due to harvesting and other causes, and one or more reference levels of harvesting rate and/or abundance at which the stock can maintain itself in the long term. Stock assessments often contain short-term (1–5 years, typically) projections or prognoses for the stock under a number of different scenarios. This information on resource status is used by managers to determine what actions are needed to promote the best use of our living marine resources.

Stock assessment reports describe a range of life history characteristics for a given species, including age, growth, natural mortality, sexual maturity and reproduction, stock boundaries, diet preferences, habitat characteristics, species interactions, and environmental factors that may affect the species. Assessment reports also include descriptions of the fishery for a species, using information from both scientists and fishermen. Additionally, stock assessments describe the **assessment model**, or the collection of mathematical and statistical techniques that were used to perform the stock assessment.

Stock assessment analyses rely on various sources of information to estimate resource abundance and population trends. The principal information comes from the commercial and recreational fisheries (**fishery-dependent information**). For example, the quantity of fish caught and the individual sizes of the fish, their biological characteristics (e.g. age, maturity, and sex), and the ratio of fish caught to the time spent fishing (catch per unit of effort) are basic data for stock assessments. In addition, the National Marine Fisheries Service (NMFS) conducts resource surveys with specialized fishery research vessels or chartered fishing vessels (**fishery-independent information**). These surveys, often conducted in cooperation with state marine resource agencies, universities, the fishing industry, international scientific organizations, and fisheries agencies of other nations, produce estimates of resource abundance.

Resource surveys are conducted differently from commercial fishing. Commercial operations seek out the greatest aggregations of fish and target them to obtain the largest or most valuable catch. Fishery research vessels operate in a standardized manner, over a wide range of locations and within waters inhabited by the stocks, to provide unbiased population abundance and distribution indices year after year. The survey results are then used with commercial and recreational catch data to assess the resource base. The final critical data comes from studies on the basic biology of the animals themselves. Understanding the natural history of the harvested species and the other species with which they interact is crucial to understanding the population dynamics of living marine resources.

Fish abundance or population size can be expressed as either the number of fish or the total fish weight (or biomass). Increases in the amount of fish are determined by body growth of individual fish in the population, and the addition or **recruitment** of new generations of young fish (i.e. **recruits**; recruits from the same year are said to comprise a **year-class** [or **cohort**]). Those gains must then be balanced against the proportion of the population removed by harvesting (called **fishing mortality**, ***F***) and other losses due, for example, to predation, starvation, or disease (called **natural mortality**, ***M***). In stock assessment work, removals of fish from the population are commonly expressed in terms of rates within a time period. The **fishing mortality rate** is a function of **fishing effort**, which includes the amount, type, and effectiveness of fishing gear and the time spent fishing. **Catch per unit of effort (CPUE)** is an index showing the ratio of a catch of fish, in numbers or in weight, and a standard measure of the fishing effort expended to catch them.

Surplus production (or production) is the total weight of fish that can be removed by fishing without changing the size of the population. It is calculated as the sum of the growth in weight of individuals in a population, plus the addition of biomass from new recruits, minus the biomass of animals lost to natural mortality.

The **production rate** is expressed as a proportion of the population size or biomass. The production rate can be highly variable owing to environmental fluctuations, predation, and other biological interactions with other populations. On average, production decreases at low and high population sizes, and biomass decreases as the amount of fishing effort increases. This means there is a relationship between average production and fishing effort. This relationship is known as the production function.

Production functions are the basis for certain important concepts used in this report: **maximum sustainable yield**, **current yield**, and **recent average yield**. In addition, the term **stock level** is employed as a biological reference for determining resource status relative to the biomass that would on average support the sustainable yield. Recent average yield also is reported in order to allow comparison of the current situation to the sustainable yield.

Many other **reference levels** are used as benchmarks for guiding management decisions. A number of these are expressed as fishing mortality rate levels that would achieve specific results from the average recruit to the fishery if the stock were subjected to fishing at those rates indefinitely. Some of these **benchmarks** are used to index potential fishery production, and others are used to index potential reproductive output. $\boldsymbol{F_{max}}$ is the fishing mortality rate that maximizes the yield obtained from the average recruit. **Growth overfishing** occurs over the range of fishing mortality, at which the losses in weight from total mortality exceed the gain in weight due to growth. This range is defined as beyond F_{max}. $\boldsymbol{F_{0.1}}$ is a rate that results in almost as much yield per recruit as F_{max} does, but can be much lower—and thus more conservative—than F_{max} (at $F_{0.1}$, only a 10% increase in yield per recruit occurs following an additional unit of fishing effort compared to the yield per recruit produced by the first unit of effort on the unexploited stock). Benchmarks used to measure reproductive potential usually express an amount of spawning output relative to the amount expected under no fishing. For example, $\boldsymbol{F_{20\%}}$ and $\boldsymbol{F_{30\%}}$ are the rates that would reduce spawning biomass per recruit to 20 or 30% of the unfished level, respectively. This percentage of the unfished level is also known as the **spawning potential ratio (SPR)**.

Maximum Sustainable Yield (MSY)

MSY is the maximum long-term average yield that can be achieved through conscientious stewardship by controlling *F* through regulating fishing effort or total catch levels. MSY is a reference point for judging the potential of the resource. However, it is not necessarily the goal of fishery managers to always set the maximum yield. Other factors influence the choice of a management objective, such as socioeconomic considerations or conservation and ecosystem concerns for other marine life indirectly affected by fishery harvests. The methods of estimating MSY, and MSY itself, may be controversial. Nevertheless, NMFS scientists have used their best professional judgment to provide these figures as a gauge of long-term production potential whenever possible.

Current Yield (CY)

CY, the potential catch that can be safely taken at the present time, depends on the current abundance of fish and population dynamics of the stock. It is usually estimated by applying the *F* associated with MSY (e.g. target fishing effort) to the current population size. This yield may be either greater than or less than MSY. CY is the amount of catch that will maintain the present population level (biomass) or, for overutilized stocks, stimulate a trend toward recovery to a population size that will produce the MSY. For stocks at high biomass levels, the CY may be larger than the MSY. In this circumstance a large fishery harvest would not be sustainable in the long run, but it would bring the stock down to the level supporting MSY.

Recent Average Yield (RAY)

RAY is equivalent to recent average catch. Unless designated otherwise, RAY is the reported fishery landings averaged for the most recent 3-year period, 2004–06.

Stock Level Relative to B_{MSY}

To further clarify resource status, stock level (i.e. abundance) in the most recent year available is compared with the biomass that on average would support the MSY harvest (B_{MSY}). This is expressed as being **below**, **near**, **above**, or **unknown** relative to B_{MSY}. In some cases, heavy fishing in the past reduced a stock to a low abundance, and even if the stock currently is harvested only lightly, it may take many years for it to rebuild.

Harvest Rate

A stock's harvest rate compares the current harvest rate to a prescribed fishing mortality (catch) threshold defined in the stock's Fishery Management Plan (FMP). A stock is described as **overfishing** when the harvesting is occurring at a rate that is above the prescribed fishing mortality rate. A stock is **not overfishing** when harvesting is below that rate. A stock may also be classified as **undefined** if no fishing mortality threshold has been set in the FMP, or its harvest rate may be **unknown**.

Stock Status

Stock status defines a stock's size relative to a prescribed biomass threshold defined in the stock's FMP. A stock is **overfished** when its stock size is below the prescribed biomass threshold, or **rebuilding** when its biomass has rebuilt to above the threshold level but not yet to the biomass target defined in the rebuilding plan. Stocks that have stock sizes above the prescribed biomass threshold are described as **not overfished**. Stocks may also be described as **undefined** if no prescribed biomass threshold has been set, or the current stock size may be **unknown**.

Classification of Resource Status

Previous editions of *Our Living Oceans* have used utilization level[1] as a major factor in determining the status of a stock. However, this classification scheme did not always give a comprehensive picture of stock status or one that was consistent with legal classifications. The classification scheme used in *OLO 6th Edition* has been updated to be based on the requirements for status determination criteria listed in Fishery Management Plans (FMPs) and match the overfishing (Harvest Rate in *OLO*) and overfished (Stock Status in *OLO*) determinations that are listed in the *Annual Report to Congress on the Status of U.S. Fisheries*.

In 1989, NMFS published revised guidelines addressing National Standards 1 and 2 of the 1976 Magnuson Fishery Conservation and Management Act, as amended (1976 Act). Among other things, the intent of the guidelines was to prevent recruitment overfishing and to have a conservation standard for each fishery such that stocks were not driven to, or maintained at, the threshold of overfishing. The guidelines defined overfishing as a level or rate of fishing mortality that jeopardizes the long-term capacity of a stock or stock-complex to produce **maximum sustainable yield (MSY)** on a continuing basis. Each FMP was required to specify, to the maximum extent possible, an objec-

[1]A qualitative measure of the level of fishery use derived by comparing the present levels of fishing effort and stock abundance to those levels necessary to achieve the long-term potential yield (analogous to the MSY). Stocks were classified as underutilized, fully utilized, overutilized, or unknown.

tive and measurable definition of overfishing for each stock or stock complex covered by that FMP, and to provide an explanation of how the definition was determined and how it relates to reproductive potential. Overfishing could be expressed in terms of a minimum level of spawning biomass, maximum level or rate of fishing mortality, or other acceptable measurable standard. If data indicated that an overfished condition existed, a program must be established for rebuilding the stock over a period of time specified by the Fishery Management Councils (FMCs) and acceptable to the Secretary of Commerce.

Over the period 1989–96, NMFS and the FMCs used the 1989 guidelines as a basis for developing, refining, and evaluating definitions of overfishing based on recruitment overfishing thresholds. There was considerable variation in the overfishing definitions developed and accepted, due to the flexibility afforded by the guidelines. Subsequently, in late 1996, the Magnuson Act was reauthorized as the Magnuson–Stevens Fishery Conservation and Management Act (MSA) with several changes that required a rethinking of the basis for defining overfishing. In particular, the MSA required MSY itself to be the upper limit on the allowable amount or rate of fishing. NMFS responded by producing new guidelines that were finalized in mid 1998. The new guidelines required the specification of **status determination criteria**, which include both a maximum fishing mortality rate (beyond which **overfishing** is deemed to be occurring) and a minimum stock-size threshold (below which the stock is deemed to be **overfished**). Both criteria must be associated with MSY-based reference points. The MSA and the new guidelines have considerably reduced the amount of flexibility allowed in defining overfishing, and require a much greater degree of conservatism in the biological reference points used to delimit overfishing.

