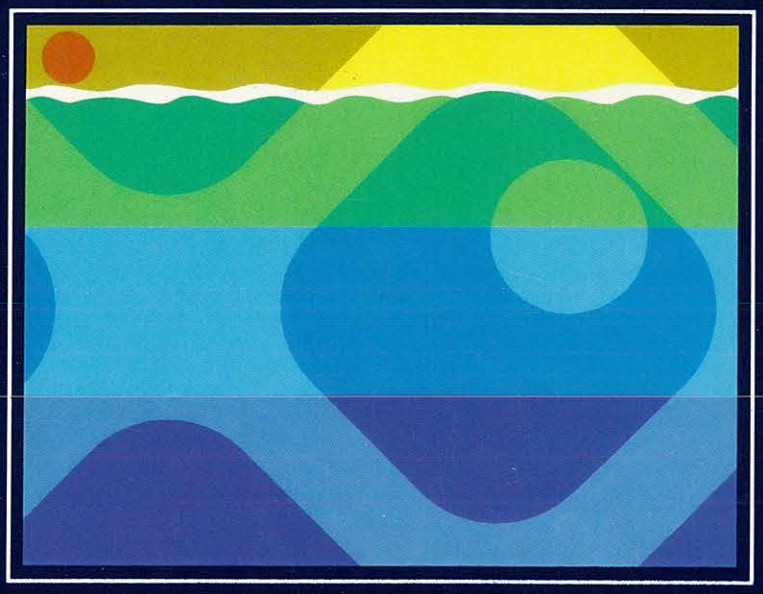
Our Living Oceans



1995
Executive Summary

United States
Department
of Commerce

Our Living Oceans

DUPLICATE
WITHDRAWN

1995
Executive Summary

REPORT ON THE STATUS OF U.S. LIVING MARINE RESOURCES

May 1996
NOAA Tech. Memo. NMFS-F/SPO-20

U.S. Department of Commerce

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Commemorating 125 Years of Federal Fisheries Science

During 1996, the National Marine Fisheries Service celebrates its 125th anniversary as the Nation's oldest natural resource conservation agency. In 1871, the United States Congress established the Commission of Fish and Fisheries. As an independent agency, the Commission's charge was to protect, manage, and restore the country's fisheries through scientific research.

In time, a new name was accorded the agency reflecting the growth in its responsibilities—the United States Bureau of Fisheries—and in 1903, a new home in the Department of Commerce and Labor. Following a 1939 reorganization into the Interior Department, the agency merged with the Biological Survey to become part of a new Fish and Wildlife Service in 1940. By 1956, the agency was again operating within the Interior Department as a distinct organization—the Bureau of Commercial Fisheries. The agency's last move came in 1970 when, under Executive Order 11564, the Bureau was renamed the National Marine Fisheries Service and placed in the newly created National Oceanic and Atmospheric Administration.

Katherine Zecca

From its inception, the Service has contributed broad scientific advances in marine biology, fisheries science, and oceanography. The vision of its first Commissioner, Spencer F. Baird, Secretary of the Smithsonian Institution and an eminent zoologist of his time, is honored by a continuing commitment to scientific excellence and Federal stewardship.

As part of the 125th anniversary celebration, the Service's Scientific Publications Office has published a chronicle of the agency's activities—"Baird's Legacy: The History and Accomplishments of NOAA's National Marine Fisheries Service, 1871–1996." ❑

Copies of this publication, as well as the full version of
Our Living Oceans 1995 (NOAA Tech. Memo.
NMFS-F/SPO-19), are available from:
National Marine Fisheries Service
Scientific Publications Office
7600 Sand Point Way NE
Seattle, WA 98115
206-526-6107

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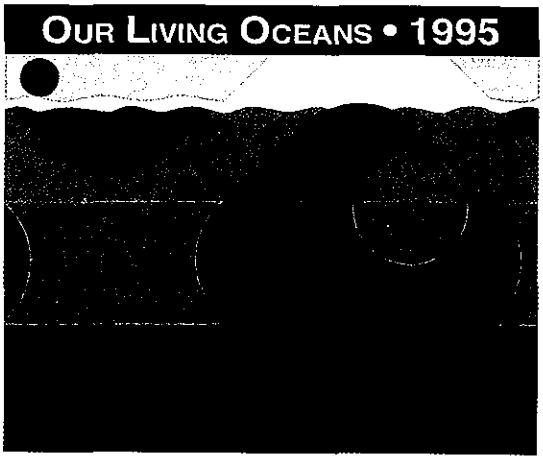