The MSA was reauthorized again in 2006 as the Magnuson–Stevens Fishery Conservation and Management Reauthorization Act of 2006 (MSRA). The reauthorization act gives NMFS even stronger laws that will enable it to stop overfishing and accelerate rebuilding of overfished stocks. One of the centerpieces of the new MSRA legislation is that it directs the regional FMC's to establish **annual catch limits (ACL's)** by 2010 for all stocks currently undergoing overfishing, and by 2011 for all other Federally managed stocks, setting a firm deadline to end overfishing in the United States.

Economic value

In many of the fishery units, a dollar figure is given for the **ex-vessel revenue** generated by the commercial fishery on a given stock or group of stocks. Ex-vessel revenue is defined as the quantity of fish landed by commercial fishermen multiplied by the average price received by them at the first point of sale. As such, ex-vessel revenue captures the immediate value of the commercial harvest, but does not reflect multiplier effects of subsequent revenues generated by seafood processors, distributors, and retailers.

The estimate of economic value often takes both recreational and commercial catches and multiplies them by an average price to arrive at a baseline measure of economic worth among various user groups. It may underestimate those fisheries where there is a large recreational component. Nevertheless, the value serves as a useful gauge of relative potential revenues generated over many disparate stocks, fisheries, and regions.

Marine Mammal Assessments

The same scientific principles apply to the population dynamics of these protected species, but the terminology of not overfished, rebuilding, and overfished does not apply. Instead, marine mammals are referred to as **depleted** when they are threatened or endangered under the Endangered Species Act (ESA) or when their population size is below their **optimum sustainable population (OSP)** level. Stocks are additionally classified as **strategic** when the level of direct human-caused mortality[2] exceeds the **potential biological removal (PBR)** level; when the stock is declining

[2]Total annual human-caused mortality is the total number of annual mortalities and serious injuries likely to result in death caused by humans and includes fisheries-caused mortality resulting from commercial fisheries, subsistence mortality resulting from subsistence hunting, and other removals such as ship strikes, strandings, orphaned animals collected for public display, mortalities associated with research activities, take by foreign countries, and mortalities associated with activities authorized through incidental take regulations.

and is likely to be listed as threatened under the ESA within the foreseeable future based on the best science available; or when the stock is listed as threatened or endangered under the ESA or depleted under the MMPA.

The Marine Mammal Protection Act (MMPA) defines OSP as the number of animals which will result in the maximum productivity of the population or the species, keeping in mind the carrying capacity of their habitat and the health of their ecosystem. For operational purposes, the U.S. Fish and Wildlife Service (USFWS)[3] and NMFS[4] have interpreted this definition to mean a population size falling within a range from the population level of a given species or stock which is the largest supportable within the ecosystem (carrying capacity) to the population level that results in maximum net productivity.

Potential biological removal is the maximum number of animals, not including natural mortalities, that may be removed from a stock while allowing that stock to reach or stay at its OSP level (50–100% of its carrying capacity). PBR is calculated using the minimum population estimate, the maximum net productivity rate, and the recovery factor. The **minimum population estimate (N_{min})** is an estimate of the minimum number of animals in a stock, based on the best available scientific information on abundance and incorporating the precision and variability associated with such information, that provides reasonable assurance that the stock size is equal to or greater than the estimate. The **maximum net productivity rate (R_{max})** is defined under the MMPA as the annual per-capita rate of increase in a stock resulting from additions due to reproduction, less losses due to mortality. The **recovery factor (F_r)** ranges between 0.1 and 1.0 and is used in calculating the PBR to compensate for endangered, threatened, depleted, or unknown stock status relative to OSP stocks.

Protected species of marine mammals may also be classified as **threatened** or **endangered** under the Endangered Species Act (ESA). A species is considered threatened if it is likely to become an endangered species in the foreseeable future. A species is considered endangered if it is in danger of extinction throughout a significant portion of its range.

[3]Implements programs and regulations for manatees, sea otters, polar bears, and walruses.
[4]Responsible for all non-USFWS-managed marine mammals, including whales, porpoises, dolphins, seals, and sea lions.

Appendix 5: Common and Scientific Names of Species

The following is a listing of common and scientific names of fish, shellfish, marine mammals, and sea turtles found in Units 1–24. This listing is included for reference purposes only and is not all-inclusive.

Unit 1: Northeast Demersal Fisheries

Principal Groundfish
- Acadian redfish, *Sebastes fasciatus*
- American plaice, *Hippoglossoides platessoides*
- Atlantic cod, *Gadus morhua*
- Atlantic halibut, *Hippoglossus hippoglossus*
- Haddock, *Melanogrammus aeglefinus*
- Ocean pout, *Zoarces americanus*
- Pollock, *Pollachius virens*
- Red hake, *Urophycis chuss*
- Silver hake (whiting), *Merluccius bilinearis*
- White hake, *Urophycis tenuis*
- Windowpane, *Scophthalmus aquosus*
- Winter flounder, *Pseudopleuronectes americanus*
- Witch flounder, *Glyptocephalus cynoglossus*
- Yellowtail flounder, *Limanda ferruginea*

Dogfish and Skates
- Smooth dogfish, *Mustelus canis*
- Spiny dogfish, *Squalus acanthias*
- Skates
  - Barndoor skate, *Dipturus laevis*
  - Clearnose skate, *Raja eglanteria*
  - Little skate, *Leucoraja erinacea*
  - Rosette skate, *Leucoraja garmani*
  - Smooth skate, *Malacoraja senta*
  - Thorny skate, *Amblyraja radiata*
  - Winter skate, *Leucoraja ocellata*

Other Finfish
- Atlantic hagfish, *Myxine glutinosa*
- Black sea bass, *Centropristis striata*
- Cusk, *Brosme brosme*
- Goosefish (monkfish), *Lophius americanus*
- Scup, *Stenotomus chrysops*
- Spot, *Leiostomus xanthurus*
- Summer flounder, *Paralichthys dentatus*
- Tilefish, *Lopholatilus chamaeleonticeps*
- Weakfish, *Cynoscion regalis*
- Wolffishes, *Anarhichas* spp.

Unit 2: Northeast Pelagic Fisheries

Atlantic herring, *Clupea harengus*
Atlantic mackerel, *Scomber scombrus*
Bluefish, *Pomatomus saltatrix*
Butterfish, *Peprilus triacanthus*

Unit 3: Atlantic Anadromous Fisheries

American shad, *Alosa sapidissima*
Atlantic salmon, *Salmo salar*
Atlantic sturgeon, *Acipenser oxyrhinchus oxyrhinchus*
Hickory shad, *Alosa mediocris*
Rainbow smelt, *Osmerus mordax*
River herring
- Alewife, *Alosa pseudoharengus*
- Blueback herring, *Alosa aestivalis*

Sea lamprey, *Petromyzon marinus*
Shortnose sturgeon, *Acipenser brevirostrum*
Striped bass, *Morone saxatilis*

Unit 4: Northeast Invertebrate Fisheries

American lobster, *Homarus americanus*

Atlantic surfclam, *Spisula solidissima*
Longfin inshore squid, *Loligo pealeii*
Northern shortfin squid, *Illex illecebrosus*
Northern shrimp, *Pandalus borealis*
Ocean quahog (mahogany clam), *Arctica islandica*
Red deepsea crab, *Chaceon quinquedens*
Sea scallop, *Placopecten magellanicus*

Unit 5: Atlantic Highly Migratory Pelagic Fisheries
Albacore, *Thunnus alalunga*
Bigeye tuna, *Thunnus obesus*
Blue marlin, *Makaira nigricans*
Bluefin tuna, *Thunnus thynnus*
Longbill spearfish, *Tetrapturus pfluegeri*
Sailfish, *Istiophorus platypterus*
Skipjack tuna, *Katsuwonus pelamis*
Swordfish, *Xiphias gladius*
White marlin, *Kajikia albidus*
Yellowfin tuna, *Thunnus albacares*
Other tunas, Family Scombridae

Unit 6: Atlantic Shark Fisheries
Large Coastal Sharks
- Blacktip shark, *Carcharhinus limbatus*
- Bull shark, *Carcharhinus leucas*
- Great hammerhead, *Sphyrna mokarran*
- Lemon shark, *Negaprion brevirostris*
- Nurse shark, *Ginglymostoma cirratum*
- Sandbar shark, *Carcharhinus plumbeus*
- Scalloped hammerhead, *Sphyrna lewini*
- Silky shark, *Carcharhinus falciformis*
- Smooth hammerhead, *Sphyrna zygaena*
- Spinner shark, *Carcharhinus brevipinna*
- Tiger shark, *Galeocerdo cuvier*

Small Coastal Sharks
- Atlantic sharpnose shark, *Rhizoprionodon terraenovae*
- Blacknose shark, *Carcharhinus acronotus*
- Bonnethead, *Sphyrna tiburo*
- Finetooth shark, *Carcharhinus isodon*

Pelagic Sharks
- Blue shark, *Prionace glauca*
- Oceanic whitetip shark, *Carcharhinus longimanus*
- Porbeagle, *Lamna nasus*
- Shortfin mako, *Isurus oxyrinchus*
- Thresher shark, *Alopias vulpinus*

Prohibited Shark Species
- Atlantic angel shark, *Squatina dumeril*
- Basking shark, *Cetorhinus maximus*
- Bigeye sand tiger, *Odontaspis noronhai*
- Bigeye sixgill shark, *Hexanchus nakamurai*
- Bigeye thresher, *Alopias superciliosus*
- Bignose shark, *Carcharhinus altimus*
- Caribbean sharpnose shark, *Rhizoprionodon porosus*
- Dusky shark, *Carcharhinus obscurus*
- Galapagos shark, *Carcharhinus galapagensis*
- Longfin mako, *Isurus paucus*
- Narrowtooth shark, *Carcharhinus brachyurus*
- Night shark, *Carcharhinus signatus*
- Reef shark, *Carcharhinus perezii*
- Sand tiger, *Carcharias taurus*
- Sevengill shark, *Notorynchus cepedianus*
- Sixgill shark, *Hexanchus griseus*
- Smalltail shark, *Carcharhinus porosus*
- Whale shark, *Rhincodon typus*
- White shark, *Carcharodon carcharias*

Unit 7: Atlantic and Gulf of Mexico Coastal Pelagic Fisheries
Cero, *Scomberomorus regalis*
Cobia, *Rachycentron canadum*
Dolphinfish, *Coryphaena hippurus*
King mackerel, *Scomberomorus cavalla*
Spanish mackerel, *Scomberomorus maculatus*

Unit 8: Atlantic, Gulf of Mexico, and Caribbean Reef Fisheries
South Atlantic
- Black sea bass, *Centropristis striata*
- Gag, *Mycteroperca microlepis*
- Goliath grouper, *Epinephelus itajara*
- Nassau grouper, *Epinephelus striatus*
- Red porgy, *Pagrus pagrus*
- Red snapper, *Lutjanus campechanus*
- Snowy grouper, *Epinephelus niveatus*
- Tilefish, *Lopholatilus chamaeleonticeps*
- Vermilion snapper, *Rhomboplites aurorubens*
- Wreckfish, *Polyprion americanus*
- Amberjacks
  - Greater amberjack, *Seriola dumerili*
  - Lesser amberjack, *Seriola fasciata*
  - Unclassified amberjacks, *Seriola* spp.

Grunts
- Black grunt, *Haemulon bonariense*
- Black margate, *Anisotremus surinamensis*
- Bluestriped grunt, *Haemulon sciurus*
- French grunt, *Haemulon flavolineatum*
- Margate, *Haemulon album*
- Pigfish, *Orthopristis chrysoptera*
- Porkfish, *Anisotremus virginicus*
- Sailors choice, *Haemulon parra*
- Spanish grunt, *Haemulon macrostomum*
- Tomtate, *Haemulon aurolineatum*
- White grunt, *Haemulon plumierii*
- Unclassified grunts, Family Haemulidae

Other groupers
- Black grouper, *Mycteroperca bonaci*
- Coney, *Cephalopholis fulva*
- Graysby, *Cephalopholis cruentata*
- Misty grouper, *Epinephelus mystacinus*
- Red grouper, *Epinephelus morio*
- Red hind, *Epinephelus gluttatus*
- Rock hind, *Epinephelus adscensionis*
- Scamp, *Mycteroperca phenax*
- Speckled hind, *Epinephelus drummondhayi*
- Tiger grouper, *Mycteroperca tigris*
- Warsaw grouper, *Epinephelus nigritus*
- Yellowedge grouper, *Epinephelus flavolimbatus*
- Yellowfin grouper, *Mycteroperca venenosa*
- Yellowmouth grouper, *Mycteroperca interstitialis*
- Unclassified groupers, Family Serranidae

Other porgies
- Jolthead porgy, *Calamus bajonado*
- Knobbed porgy, *Calamus nodosus*
- Littlehead porgy, *Calamus proridens*
- Longspine porgy, *Stenotomus caprinus*
- Saucereye porgy, *Calamus calamus*
- Scup, *Stenotomus chrysops*
- Spottail pinfish, *Diplodus holbrookii*
- Whitebone porgy, *Calamus leucosteus*
- Unclassified porgies, Family Sparidae

Other sea basses
- Bank sea bass, *Centropristis ocyurus*
- Rock sea bass, *Centropristis philadelphica*

Other snappers
- Black snapper, *Apsilus dentatus*
- Blackfin snapper, *Lutjanus buccanella*
- Cubera snapper, *Lutjanus cyanopterus*
- Gray (mangrove) snapper, *Lutjanus griseus*
- Lane snapper, *Lutjanus synagris*
- Mahogany snapper, *Lutjanus mahogoni*
- Mutton snapper, *Lutjanus analis*
- Queen snapper, *Etelis oculatus*
- Schoolmaster, *Lutjanus apodus*
- Silk snapper, *Lutjanus vivanus*
- Yellowtail snapper, *Ocyurus chrysurus*
- Unclassified snappers, Family Lutjanidae

Other species
- Angelfishes, Family Pomacanthidae
- Atlantic spadefish, *Chaetodipterus faber*
- Blackline tilefish, *Caulolatilus cyanops*
- Blueline tilefish, *Caulolatilus microps*
- Gray triggerfish, *Balistes capriscus*
- Great barracuda, *Sphyraena barracuda*
- Hogfish, *Lachnolaimus maximus*
- Ocean triggerfish, *Canthidermis sufflamen*
- Queen triggerfish, *Balistes vetula*
- Sheepshead, *Archosargus probatocephalus*
- Other tilefishes, Family Malacanthidae
- Other triggerfishes, Family Balistidae

Caribbean

Nassau grouper, *Epinephelus striatus*

Grunts
- Bluestriped grunt, *Haemulon sciurus*
- French grunt, *Haemulon flavolineatum*
- Margate, *Haemulon album*
- Tomtate, *Haemulon aurolineatum*
- White grunt, *Haemulon plumierii*
- Unclassified grunts, Family Haemulidae

Other groupers
- Coney, *Cephalopholis fulva*
- Graysby, *Cephalopholis cruentata*
- Red hind, *Epinephelus guttatus*
- Rock hind, *Epinephelus adscensionis*
- Yellowfin grouper, *Mycteroperca venenosa*
- Yellowmouth grouper, *Mycteroperca interstitialis*

- Unclassified groupers, Family Serranidae

Snappers

- Black snapper, *Apsilus dentatus*
- Blackfin snapper, *Lutjanus buccanella*
- Lane snapper, *Lutjanus synagris*
- Mahogany snapper, *Lutjanus mahogoni*
- Mutton snapper, *Lutjanus analis*
- Queen snapper, *Etelis oculatus*
- Schoolmaster, *Lutjanus apodus*
- Silk snapper, *Lutjanus vivanus*
- Vermilion snapper, *Rhomboplites aurorubens*
- Yellowtail snapper, *Ocyurus chrysurus*
- Unclassified snappers, Family Lutjanidae

Other species

- Atlantic spadefish, *Chaetodipterus faber*
- Bar jack, *Carangoides ruber*
- Bigeye, *Priacanthus arenatus*
- Bigeye scad, *Selar crumenophthalmus*
- Black durgon, *Melichthys niger*
- Black jack, *Caranx lugubris*
- Blue parrotfish, *Scarus coeruleus*
- Blue runner, *Caranx crysos*
- Blue tang, *Acanthurus coeruleus*
- Crevalle jack, *Caranx hippos*
- Doctorfish, *Acanthurus chirurgus*
- French angelfish, *Pomacanthus paru*
- Gray angelfish, *Pomacanthus arcuatus*
- Gray triggerfish, *Balistes capriscus*
- Greater amberjack, *Seriola dumerili*
- Hogfish, *Lachnolaimus maximus*
- Honeycomb cowfish, *Acanthostracion polygonius*
- Horse-eye jack, *Caranx latus*
- Jolthead porgy, *Calamus bajonado*
- Longspine squirrelfish, *Holocentrus rufus*
- Lookdown, *Selene vomer*
- Midnight parrotfish, *Scarus coelestinus*
- Mutton hamlet, *Alphestes afer*
- Ocean surgeon, *Acanthurus bahianus*
- Ocean triggerfish, *Canthidermis sufflamen*
- Porkfish, *Anisotremus virginicus*
- Princess parrotfish, *Scarus taeniopterus*
- Puddingwife, *Halichoeres radiatus*
- Queen angelfish, *Holacanthus ciliaris*
- Queen parrotfish, *Scarus vetula*
- Rainbow parrotfish, *Scarus guacamaia*
- Redband parrotfish, *Sparisoma aurofrenatum*
- Redtail parrotfish, *Sparisoma chrysopterum*
- Rock beauty, *Holacanthus tricolor*
- Scrawled cowfish, *Acanthostracion quadricornis*
- Sea bream, *Archosargus rhomboidalis*
- Sheepshead porgy, *Calamus penna*
- Smooth trunkfish, *Lactophrys triqueter*
- Spanish hogfish, *Bodianus rufus*
- Spotfin butterflyfish, *Chaetodon ocellatus*
- Spotted goatfish, *Pseudupeneus maculatus*
- Spotted trunkfish, *Lactophrys bicaudalis*
- Squirrelfish, *Holocentrus adscensionis*
- Stoplight parrotfish, *Sparisoma viride*
- Striped parrotfish, *Scarus iseri*
- Trunkfish, *Lactophrys trigonus*
- Yellow goatfish, *Mulloidichthys martinicus*
- Yellow jack, *Caranx bartholomaei*
- Yellowtail parrotfish, *Sparisoma rubripinne*

Gulf of Mexico

- Goliath grouper, *Epinephelus itajara*
- Gray triggerfish, *Balistes capriscus*
- Nassau grouper, *Epinephelus striatus*
- Red grouper, *Epinephelus morio*
- Red snapper, *Lutjanus campechanus*
- Vermilion snapper, *Rhomboplites aurorubens*
- Amberjacks
    - Almaco jack, *Seriola rivoliana*
    - Greater amberjack, *Seriola dumerili*
    - Lesser amberjack, *Seriola fasciata*
    - Unclassified amberjacks, *Seriola* spp.
- Grunts
    - Bluestriped grunt, *Haemulon sciurus*
    - French grunt, *Haemulon flavolineatum*
    - White grunt, *Haemulon plumierii*
    - Unclassified grunts, Family Haemulidae
- Shallow groupers
    - Black grouper, *Mycteroperca bonaci*
    - Gag, *Mycteroperca microlepis*
    - Red hind, *Epinephelus guttatus*
    - Rock hind, *Epinephelus adscensionis*