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Our Living Oceans

1995

Executive Summary

Preface

This publication is a compilation of the Executive Summary and feature articles of Our Living Oceans 1995 (OLO '95), the fourth volume in a recent series of reviews on the status of U.S. living marine resources. Full editions of "Our Living Oceans" were published for the years 1991, 1992, and 1993. The 1995 volume also inaugurated a biennial reporting schedule; this schedule better captures the often extended period of time required to observe and document changes in the marine environment. The OLO series covers resources from five large geographical regions of the United States: Northeast, Southeast (including the Gulf of Mexico and Caribbean), Alaska, Pacific coast, and the far western Pacific oceanic waters.

The stewardship of the Nation's living marine resources largely is entrusted to the National Oceanic and Atmospheric Administration's National Marine Fisheries Service, or NOAA Fisheries, an agency of the Department of Commerce. NOAA Fisheries carries out this responsibility in partnership with eight regional fishery management councils, three interstate marine fishery commissions, all coastal states, and many international marine science and management organizations.

OLO '95 focuses on the principal fishery resources, marine mammals, and sea turtles that are under the management jurisdiction of NOAA Fisheries. It also summarizes the status of many nearshore species which are managed primarily by the coastal states, and provides the estimates of fishery stock productivity and status of the resources through 1994. The assessments are drawn from results of field surveys, biological and physical studies, and independent monitoring of the recreational, subsistence, and commercial fisheries. The level of fishery utilization and management of the resources are also summarized, and important local and national issues, as well as the near-term outlook, are highlighted.

As with the previous editions of "Our Living Oceans," the information provided here is the result of the collective efforts of the NOAA Fisheries staff from around the country. ❑

Foreword

The National Oceanic and Atmospheric Administration's National Marine Fisheries Service began as the U.S. Commission of Fish and Fisheries in 1871. This year, the Service celebrates its 125th anniversary of scientific endeavor and fisheries management. NOAA Fisheries is entrusted with the conservation and management of fish, shellfish, sea turtle, marine mammal, and other resources that live in U.S. waters. We work on behalf of the American public to manage and sustain the Nation's living marine resources and their habitats.

NOAA Fisheries advocates sustainable use of living marine resources. These uses include commercial, subsistence, and recreational fishing, observation, and research. We support maximizing benefits to the Nation, without compromising the coexistence of species and their habitats. We strive to balance competing public needs and interests in the use and enjoyment of our ocean's resources.

NOAA Fisheries is responsible for ensuring that the best scientific information is used in management decisions. Our data collection and research are conducted over a broad range of scientific disciplines, including the natural and social sciences. Our scientists conduct research that contributes to the knowledge of fisheries science and the design of innovative management approaches. These efforts are augmented by improvements in the agency's monitoring and enforcement capabilities.

NOAA Fisheries supports the open exchange of information. Effective communication is essential to the development and support of successful resource management and conservation policies. We believe that an informed public can help us reach attainable and measurable objectives. This report is an example of our continuing efforts to inform the American people of our science-based findings.

NOAA Fisheries is fundamentally dedicated to maintaining the Nation's marine heritage by ensuring the existence of productive, diverse, and healthy ocean ecosystems. Our long history has given us the experience and expertise to make progress towards resolving living marine resource issues. This report shows the many areas where improvement is needed. We must reverse the path to overfishing, rebuild and maintain sustainable fisheries, improve economic performance, and strengthen the conservation of protected species and the marine habitat.

As Assistant Administrator for Fisheries, I will focus on our performance in improving the management of U.S. living marine resources through better understanding of ocean science, careful reviews of resource status, improved communications with our constituents, and a more streamlined and effective NOAA Fisheries.

This report provides an overview of the Nation's living marine resources and illustrates the successes and shortcomings in our stewardship of them. It highlights the progress we have made, and more importantly, the significant issues which we must face over the coming years. ❑

Rolland A. Schmitten

Assistant Administrator
for Fisheries
National Oceanic and
Atmospheric Administration

February 1996

About the NMFS

The National Marine Fisheries Service (NMFS or NOAA Fisheries), an agency of the National Oceanic and Atmospheric Administration (NOAA) within the Department of Commerce (DOC), is responsible for the conservation of living marine resources and the protection of marine mammals, endangered marine species, and the habitats on which they depend.