Scamp, *Mycteroperca phenax*
Speckled hind, *Epinephelus drummondhayi*
Yellowfin grouper, *Mycteroperca venenosa*
Other groupers
Misty grouper, *Epinephelus mystacinus*
Snowy grouper, *Epinephelus niveatus*
Warsaw grouper, *Epinephelus nigritus*
Yellowedge grouper, *Epinephelus flavolimbatus*
Yellowmouth grouper, *Mycteroperca interstitialis*
Unclassified groupers, Family Serranidae
Other snappers
Black snapper, *Apsilus dentatus*
Blackfin snapper, *Lutjanus buccanella*
Cubera snapper, *Lutjanus cyanopterus*
Dog snapper, *Lutjanus jocu*
Gray (mangrove) snapper, *Lutjanus griseus*
Lane snapper, *Lutjanus synagris*
Mahogany snapper, *Lutjanus mahogoni*
Mutton snapper, *Lutjanus analis*
Queen snapper, *Etelis oculatus*
Schoolmaster, *Lutjanus apodus*
Silk snapper, *Lutjanus vivanus*
Yellowtail snapper, *Ocyurus chrysurus*
Unclassified snappers, Family Lutjanidae
Other species
Angelfishes, Family Pomacanthidae
Atlantic spadefish, *Chaetodipterus faber*
Bank sea bass, *Centropristis ocyurus*
Black sea bass, *Centropristis striata*
Blackline tilefish, *Caulolatilus cyanops*
Blueline tilefish, *Caulolatilus microps*
Blue runner, *Caranx crysos*
Crevalle jack, *Caranx hippos*
Dash-dot goatfish, *Parupeneus barberinus*
Great barracuda, *Sphyraena barracuda*
Hogfish, *Lachnolaimus maximus*
Jolthead porgy, *Calamus bajonado*
Knobbed porgy, *Calamus nodosus*
Littlehead porgy, *Calamus proridens*
Longspine porgy, *Stenotomus caprinus*
Ocean triggerfish, *Canthidermis sufflamen*
Queen triggerfish, *Balistes vetula*
Red porgy, *Pagrus pagrus*
Rock sea bass, *Centropristis philadelphica*
Sheepshead, *Archosargus probatocephalus*
Tilefish, *Lopholatilus chamaeleonticeps*
Whitebone porgy, *Calamus leucosteus*
Other tilefishes, Family Malacanthidae
Other triggerfishes, Family Balistidae

Unit 9: Southeast Drum and Croaker Fisheries

Atlantic croaker, *Micropogonias undulatus*
Black drum, *Pogonias cromis*
Kingfishes (whiting), *Menticirrhus* spp.
Red drum, *Sciaenops ocellatus*
Sand seatrout, *Cynoscion arenarius*
Silver seatrout, *Cynoscion nothus*
Spot, *Leiostomus xanthurus*
Spotted seatrout, *Cynoscion nebulosus*
Weakfish (grey seatrout), *Cynoscion regalis*
Other seatrouts, *Cynoscion* spp.

Unit 10: Southeast Menhaden Fisheries

Atlantic menhaden, *Brevoortia tyrannus*
Gulf menhaden, *Brevoortia patronus*

Unit 11: Southeast and Caribbean Invertebrate Fisheries

Brown shrimp, *Farfantepenaeus aztecus*
Caribbean spiny lobster, *Panulirus argus*
Golden deepsea crab, *Chaceon fenneri*
Pink shrimp, *Farfantepenaeus duorarum*
Queen conch, *Strombus gigas*
Rock shrimp, *Sicyonia brevirostris*
Royal red shrimp, *Pleoticus robustus*
Seabob shrimp, *Xiphopenaeus kroyeri*
Soft corals (gorgonians and sea fans), Order Gorgonacea
Stone crabs, *Menippe* spp.
Stony corals, Order Scleractinia
White shrimp, *Litopenaeus setiferus*
Other conchs, *Strombus* spp.

Units 12 and 13: Pacific Coast and Alaska Salmon Fisheries

Chinook salmon, *Oncorhynchus tshawytscha*
Chum salmon, *Oncorhynchus keta*
Coho salmon, *Oncorhynchus kisutch*
Pink salmon, *Oncorhynchus gorbuscha*
Sockeye salmon, *Oncorhynchus nerka*

Unit 14: Pacific Coast and Alaska Pelagic Fisheries

California market (opalescent inshore) squid, *Loligo opalescens*
Jack mackerel, *Trachurus symmetricus*
Northern anchovy, *Engraulis mordax*
Pacific herring, *Clupea pallasii*
Pacific chub mackerel, *Scomber japonicus*
Pacific sardine, *Sardinops sagax*

Unit 15: Pacific Coast Groundfish Fisheries

Flatfish
- Arrowtooth flounder, *Atheresthes stomias*
- Dover sole, *Microstomus pacificus*
- English sole, *Parophrys vetulus*
- Petrale sole, *Eopsetta jordani*
- Other flatfishes
  - Butter sole, *Isopsetta isolepis*
  - Curlfin sole, *Pleuronichthys decurrens*
  - Flathead sole, *Hippoglossoides elassodon*
  - Pacific sanddab, *Citharichthys sordidus*
  - Rex sole, *Glyptocephalus zachirus*
  - Rock sole, *Lepidopsetta bilineata*
  - Sand sole, *Psettichthys melanostictus*
  - Starry flounder, *Platichthys stellatus*

Rockfish
- Black rockfish, *Sebastes melanops*
- Blackgill rockfish, *Sebastes melanostomus*
- Bocaccio, *Sebastes paucispinis*
- Canary rockfish, *Sebastes pinniger*
- Chilipepper, *Sebastes goodei*
- Cowcod, *Sebastes levis*
- Darkblotched rockfish, *Sebastes crameri*
- Longspine thornyhead, *Sebastolobus altivelis*
- Pacific ocean perch, *Sebastes alutus*
- Shortbelly rockfish, *Sebastes jordani*
- Shortspine thornyhead, *Sebastolobus alascanus*
- Splitnose rockfish, *Sebastes diploproa*
- Widow rockfish, *Sebastes entomelas*
- Yelloweye rockfish, *Sebastes ruberrimus*
- Yellowtail rockfish, *Sebastes flavidus*
- Other rockfishes
  - Aurora rockfish, *Sebastes aurora*
  - Bank rockfish, *Sebastes rufus*
  - Black-and-yellow rockfish, *Sebastes chrysomelas*
  - Blue rockfish, *Sebastes mystinus*
  - Bronzespotted rockfish, *Sebastes gilli*
  - Brown rockfish, *Sebastes auriculatus*
  - Calico rockfish, *Sebastes dallii*
  - California scorpionfish, *Scorpaena guttata*
  - Chameleon rockfish, *Sebastes phillipsi*
  - China rockfish, *Sebastes nebulosus*
  - Copper rockfish, *Sebastes caurinus*
  - Dusky rockfish, *Sebastes ciliatus*
  - Dwarf-red rockfish, *Sebastes rufinanus*
  - Flag rockfish, *Sebastes rubrivinctus*
  - Freckled rockfish, *Sebastes lentiginosus*
  - Gopher rockfish, *Sebastes carnatus*
  - Grass rockfish, *Sebastes rastrelliger*
  - Greenblotched rockfish, *Sebastes rosenblatti*
  - Greenspotted rockfish, *Sebastes chlorostictus*
  - Greenstriped rockfish, *Sebastes elongatus*
  - Halfbanded rockfish, *Sebastes semicinctus*
  - Harlequin rockfish, *Sebastes variegatus*
  - Honeycomb rockfish, *Sebastes umbrosus*
  - Kelp rockfish, *Sebastes atrovirens*
  - Mexican rockfish, *Sebastes macdonaldi*
  - Olive rockfish, *Sebastes serranoides*
  - Pink rockfish, *Sebastes eos*
  - Pinkrose rockfish, *Sebastes simulator*
  - Puget Sound rockfish, *Sebastes emphaeus*
  - Pygmy rockfish, *Sebastes wilsoni*
  - Quillback rockfish, *Sebastes maliger*
  - Redbanded rockfish, *Sebastes babcocki*
  - Redstripe rockfish, *Sebastes proriger*
  - Rosethorn rockfish, *Sebastes helvomaculatus*
  - Rosy rockfish, *Sebastes rosaceus*
  - Rougheye rockfish, *Sebastes aleutianus*
  - Semaphore rockfish, *Sebastes melanosema*
  - Sharpchin rockfish, *Sebastes zacentrus*

Shortraker rockfish, *Sebastes borealis*
Silvergray rockfish, *Sebastes brevispinis*
Speckled rockfish, *Sebastes ovalis*
Squarespot rockfish, *Sebastes hopkinsi*
Starry rockfish, *Sebastes constellatus*
Stripetail rockfish, *Sebastes saxicola*
Swordspine rockfish, *Sebastes ensifer*
Tiger rockfish, *Sebastes nigrocinctus*
Treefish, *Sebastes serriceps*
Vermilion rockfish, *Sebastes miniatus*
Yellowmouth rockfish, *Sebastes reedi*

Other groundfish
Cabezon, *Scorpaenichthys marmoratus*
Lingcod, *Ophiodon elongatus*
Pacific cod, *Gadus macrocephalus*
Pacific hake (whiting), *Merluccius productus*
Sablefish (blackcod), *Anoplopoma fimbria*
Other groundfishes
Big skate, *Raja binoculata*
California skate, *Raja inornata*
Kelp greenling, *Hexagrammos decagrammus*
Leopard shark, *Triakis semifasciata*
Longnose skate, *Raja rhina*
Pacific flatnose, *Antimora microlepis*
Pacific grenadier (rattail), *Coryphaenoides acrolepis*
Spiny dogfish, *Squalus acanthias*
Spotted ratfish, *Hydrolagus colliei*
Tope, *Galeorhinus galeus*

Unit 16: Western Pacific Invertebrate Fisheries

Aesop slipper lobster, *Scyllarides haanii*
Bamboo corals, *Lepidisis olapa*, *Acanella* spp.
Banded (Hawaiian) spiny lobster, *Panulirus marginatus*
Black corals, *Antipathes dichotoma*, *A. grandis, Myriopathes ulex*
Blunt slipper lobster (ula-pāpapa), *Scyllarides squammosus*
Gold corals, *Callogorgia gilberti*, *Calyptrophora* spp., *Gerardia* spp., *Narella* spp.
Pink corals, *Corallium* spp.
Pronghorn spiny lobster (ʻula hiwa), *Panulirus penicillatus*
Sculptured mitten lobster (ula-pehu), *Parribacus antarcticus*
White telesto (invasive soft coral), *Carijoa riisei*

Unit 17: Western Pacific Bottomfish and Groundfish Fisheries

Bottomfish
Snappers, Family Lutjanidae
Crimson jobfish (opakapaka), *Pristipomoides filamentosus*
Flame snapper (onaga), *Etelis coruscans*
Green jobfish (uku), *Aprion virescens*
Oblique-banded snapper (gindai), *Pristopomoides zonatus*
Ruby snapper (ehu), *Etelis carbunculus*
Jacks, Family Carangidae
Jacks (ulua), *Caranx* spp.
White trevally (butaguchi), *Pseudocaranx dentex*
Groupers, Family Serranidae
Hawaiian grouper (hapu'upu'u), *Epinephelus quernus*
Emperors, Family Lethrinidae

Seamount groundfish
Alfonsino, *Beryx splendens*
North Pacific armorhead, *Pseudopentaceros wheeleri*
Raftfish, *Hyperoglyphe japonica*

Unit 18: Pacific Highly Migratory Pelagic Fisheries

Tropical tunas
Bigeye tuna, *Thunnus obesus*
Skipjack tuna, *Katsuwonus pelamis*
Yellowfin tuna, *Thunnus albacares*

Temperate tunas
Albacore, *Thunnus alalunga*
Pacific bluefin tuna, *Thunnus orientalis*

Billfish
Black marlin, *Istiompax indica*
Blue marlin, *Makaira nigricans*
Sailfish, *Istiophorus platypterus*
Shortbill spearfish, *Tetrapturus angustirostris*
Striped marlin, *Kajikia audax*
Swordfish, *Xiphias gladius*

Oceanic sharks
Megamouth shark, *Megachasma pelagios*
Mackerel sharks, Family Lamnidae
Shortfin mako, *Isurus oxyrinchus*
White shark, *Carcharodon carcharias*
Requiem sharks, Family Carcharhinidae
Blue shark, *Prionace glauca*
Thresher sharks, Family Alopiidae

Bigeye thresher, *Alopias superciliosus*
Pelagic thresher, *Alopias pelagicus*
Thresher shark, *Alopias vulpinus*
Other migratory species
Dolphinfish (mahi mahi), *Coryphaena hippurus*
Wahoo, *Acanthocybium solandri*

Unit 19: Alaska Groundfish Fisheries
Pacific halibut, *Hippoglossus stenolepis*
Flatfish
Alaska plaice, *Pleuronectes quadrituberculatus*
Arrowtooth flounder, *Reinhardtius stomias*
Flathead sole, *Hippoglossoides elassodon*
Greenland halibut, *Reinhardtius hippoglossoides*
Northern rock sole, *Lepidopsetta polyxystra*
Rex sole, *Glyptocephalus zachirus*
Yellowfin sole, *Limanda aspera*
BSAI Other Flatfishes
Arctic flounder, *Pleuronectes glacialis*
Butter sole, *Isopsetta isolepis*
Curlfin sole, *Pleuronichthys decurrens*
Deepsea sole, *Microstomus bathybius*
Dover sole, *Microstomus pacificus*
English sole, *Parophrys vetulus*
Longhead dab, *Limanda proboscidea*
Pacific sanddab, *Citharichthys sordidus*
Petrale sole, *Eopsetta jordani*
Rex sole, *Glyptocephalus zachirus*
Roughscale sole, *Clidoderma asperrimum*
Sakhalin sole, *Limanda sakhalinensis*
Sand sole, *Psettichthys melanostictus*
Slender sole, *Lyopsetta exilis*
Starry flounder, *Platichthys stellatus*
Gulf of Alaska Deepwater Flatfishes
Deepsea sole, *Microstomus bathybius*
Dover sole, *Microstomus pacificus*
Greenland halibut, *Reinhardtius hippoglossoides*
Gulf of Alaska Shallow Water Flatfishes
Alaska plaice, *Pleuronectes quadrituberculatus*
Butter sole, *Iopsetta isolepis*
C-O sole, *Pleuronichthys coenosus*
Curlfin sole, *Pleuronichthys decurrens*
English sole, *Parophrys vetulus*
Northern rock sole, *Lepidopsetta polyxystra*
Pacific sanddab, *Citharichthys sordidus*
Petrale sole, *Eopsetta jordani*
Rock sole, *Lepidopsetta bilineata*
Sand sole, *Psettichthys melanostictus*
Slender sole, *Lyopsetta exilis*
Speckled sanddab, *Citharichthys stigmaeus*
Starry flounder, *Platichthys stellatus*
Yellowfin sole, *Limanda aspera*
Rockfish
Northern rockfish, *Sebastes polyspinis*
Pacific ocean perch, *Sebastes alutus*
Rougheye rockfish, *Sebastes aleutianus*
Shortraker rockfish, *Sebastes borealis*
BSAI Other Rockfishes
Dark rockfish, *Sebastes ciliatus*
Dusky rockfish, *Sebastes variabilis*
Harlequin rockfish, *Sebastes variegatus*
Redbanded rockfish, *Sebastes babcocki*
Redstripe rockfish, *Sebastes proriger*
Sharpchin rockfish, *Sebastes zacentrus*
Shortspine thornyhead, *Sebastolobus alascanus*
Yelloweye rockfish, *Sebastes ruberrimus*
Gulf of Alaska Demersal Shelf Rockfishes
Canary rockfish, *Sebastes pinniger*
China rockfish, *Sebastes nebulosus*
Copper rockfish, *Sebastes caurinus*
Quillback rockfish, *Sebastes maliger*
Rosethorn rockfish, *Sebastes helvomaculatus*
Tiger rockfish, *Sebastes nigrocinctus*
Yelloweye rockfish, *Sebastes ruberrimus*
Gulf of Alaska Other Slope Rockfishes
Blackgill rockfish, *Sebastes melanostomus*
Bocaccio, *Sebastes paucispinis*
Chilipepper, *Sebastes goodei*
Darkblotched rockfish, *Sebastes crameri*
Greenstriped rockfish, *Sebastes elongatus*
Harlequin rockfish, *Sebastes variegatus*
Northern rockfish, *Sebastes polyspinis*
Pygmy rockfish, *Sebastes wilsoni*
Redbanded rockfish, *Sebastes babcocki*
Redstripe rockfish, *Sebastes proriger*
Sharpchin rockfish, *Sebastes zacentrus*

Silvergray rockfish, *Sebastes brevispinis*
Splitnose rockfish, *Sebastes diploproa*
Stripetail rockfish, *Sebastes saxicola*
Vermilion rockfish, *Sebastes miniatus*
Yellowmouth rockfish, *Sebastes reedi*
Gulf of Alaska Pelagic Shelf Rockfishes
Dark rockfish, *Sebastes ciliatus*
Dusky rockfish, *Sebastes variabilis*
Widow rockfish, *Sebastes entomelas*
Yellowtail rockfish, *Sebastes flavidus*
Gulf of Alaska Thornyheads
Longspine thornyhead, *Sebastolobus altivelis*
Shortspine thornyhead, *Sebastolobus alascanus*
Other Groundfish
Atka mackerel, *Pleurogrammus monopterygius*
Pacific cod, *Gadus macrocephalus*
Sablefish (blackcod), *Anoplopoma fimbria*
Walleye pollock, *Theragra chalcogramma*
BSAI Other Species
Pacific sleeper shark, *Somniosus pacificus*
Salmon shark, *Lamna ditropis*
Spiny dogfish, *Squalus acanthias*
Antlered sculpin, *Enophrys diceraus*
Arctic staghorn sculpin, *Gymnocanthus tricuspis*
Armorhead sculpin, *Gymnocanthus galeatus*
Banded Irish lord, *Hemilepidotus gilberti*
Bigmouth sculpin, *Hemitripterus bolini*
Blackfin sculpin, *Malacocottus kincaidi*
Blacknose sculpin, *Icelus canaliculatus*
Blob sculpin, *Psychrolutes phrictus*
Bride sculpin, *Artediellus miacanthus*
Broadfin sculpin, *Bolinia euryptera*
Butterfly sculpin, *Melletes papilio*
Crested sculpin, *Blepsias bilobus*
Darkfin sculpin, *Malacocottus zonurus*
Eyeshade sculpin, *Nautichthys pribilovius*
Flabby sculpin, *Zesticelus profundorum*
Fourhorn sculpin, *Myoxocephalus quadricornis*
Great sculpin, *Myoxocephalus polyacanthocephalus*
Grunt sculpin, *Rhamphocottus richardsonii*
Highbrow (crescent-tail) sculpin, *Triglops metopias*
Hookhorn sculpin, *Artediellus pacificus*
Leister sculpin, *Enophrys lucasi*
Longfin Irish lord, *Hemilepidotus zapus*
Longfin sculpin, *Jordania zonope*
Northern sculpin, *Icelinus borealis*
Pacific staghorn sculpin, *Leptocottus armatus*
Plain sculpin, *Myoxocephalus jaok*
Purplegray sculpin, *Gymnocanthus detrisus*
Red Irish lord, *Hemilepidotus hemilepidotus*
Ribbed sculpin, *Triglops pingelii*
Roughspine sculpin, *Triglops macellus*
Roughskin sculpin, *Rastrinus scutiger*
Sailfin sculpin, *Nautichthys oculofasciatus*
Scaled sculpin, *Archistes biseriatus*
Scalybreasted sculpin, *Triglops xenostethus*
Scissortail sculpin, *Triglops forficatus*
Slim sculpin, *Radulinus asprellus*
Smoothcheek sculpin, *Eurymen gyrinus*
Spatulate sculpin, *Icelus spatula*
Spectacled sculpin, *Triglops scepticus*
Spinyhead sculpin, *Dasycottus setiger*
Sponge sculpin, *Thyriscus anoplus*
Tadpole sculpin, *Psychrolutes paradoxus*
Thorny sculpin, *Icelus spiniger*
Threaded sculpin, *Gymnocanthus pistilliger*
Uncinate sculpin, *Icelus uncinalis*
Warty sculpin, *Myoxocephalus verrucosus*
Wide-eye sculpin, *Icelus euryops*
Yellow Irish lord, *Hemilepidotus jordani*
Flapjack octopus, *Opisthoteuthis californiana*
Giant octopus, *Enteroctopus dofleini*
Pelagic octopus, *Japetella diaphana*
Smoothskin octopus, *Benthoctopus leioderma*
Spoonarm octopus, *Bathypolypus arcticus*
Octopus *Benthoctopus oregonensis*