The nearly 2,000 men and women of NMFS have some of the most challenging and exciting work in the Federal Government: managing America's ocean fisheries, guarding protected species and coastal habitat, and ensuring the quality and safety of the nation's seafood products.

The 1976 extension of U.S. Jurisdiction to 200 miles from shore ushered in the era of modern American fishery management. It also opened the door to increased demand for U.S. fishery resources and led to strong growth of the domestic fishing fleet.

U.S. fisheries are extremely valuable, contributing over $25 billion annually to the nation's economy. Additional economic benefits are derived from subsistence fishing by Native American groups, from aquaculture, and from recreational viewing, such as "fish watching" on coral reefs. Nearly 300,000 men and women are full-time workers in American commercial fisheries, and nearly 100,000 commercial fishing craft annually ply U.S. waters. In addition, the opportunity for saltwater angling adds to the quality of life for over 17 million Americans.

NMFS, together with eight Regional Fishery Management Councils and the coastal States, manages U.S. fisheries under the authority of the Magnuson Fishery Conservation and Management Act, the Fish and Wildlife Coordination Act, and many other Federal statutes. Together with the states and the U.S. Coast Guard, NMFS also operates a stringent program to enforce fisheries and protected species laws.

NMFS serves as caretaker for many marine species protected under the Endangered Species Act and the Marine Mammal Protection Act. Some species of dolphins, whales, seals, sea lions, sea turtles, and (increasingly) stocks of Pacific salmon have declined in abundance so much that their future existence is now in jeopardy. NMFS works to recover these depleted resources,

Serving Nationwide

Headquartered in Silver Spring, Maryland, near the Nation's capitol, NMFS carries out its duties in five regions: Northeast, Southeast (including the U.S. Caribbean), Southwest (including Hawaii and U.S. South Pacific territories), Northwest, and Alaska. Regions work with the Fishery Management Councils, made up of representatives of state governments, commercial and recreational fisheries, and environmental and consumer groups, to develop and implement Fishery Management Plans for all species under Federal control. Regions also conduct important economic analyses of the nation's fisheries.

Each NMFS Regional Office is served by a Science and Research Center that conducts the studies necessary to support management decisions. Research that contributes to this important work is conducted at the 24 NMFS laboratories which collect fisheries statistics, perform resource and environmental surveys, study the biology and population structures of marine species, analyze the ecosystems that control the abundance and distribution of living marine resources, and investigate contaminants of the nation's seafood supply.

NMFS Science Centers work closely with other NOAA units—the National Ocean Service, Office of Oceanic and Atmospheric Research, National Weather Service, NOAA Corps, Coastal Ocean Program, Climate and Global Change Program, and National Environmental Satellite, Data, and Information Service—to carry out NOAA's mission of monitoring, recording, and predicting changes in the Earth's oceans and atmosphere.

protecting species from activities that threaten their safety and critical habitat.

The continuing and alarming loss of U.S. wetlands due to development, pollution, subsidence, and dredging seriously jeopardizes fisheries productivity. NMFS monitors and protects the health of the nation's abundant coastal habitats—estuarine marshes, coral reefs, seagrass beds, and mangroves—that are vitally important to living marine resources. Together with NOAA's National Ocean Service and General Counsel, NMFS shares management of NOAA's Damage Assessment and Restoration Program, which works to mitigate coastal habitat damage resulting from oil and chemical spills and other environmental disasters.

NMFS plays a key role in safeguarding the health of the nation's seafood consumers by assisting industry's production of wholesome, quality products. Together with the Food and Drug Administration, NMFS inspects hundreds of processing plants, distributors, and vessels, and works cooperatively with other nations to ensure that both domestic and imported fish and shellfish are safe to eat.

Since many U.S. stocks of marine animals are shared with other countries, Congress has approved international treaties and agreements to conserve and manage these resources. NMFS fishery managers and scientists are key participants in many worldwide organizations such as the International Whaling Commission, International Commission for the Conservation of Atlantic Tunas, Inter-American Tropical Tuna Commission, International Council for Exploration of the Seas, Pacific Halibut Commission, Convention for the Conservation of Antarctic Marine Living Resources, MEXUS-Gulf and MEXUS-Pacifico, and many others.

NMFS counts on many partners to help conserve and manage living marine resources. It works closely with industry, with hundreds of Federal, state, academic, and environmental organization, and with many Native American groups. Guidance is provided by the Federal Marine Fisheries Advisory Committee (MAFAC), representing commercial and recreational fishing interests and fishery management agencies, the three Interstate Marine Fisheries Commissions (Atlantic States, Gulf States, and Pacific), conservation groups, and academia. NMFS encourages the active interest of the American public in conserving and protecting its ocean heritage. If you would like more information about NMFS programs or activities, write: Office of Public Affairs, National Marine Fisheries Service, NOAA, 1335 East-West Highway, Silver Spring, MD 20910.

A Word About NOAA

The National Oceanic and Atmospheric Administration (NOAA) conducts research and gathers data about the global oceans, atmosphere, space, and sun, and applies this knowledge to science and service that touch the lives of all Americans.

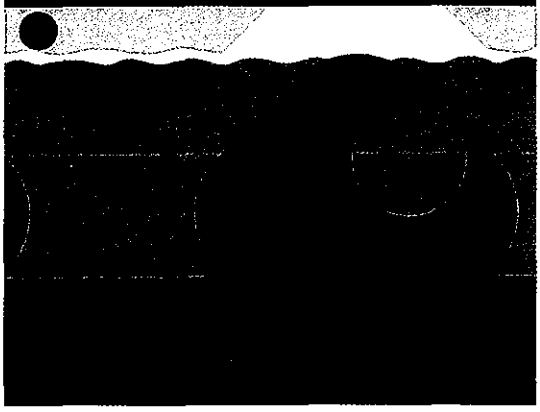
NOAA warns of dangerous weather, charts our seas and skies, guides our use and protection of ocean and coastal resources, and conducts research to improve our understanding and stewardship of the environment which sustains us all.

A Commerce Department agency, NOAA provides these services through five major organizations: the National Weather Service, National Ocean Service, National Marine Fisheries Service, National Environmental Satellite, Data, and Information Service, Office of Oceanic and Atmospheric Research, and numerous special program units. In addition, NOAA research and operational activities are supported by the Nation's seventh uniformed service, the NOAA Corps, a commissioned officer corps of 400 men and women who operate NOAA ships and aircraft, and serve in scientific and administrative posts.

For further information, contact: NOAA Office of Public Affairs, Room 6013, Herbert Clark Hoover Building, Washington, D.C. 20230. Phone: (202) 482-6090; Fax (202) 482-3154.

NATIONAL OVERVIEW

OUR LIVING OCEANS • 1995



National Overview

Introduction

The United States ranked fifth in the world for fisheries landings as reported by the Food and Agriculture Organization (FAO) of the United Nations in 1993, its latest survey year. The U.S. catch was 5.9% of the world's total catch of marine and freshwater fisheries products. The FAO survey also ranked the United States second in value for imports as well as exports of these products.

The stewardship of the U.S. living marine resources (LMRs) is entrusted to the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (hereafter referred to as NOAA Fisheries or NMFS) which carries out its charge under many laws, treaties and mandates from the U.S. Congress. Most of NOAA Fisheries conservation responsibilities emanate from four statutes: the Magnuson Fishery Conservation and Management Act (MFCMA) regulates fisheries within the U.S. Exclusive Economic Zone (EEZ), the Endangered Species Act (ESA) protects species threatened or endangered, the Marine Mammal Protection Act (MMPA) regulates taking of marine mammals, the Fish and Wildlife Coordination Act authorizes collection of fisheries data and coordination with other agencies for environmental decisions affecting LMRs. A fifth statue, the Federal Power Act, provides for concurrent responsibilities with the U.S. Fish and Wildlife Service (USFWS) for protecting aquatic habitat.

The purview of NOAA Fisheries is the U.S. EEZ or the 200-nautical mile (n.mi.) zone off the United States (Fig. 1). Within the 3-n.mi. territorial sea, management jurisdiction belongs to the coastal states. Beyond the 200-n.mi. Federal zone are international waters where living marine resources are intended to be regulated by applicable international laws and multilateral arrangements between governments. NOAA Fisheries plays an important role on behalf of the U.S. in the implementation of these international arrangements.