Octopus *Graneledone boreopacifica*
Berry armhook squid, *Gonatus berryi*
Boreopacific armhook squid, *Gonatopsis borealis*
Clawed armhook squid, *Gonatus onyx*
Fiery armhook squid, *Gonatus pyros*
Flowervase jewel squid, *Histioteuthis hoylei*
Madokai armhook squid, *Gonatus madokai*
Magister armhook squid, *Berryteuthis magister magister*
Makko armhook squid, *Gonatopsis makko*
Minimal armhook squid, *Berryteuthis anonychus*
Robust clubhook squid, *Moroteuthis robusta*
North Pacific bobtail squid, *Rossia pacifica*
Squid *Belonella borealis*
Squid *Chiroteuthis calyx*
Squid *Cranchia scabra*
Squid *Eogonatus tinro*
Squid *Galiteuthis phyllura*
Squid *Gonatus kamtschaticus*
Alaska skate, *Bathyraja parmifera*
Aleutian skate, *Bathyraja aleutica*
Big skate, *Raja binoculata*
Butterfly skate, *Bathyraja mariposa*
Commander skate, *Bathyraja lindbergi*
Deepsea skate, *Bathyraja abyssicola*
Mud skate, *Bathyraja hubbsi*
Okhotsk skate, *Bathyraja violacea*
Roughshoulder skate, *Amblyraja badia*
Roughtail skate, *Bathyraja trachura*
Sandpaper (Bering) skate, *Bathyraja interrupta*
Whiteblotched skate, *Bathyraja maculata*
Whitebrow skate, *Bathyraja minispinosa*

Gulf of Alaska Other Species

Pacific sleeper shark, *Somniosus pacificus*
Salmon shark, *Lamna ditropis*
Spiny dogfish, *Squalus acanthias*
Antlered sculpin, *Enophrys diceraus*
Armorhead sculpin, *Gymnocanthus galeatus*
Bigmouth sculpin, *Hemitripterus bolini*
Blackfin sculpin, *Malacocottus kincaidi*
Blob sculpin, *Psychrolutes phrictus*
Brightbelly sculpin, *Microcottus sellaris*
Brown Irish lord, *Hemilepidotus spinosus*
Buffalo sculpin, *Enophrys bison*
Crested sculpin, *Blepsias bilobus*
Darkfin sculpin, *Malacocottus zonurus*
Dusky sculpin, *Icelinus burchami*
Eyeshade sculpin, *Nautichthys pribilovius*
Fourhorn sculpin, *Myoxocephalus quadricornis*
Frog sculpin, *Myoxocephalus stelleri*
Frogmouth sculpin, *Icelinus oculatus*
Great sculpin, *Myoxocephalus polyacanthocephalus*
Grunt sculpin, *Rhamphocottus richardsonii*
Hookear sculpins, *Artediellus* spp.
Longfin sculpin, *Jordania zonope*
Northern sculpin, *Icelinus borealis*
Pacific staghorn sculpin, *Leptocottus armatus*
Plain sculpin, *Myoxocephalus jaok*
Red Irish lord, *Hemilepidotus hemilepidotus*
Ribbed sculpin, *Triglops pingelii*
Roughskin sculpin, *Rastrinus scutiger*
Roughspine sculpin, *Triglops macellus*
Sailfin sculpin, *Nautichthys oculofasciatus*
Scissortail sculpin, *Triglops forficatus*
Silverspotted sculpin, *Blepsias cirrhosus*
Slim sculpin, *Radulinus asprellus*
Smoothcheek sculpin, *Eurymen gyrinus*
Smoothhead sculpin, *Artedius lateralis*
Spatulate sculpin, *Icelus spatula*
Spectacled sculpin, *Triglops scepticus*
Spinyhead sculpin, *Dasycottus setiger*
Sponge sculpin, *Thyriscus anoplus*
Spotfin sculpin, *Icelinus tenuis*
Tadpole sculpin, *Psychrolutes paradoxus*
Thorny sculpin, *Icelus spiniger*
Threaded sculpin, *Gymnocanthus pistilliger*

Threadfin sculpin, *Icelinus filamentosus*
Warty sculpin, *Myoxocephalus verrucosus*
Wide-eye sculpin, *Icelus euryops*
Yellow Irish lord, *Hemilepidotus jordani*
East Pacific red octopus, *Octopus rubescens*
Flapjack octopus, *Opisthoteuthis californiana*
Giant octopus, *Enteroctopus dofleini*
North Pacific bigeye octopus, *Octopus californicus*
Pelagic octopus, *Japetella diaphana*
Smoothskin octopus, *Benthoctopus leioderma*
Berry armhook squid, *Gonatus berryi*
Boreal clubhook squid, *Onychoteuthis borealijaponicus*
Clawed armhook squid, *Gonatus onyx*
Fiery armhook squid, *Gonatus pyros*
Flowervase jewel squid, *Histioteuthis hoylei*
Madokai armhook squid, *Gonatus madokai*
Magister armhook squid, *Berryteuthis magister magister*
Makko armhook squid, *Gonatopsis makko*
Minimal armhook squid, *Berryteuthis anonychus*
Octopus squid, *Octopoteuthis deletron*
Opalescent inshore squid, *Loligo opalescen*
Robust clubhook squid, *Moroteuthis robusta*
Vampire squid, *Vampyroteuthis infernalis*
Squid *Chiroteuthis calyx*
Squid *Cranchia scabra*
Squid *Eogonatus tinro*
Squid *Galiteuthis phyllura*
Squid *Gonatus kamtschaticus*
Alaska skate, *Bathyraja parmifera*
Aleutian skate, *Bathyraja aleutica*
Big skate, *Raja binoculata*
Deepsea skate, *Bathyraja abyssicola*
Longnose skate, *Raja rhina*
Roughshoulder skate, *Amblyraja badia*
Roughtail skate, *Bathyraja trachura*
Sandpaper (Bering) skate, *Bathyraja interrupta*
Whiteblotched skate, *Bathyraja maculata*

Unit 20: Alaska Shellfish Fisheries

King Crabs
- Blue king crab, *Paralithodes platypus*
- Golden (brown) king crab, *Lithodes aequispinus*
- Red king crab, *Paralithodes camtschaticus*
- Scarlet king crab, *Lithodes couesi*

Snow and Tanner Crabs
- Grooved Tanner crab, *Chionoecetes tanneri*
- Snow crab, *Chionoecetes opilio*
- Southern Tanner crab, *Chionoecetes bairdi*
- Triangle Tanner crab, *Chionoecetes angulatus*

Other Shellfishes
- Pink shrimp, *Farfantepenaeus duorarum*
- Sea snails, Class Gastropoda
- Other shrimps, Family Penaeidae

Unit 21: Marine Mammals of the Alaska Region

Seals and Sea Lions
- Bearded seal, *Erignathus barbatus*
- Harbor seal, *Phoca vitulina*
- Northern fur seal, *Callorhinus ursinus*
- Ribbon seal, *Histriophoca fasciata*
- Ringed seal, *Pusa hispida*
- Spotted seal, *Phoca largha*
- Steller sea lion, *Eumetopias jubatus*

Whales and Porpoises
- Baird's beaked whale, *Berardius bairdii*
- Beluga whale, *Delphinapterus leucas*
- Bowhead whale, *Balaena mysticetus*
- Common dolphin, *Delphinus delphis*
- Cuvier's beaked whale, *Ziphius cavirostris*
- Dall's porpoise, *Phocoenoides dalli*
- Fin whale, *Balaenoptera physalus*
- Gray whale, *Eschrichtius robustus*
- Harbor porpoise, *Phocoena phocoena*
- Humpback whale, *Megaptera novaeangliae*
- Killer whale, *Orcinus orca*
- Minke whale, *Balaenoptera acutorostrata*
- North Pacific right whale, *Eubalaena japonica*
- Pacific white-sided dolphin, *Lagenorhynchus obliquidens*

Sperm whale, *Physeter catodon*
Stejneger's beaked whale, *Mesoplodon stejnegeri*
Other Marine Mammals (USFWS jurisdiction)
Polar bear, *Ursus maritimus*
Sea otter, *Enhydra lutris*
Walrus, *Odobenus rosmarus*