The intent of Federal resource conservation laws requires that the best scientific information be used as the basis for management actions. NOAA Fisheries scientists collect and analyze much of this data. From these databases, the agency prepares scientific reports along with technical presentations to fishery managers, industry groups, and the public for use in formulating sound policies governing the use and protection of LMRs.

Ultimately, the Secretary of Commerce has management responsibility as the designated manager of the Nation's living marine resources within the U.S. EEZ. The fisheries resources are managed largely through well documented fishery management plans (FMPs). These management plans are developed through extensive consultations with state and other Federal government agencies, public interest groups, and, in pertinent cases, international science and management organizations.

The FMPs originate through the MFCMA which established eight regional fishery management councils (FMCs) to develop management plans for the Nation's fishery resources. The

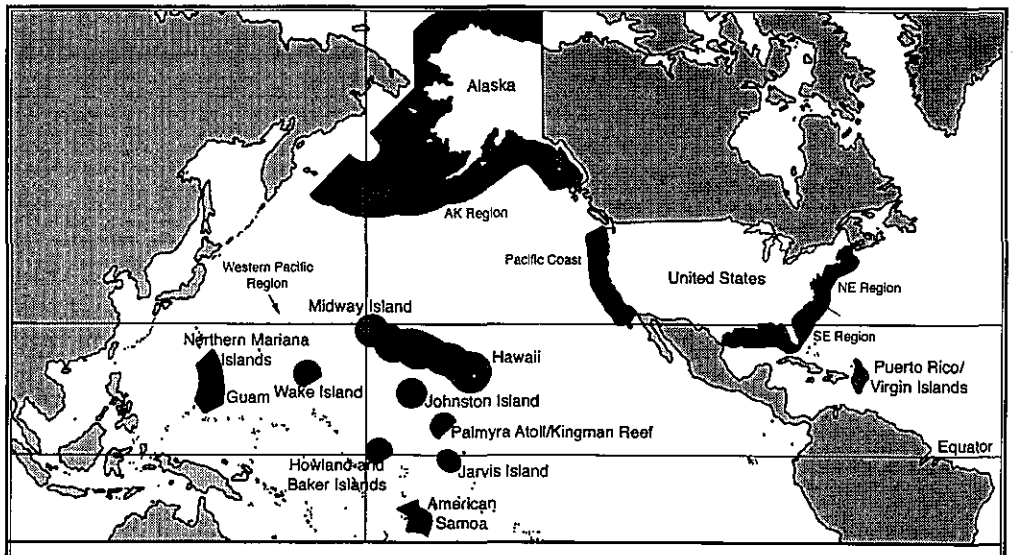


Fig. 1. Exclusive Economic Zones of the United States and representation of the five large geographic regions.

Common Terms

- **Stock** ideally refers to a biologically isolated group of organisms (e.g., fish) that are genetically related. Since stocks intermix in the marine habitat, it may be necessary to consider all of the individuals of a species or several species in a geographical area as a stock when it is impractical to isolate them. Thus, a unit stock defined for management purposes may not necessarily correspond to a genetic unit.

- **Recent Average Yield (RAY)** is equivalent to the recent average catch. Unless otherwise designated, RAY is the reported fishery landings averaged for the most recent 3-year period of workable data, 1992–94.

- **Current Potential Yield (CPY)** is the current potential catch that can be taken depending on the current resource abundance and prevailing ecosystem considerations. This term is analogous to acceptable biological catch (ABC) that is specified in some FMPs.

- **Long-term Potential Yield (LTPY)** is the maximum long-term average catch that can be achieved from the resource. This term is analogous to the concept of maximum sustainable yield (MSY).

- **Stock Level Relative to LTPY** is a measure of stock status. The present abundance level of the stock is compared with the level of abundance which on average would support the LTPY harvest. This level is expressed as below, near, above, or unknown relative to the abundance level that would produce LTPY.

- **Status of Resource Utilization** describes the level of fishery use of the resource (i.e., underutilized, fully utilized, overutilized, or unknown). It shows how the existing fishing effort compares with those levels necessary to achieve LTPY.

- **Threatened** or **Endangered** are terms defined under the Endangered Species Act. 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.

- **Potential Biological Removal (PBR)** is the sustainable removal level (in numbers) for marine mammals as calculated by the 1994 Amendments to the MMPA.