Unit 22: Marine Mammals of the Pacific Region and Hawaii

Seals and Sea Lions
California sea lion, *Zalophus californianus*
Guadalupe fur seal, *Arctocephalus townsendi*
Harbor seal, *Phoca vitulina*
Hawaiian monk seal, *Monachus schauinslandi*
Northern elephant seal, *Mirounga angustirostris*
Northern fur seal, *Callorhinus ursinus*
Whales and Porpoises
Baird's beaked whale, *Berardius bairdii*
Blainville's beaked whale, *Mesoplodon densirostris*
Blue whale, *Balaenoptera musculus*
Bottlenose dolphin, *Tursiops truncatus*
Brydes whale, *Balaenoptera edeni*
Cuvier's beaked whale, *Ziphius cavirostris*
Dall's porpoise, *Phocoenoides dalli*
Dwarf sperm whale, *Kogia sima*
False killer whale, *Pseudorca crassidens*
Fin whale, *Balaenoptera physalus*
Fraser's dolphin, *Lagenodelphis hosei*
Harbor porpoise, *Phocoena phocoena*
Humpback whale, *Megaptera novaeangliae*
Killer whale, *Orcinus orca*
Long-beaked common dolphin, *Delphinus capensis*
Longman's beaked whale, *Indopacetus pacificus*
Melon-headed whale, *Peponocephala electra*
Mesoplodont beaked whales, *Mesoplodon* spp.
Minke whale, *Balaenoptera acutorostrata*
Northern right whale dolphin, *Lissodelphis borealis*
Pacific white-sided dolphin, *Lagenorhynchus obliquidens*
Pantropical spotted dolphin, *Stenella attenuata*
Pygmy killer whale, *Feresa attenuata*
Pygmy sperm whale, *Kogia breviceps*
Risso's dolphin, *Grampus griseus*
Rough-toothed dolphin, *Steno bredanensis*
Sei whale, *Balaenoptera borealis*
Short-finned pilot whale, *Globicephala macrorhynchus*
Sperm whale, *Physeter catodon*
Spinner dolphin, *Stenella longirostris*
Striped dolphin, *Stenella coeruleoalba*
Other Marine Mammals (USFWS jurisdiction)
Southern sea otter, *Enhydra lutris nereis*

Unit 23: Marine Mammals of the Atlantic Region and the Gulf of Mexico

Seals and Sea Lions
Grey seal, *Halichoerus grypus*
Harbor seal, *Phoca vitulina*
Harp seal, *Pagophilus groenlandicus*
Hooded seal, *Cystophora cristata*
Whales and Porpoises
Atlantic spotted dolphin, *Stenella frontalis*
Atlantic white-sided dolphin, *Lagenorhynchus acutus*
Blainville's beaked whale, *Mesoplodon densirostris*
Blue whale, *Balaenoptera musculus*
Bottlenose dolphin, *Tursiops truncatus*
Brydes whale, *Balaenoptera edeni*
Clymene dolphin, *Stenella clymene*
Common dolphin, *Delphinus delphis*
Cuvier's beaked whale, *Ziphius cavirostris*
Dwarf sperm whale, *Kogia sima*
False killer whale, *Pseudorca crassidens*
Fin whale, *Balaenoptera physalus*
Fraser's dolphin, *Lagenodelphis hosei*
Gervais' beaked whale, *Mesoplodon europaeus*
Harbor porpoise, *Phocoena phocoena*
Humpback whale, *Megaptera novaeangliae*
Killer whale, *Orcinus orca*
Long-finned pilot whale, *Globicephala melas*
Melon-headed whale, *Peponocephala electra*
Mesoplodont beaked whales, *Mesoplodon* spp.
Minke whale, *Balaenoptera acutorostrata*
North Atlantic right whale, *Eubalaena glacialis*
Northern bottlenose whale, *Hyperodon ampullatus*

Pantropical spotted dolphin, *Stenella attenuata*
Pygmy killer whale, *Feresa attenuata*
Pygmy sperm whale, *Kogia breviceps*
Risso's dolphin, *Grampus griseus*
Rough-toothed dolphin, *Steno bredanensis*
Sei whale, *Balaenoptera borealis*
Short-finned pilot whale, *Globicephala macrorhynchus*
Sperm whale, *Physeter catodon*
Spinner dolphin, *Stenella longirostris*
Striped dolphin, *Stenella coeruleoalba*
White-beaked dolphin, *Lagenorhynchus albirostris*
Other Marine Mammals (USFWS jurisdiction)
West Indian manatee, *Trichechus manatus*

Unit 24: Sea Turtles
Green sea turtle, *Chelonia mydas*
Hawksbill sea turtle, *Eretmochelys imbricata*
Kemp's ridley sea turtle, *Lepidochelys kempii*
Leatherback sea turtle, *Dermochelys coriacea*
Loggerhead sea turtle, *Caretta caretta*
Olive ridley sea turtle, *Lepidochelys olivacea*

Appendix 6: Acronyms and Abbreviations

1976 Act	Magnuson Fishery Conservation and Management Act of 1976
AABM	aggregate abundance-based management
ABC	acceptable biological catch; also allowable biological catch
ACIA	Arctic Climate Impact Assessment
ACL	Annual Catch Limit
ADCP	acoustic Doppler current profiler
ADFG	Alaska Department of Fish and Game
AFSC	Alaska Fisheries Science Center
AIDCP	Agreement on the International Dolphin Conservation Program
AMPDT	Atlantic Menhaden Plan Development Team
ASMFC	Atlantic States Marine Fisheries Commission
ASMI	Alaska Seafood Marketing Institute
ASSRT	Atlantic Sturgeon Status Review Team
ASTWG	Advanced Sampling Technology Working Group
ATCA	Atlantic Tunas Convention Act
AUV	autonomous underwater vehicle
B	biomass
B_{MSY}	biomass that on average will produce the maximum sustainable yield
BRD	bycatch reduction device
BSAI	Bering Sea/Aleutian Islands
CalCOFI	California Cooperative Oceanic Fisheries Investigations
CA/OR/WA	California, Oregon, and Washington
CDFG	California Department of Fish and Game
CDQ	community development quota
CETAP	Cetacean and Turtle Assessment Program
CFMC	Caribbean Fishery Management Council
cm	centimeter
CNMI	Commonwealth of the Northern Mariana Islands
CPS	coastal pelagic species
CPUE	catch per unit of effort
CT	computed tomography
CTD	conductivity, temperature, and depth sensor
CV	coefficient of variation
CWP	central western Pacific Ocean
CY	current yield
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane

DFO	Department of Fisheries and Oceans (Canada)
DFW	Division of Fish and Wildlife (U.S. Virgin Islands)
DNA	deoxyribonucleic acid
DPS	distinct population segment
DTS	Dover sole, thornyheads, and sablefish complex
dw	dressed weight
EAFM	ecosystem approach to fisheries management
EBS	eastern Bering Sea
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EO	Executive Order
ESA	Endangered Species Act
Est.	estimated
ESU	evolutionarily significant unit
F	fishing mortality rate
$F_{X\%}$	the fishing mortality rate that reduces the spawning stock biomass per recruit to X% of the amount present in the absence of fishing
$F_{X\%}$SPR	the fishing mortality rate expected to produce X% spawning potential ratio
F_{max}	rate of fishing mortality that results in the maximum level of yield per recruit
F_{MSY}	rate of fishing mortality that, if applied constantly, would produce the greatest yield from the fishery
F_r	recovery factor
FAO	Food and Agriculture Organization of the United Nations
FEP	Fisheries Ecosystem Plan
fm	fathom
FMC	Fishery Management Council
FMP	Fishery Management Plan
FP	fibropapillomatosis
FPA	Federal Power Act
FR	Federal Register
FSSI	Fish Stock Sustainability Index
FSV	Fishery Survey Vessel
F/V	fishing vessel
FWCA	Fish and Wildlife Coordination Act
FWCC	Fish and Wildlife Conservation Commission (Florida)
FY	fiscal year
GARM	Groundfish Assessment Review Meeting
GIS	Geographic Information System
GLM	General Linear Modeling
GMAC	Gulf Menhaden Advisory Committee
GMFMC	Gulf of Mexico Fishery Management Council
GOA	Gulf of Alaska
GPRA	Government Performance and Results Act
GPS	global positioning system
GSMFC	Gulf States Marine Fisheries Commission
HAPC	Habitat Area of Particular Concern
HARP	high-frequency acoustic recording package
HICEAS	Hawaiian Islands Cetacean and Ecosystem Assessment Survey
HMS	highly migratory species

IATTC	Inter-American Tropical Tuna Commission
ICCAT	International Commission for the Conservation of Atlantic Tunas
ICES	International Council for the Exploration of the Seas
IFQ	individual fishing quota
INPFC	International North Pacific Fisheries Commission
IPHC	International Pacific Halibut Commission
IPQ	individual processing quota
ISBM	individual stock-based management
ISC	Interim Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean
ITQ	individual transferable quota
IUCN	International Union for the Conservation of Nature
IUU	illegal, unreported, and unregulated fishing
IWC	International Whaling Commission
JV	joint venture
K	carrying capacity
kg	kilogram
kHz	kilohertz
km	kilometer
LAPP	limited access privilege program
lb	pound
LCS	large coastal shark
LIDAR	light detection and ranging
LMR	living marine resource
m	meter
M	instantaneous rate of natural mortality
MAFMC	Mid-Atlantic Fishery Management Council
MDNR	Mississippi Department of Natural Resources
MFMT	maximum fishing mortality threshold
MHI	Main Hawaiian Islands
mi	mile
MLPA	Marine Life Protection Act
mm	millimeter
MMPA	Marine Mammal Protection Act
MMS	Minerals Management Service (Department of Interior)
MNA	minimum number alive
MNP	maximum net productivity
MPA	marine protected area
MRFSS	Marine Recreational Fisheries Statistics Survey
MRIP	Marine Recreational Information Program
MSA	Magnuson-Stevens Fishery Conservation and Management Act (as amended through 11 October 1996; also called the Sustainable Fisheries Act)
MSRA	Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006
MSST	minimum spawning stock threshold
MSVPA	multispecies virtual population analysis
MSY	maximum sustainable yield
N_{min}	minimum population estimate
NASCO	North Atlantic Salmon Conservation Organization

NEFMC	New England Fishery Management Council
NEFSC	Northeast Fisheries Science Center
NEPA	National Environmental Policy Act
NERR	National Estuarine Research Reserve
NMFS	National Marine Fisheries Service
n.mi.	nautical mile
NOAA	National Oceanic and Atmospheric Administration
NPAFC	North Pacific Anadromous Fish Commission
NPFMC	North Pacific Fishery Management Council
NRC	National Research Council
NS	National Standard
NWFSC	Northwest Fisheries Science Center
NWHI	Northwestern Hawaiian Islands
Obs.	observed
OLO	*Our Living Oceans*
OLO 6th Edition	*Our Living Oceans. Report on the Status of U.S. Living Marine Resources, 6th Edition*
OLO '99	*Our Living Oceans. Report on the Status of U.S. Living Marine Resources, 1999*
OPC	optical plankton counter
OSP	optimum sustainable population
OY	optimal yield
p	probability
PBR	potential biological removal
PCB	polychlorinated biphenyl
PFMC	Pacific Fishery Management Council
PIFSC	Pacific Islands Fisheries Science Center
PIT	passive integrated transponder
ppt	parts per thousand
PSC	Pacific Salmon Commission
PSMFC	Pacific States Marine Fisheries Commission
R_{max}	maximum productivity rate
RAY	recent average yield
RCA	rockfish conservation area
RE	Regional Ecosystem
ROV	remotely operated vehicle
SAFMC	South Atlantic Fishery Management Council
SAR	Stock Assessment Report
SARC	Stock Assessment Review Committee
SAW	Stock Assessment Workshop
$SB_{X\%}$	spawning biomass at X% of the unfished level
SBR	spawning stock biomass per recruit
SCS	small coastal shark
SEDAR	Southeast Data, Assessment, and Review
SEFSC	Southeast Fisheries Science Center
SERO	Southeast Regional Office
SNE	southern New England
SONAR	sound navigation and ranging
SPR	spawning potential ratio; also spawner per recruit
SRT	Status Review Team
SSB	spawning stock biomass

SWFSC	Southwest Fisheries Science Center
t	metric tons
TAC	total allowable catch
TALFF	total allowable level of foreign fishing
TCCHINOOK	Joint Chinook Technical Committee
TED	turtle excluder device
TEWG	Turtle Expert Working Group
TMGC	Transboundary Management Guidance Committee
TRAC	Transboundary Resources Assessment Committee
UME	unusual mortality event
UNGA	United Nations General Assembly
U.S.C.	United States Code
USFWS	U.S. Fish and Wildlife Service
USVI	U.S. Virgin Islands
VMS	vessel monitoring system
VPR	video plankton recorder
WCPFC	Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific
WIMARCS	West Indies Marine Animal Research and Conservation Service
WPFMC	West Pacific Fishery Management Council

Appendix 7: ESA Listed Species

The following is a list of species under NMFS jurisdiction that are currently listed under the Endangered Species Act (ESA). Endangered Species are those species that are in danger of extinction throughout a significant portion of their range. Threatened Species are species that are likely to be become endangered within the foreseeable future.

Also listed here are Species of Concern, those species about which NMFS has some concerns regarding status and threats, but for which insufficient information is available to indicate a need to officially list the species under the ESA. Candidate Species are those species that are actively being considered for listing as either endangered or threatened under the ESA. Neither Candidate Species nor Species of Concern designations carry any procedural or substantive protections under the ESA.

For more information, please see the Species Information page at the NMFS Office of Protected Species website at http://www.nmfs.noaa.gov/pr/species/.

ENDANGERED SPECIES

Marine and Anadromous Fishes

Atlantic salmon (Gulf of Maine DPS)
Chinook salmon (Upper Columbia River spring-run ESU; Sacramento winter-run ESU)
Coho salmon (Central California coast ESU; listed as threatened in 1996, status changed to endangered in 2005)
Shortnose sturgeon
Sockeye salmon (Snake River ESU)
Smalltooth sawfish (U.S. portion of range DPS)
Steelhead trout (Southern California DPS)
Totoaba (foreign, no U.S. stocks)

Invertebrates

White abalone

Marine Mammals

Cetaceans
- Blue whale
- Bowhead whale
- Chinese River dolphin (baiji; foreign, no U.S. stocks)
- Fin whale
- Gray whale (Western North Pacific DPS; Eastern North Pacific DPS delisted in 1994)
- Gulf of California harbor porpoise (vaquita; foreign, no U.S. stocks)
- Humpback whale
- Indus River dolphin (foreign, no U.S. stocks)
- Killer whale (Southern Resident DPS)
- North Atlantic right whale
- North Pacific right whale
- Sei whale
- Southern right whale (foreign, no U.S. stocks)
- Sperm whale

Pinnipeds
- Caribbean monk seal (proposed for delisting in 2008—believed to be extinct)
- Hawaiian monk seal
- Mediterranean monk seal (foreign, no U.S. stocks)
- Saimaa seal (foreign, no U.S. stocks)

Steller sea lion (Western DPS; listed as threatened in 1990, status changed to endangered in 1997)

Sea Turtles

Green turtle (Florida & Mexico's Pacific Coast breeding colonies)
Hawksbill turtle
Kemp's ridley turtle
Leatherback turtle
Olive ridley turtle (Mexico's Pacific Coast breeding colonies)

THREATENED SPECIES

Marine and Anadromous Fishes

Chinook salmon (California coastal ESU; Central Valley spring-run ESU; Lower Columbia River ESU; Puget Sound ESU; Snake River fall-run ESU; Snake River spring/summer-run ESU; Upper Willamette River ESU)
Chum salmon (Columbia River ESU; Hood Canal summer-run ESU)
Coho salmon (Lower Columbia River ESU; Oregon Coast ESU; Southern Oregon & Northern California coasts ESU)
Green sturgeon (southern DPS)
Gulf sturgeon
Sockeye salmon (Ozette Lake ESU)
Steelhead trout (Central California Coast DPS; Central California Valley DPS; Lower Columbia River DPS; Middle Columbia River DPS; Northern California DPS; Puget Sound DPS; Snake River Basin DPS; South-Central California Coast DPS; Upper Columbia River DPS [listed as endangered in 1997, status changed to threatened in 2006]; Upper Willamette River DPS)

Invertebrates

Elkhorn coral
Staghorn coral

Marine Mammals

Guadalupe fur seal (foreign)
Steller sea lion (Eastern DPS)

Sea Turtles

Green turtle (all areas not listed as endangered)
Loggerhead turtle
Olive ridley turtle (all areas not listed as endangered)

Marine Plants

Johnson's seagrass

PROPOSED SPECIES

Marine and Anadromous Fishes

Atlantic salmon (Gulf of Maine other populations in streams and rivers in Maine outside the range of the listed Gulf of Maine DPS)

Invertebrates

Black abalone (Oregon, California, Baja California)

Marine Mammals

Beluga whale (Cook Inlet population)

CANDIDATE SPECIES

Marine and Anadromous Fishes

Atlantic sturgeon (Atlantic coastal waters)
Bocaccio (Puget Sound)
Canary rockfish (Puget Sound)
Cusk
Greenstriped rockfish (Puget Sound)
Pacific eulachon/smelt (Washington, Oregon, and California)
Pacific herring (southeastern Alaska)
Redstripe rockfish (Puget Sound)
Yelloweye rockfish (Puget Sound)

Marine Mammals

Bearded seal
Ribbon seal
Ringed seal
Spotted seal

SPECIES OF CONCERN

Marine and Anadromous Fishes

Alabama shad (Gulf of Mexico–Alabama, Florida)
Alewife (Newfoundland to North Carolina)
Atlantic halibut (Labrador to southern New England)
Atlantic wolffish (Georges Bank and western Gulf of Maine)
Barndoor skate (Newfoundland, Canada to Cape Hatteras, North Carolina)
Blueback herring (Cape Breton, Nova Scotia, to St. John's River, Florida)
Bocaccio (Southern DPS: Northern California to Mexico)
Bumphead parrotfish (Indo-Pacific-Red Sea and East Africa to the Line Islands and Samoa; north to Yaeyama, south to the Great Barrier Reef and New Caledonia; Paulau, Caroline, Mariana in Micronesia; in U.S. waters it occurs in Guam, American Samoa, CNMI, and the Pacific Remote Island Areas-Wake Islands)
Chinook salmon (Central Valley, fall and late fall-run ESU)
Coho salmon (Puget Sound/Strait of Georgia ESU)
Cowcod (Central Oregon to central Baja California and Guadalupe Island, Mexico)
Dusky shark (Atlantic; Gulf of Mexico; Pacific)
Green sturgeon (northern DPS, including coastal spawning populations from the Eel River north to the Klamath River)
Humphead wrasse (Indo-Pacific-Red Sea to Tuamotus, north to the Ryukyus, east to Wake Islands, south to New Caledonia, throughout Micronesia; includes U.S. territories of Guam and American Samoa)
Key silverside (Atlantic: Florida Keys)
Largetooth sawfish (Atlantic: Texas–Florida)
Mangrove rivulus (Atlantic: Florida)
Nassau grouper (North Carolina southward to Gulf of Mexico)
Night shark (Atlantic; Gulf of Mexico)
Opossum pipefish (Atlantic: Florida; Indian River Lagoon)
Pacific hake (Georgia Basin DPS)
Porbeagle shark (Newfoundland, Canada to New Jersey)
Rainbow smelt (Labrador to New Jersey)
Saltmarsh topminnow (Atlantic: Texas, Louisiana, Mississippi, Alabama, and Florida)
Sand tiger shark (Atlantic; Gulf of Mexico)
Speckled hind (North Carolina to Gulf of Mexico)
Steelhead trout (Oregon Coast ESU)
Striped croaker (Atlantic: Florida; Antilles and Caribbean from Costa Rica to Guyana)
Thorny skate (West Greenland to New York)
Warsaw grouper (Massachusetts southward to Gulf of Mexico)
White marlin (Atlantic)

Invertebrates

Green abalone (Point Conception, California to Bahia de Magdalena, Mexico)
Hawaiian reef coral (Hawaii: Kaneohe Bay; Midway Atoll; and Maro Reef)
Inarticulated brachiopod (Hawaii: Kaneohe Bay)
Ivory bush coral (West Indies, Bermuda, North Carolina, Florida, Gulf of Mexico, Caribbean)
Pink abalone (Point Conception, California, to Bahia de Tortuga, Mexico)
Pinto abalone (Sitka, Alaska, to Point Conception, California)

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