Councils represent diverse interests through their members who are nominated by state governors in each region and appointed by the Secretary of Commerce. For some fisheries and for protected resources such as marine mammals and sea turtles, FMPs and protected species recovery plans may be developed directly by NOAA Fisheries, with advice from the public and the regional FMCs.

This Executive Summary covers most of the LMRs that are of interest for commercial, recreational, subsistence, or aesthetic reasons to the United States. The status of fishery resources is reported by regional units in the full report. Current and potential harvest levels are given, along with information on fishery utilization and management. The status of the marine mammal and sea turtle resources are included. Nearshore species, largely the management responsibility of coastal states, are also summarized.

The information contained in this publication has been collected from many sources. Ideally, the most current peer-reviewed stock assessment reports and publications, which serve as the scientific basis for management, are used. For some species, stock assessments may not be complete owing to lack of data, but they may still be adequate for fishery scientists to exercise professional judgments as to stock status and magnitude of potential yields. When information is inadequate, the status is classified as unknown. In such cases, potential yield would be estimated from recent catch levels. More detailed information on specific resources may be obtained from regional status of fisheries resources reports available from NOAA Fisheries science centers around the country, and from coastal state fish and wildlife agencies.

Contents

This Executive Summary of OLO '95 contains the national overview of significant LMRs, including a brief introduction of terms, region-by-region resource summaries, a discussion of issues of national concern, and a discussion of near-term outlook. Two feature articles are also included—an essay on Pacific Northwest salmon and an examination of the implications of the 1994 Amendments to the Marine Mammal Protection Act.

Productivity of Stocks

The productivity and status of fishery resources utilized by the United States, reviewed in Units 1 to 21 of the full OLO '95 publication, are summarized here (Tables 1–4). Productivity is represented by RAY, CPY, and LTPY. For some stocks, the U.S. shares fishery productivity with other fishing nations because these stocks range beyond the U.S. EEZ. For the purposes of this report, the productivity of transboundary species is compiled for the entire stock as well as the prorated portion of the stock within the U.S. EEZ. OLO '95 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 is taken primarily within the U.S. EEZ; any amount taken outside the U.S. EEZ has generally been small.

The total LTPY of all U.S. fishery resources is estimated at 10.3 million t (Table 1). Total CPY is 9.1 million t, indicating that the present productivity of the stocks is 12% below the long-term potential. Total RAY is 7.2 million t or 30% below the long-term potential.

When only the U.S. prorated share of the resources is considered, the U.S. LTPY is 8.1 million t or 21% below total LTPY (Fig. 2). By region, the percentage distribution of U.S. LTPYs is 10% for the Northeast, 18% for the Southeast, 54% for Alaska, 14% for the Pacific coast, and 4% for the western Pacific oceanic regions (Table 2, Fig. 3).

The U.S. RAY is 5.06 million t or 37% below U.S. LTPY. The additional 37% potential yield was not realized because some of the stocks were underutilized while some have been overexploited and currently no longer producing at their full long-term potential. By region, the percentage distribution of U.S. RAYs is 9% Northeast, 23% Southeast, 54% Alaska, 9% Pacific coast, and 5% western Pacific oceanic (Table 2, Fig. 4).

Table 1. Productivity of Fisheries Resources Utilized by the United States

Productivity indicators are expressed in metric tons by long-term potential yield (LTPY), current potential yield (CPY), and recent average yield (RAY)[1]

Unit[2] / Fishery	Entire Range of Stock			Prorated within U.S. EEZ	
	Total RAY	Total CPY	Total LTPY	U.S. RAY	U.S. LTPY
1. Northeast demersals	185,535	183,735	479,335	145,900	402,365
2. Northeast pelagics	165,800	724,300	412,000	115,600	253,920
3. Atlantic anadromous	4,836	4,836	4,836	4,836	4,836
4. Northeast invertebrates	99,500	99,900	72,500	93,568	89,357
5. Atlantic highly migratory pelagics	246,955	242,455	245,519	14,600	19,100
6. Atlantic sharks	9,324	9,213	10,240	9,324	10,240
7. Atlantic/Gulf of Mexico coastal migratory pelagics	17,884	20,127	26,236	17,884	26,236
8. Atlantic/Gulf of Mexico reef fish	31,225	30,750	43,158	31,225	43,158
9. Southeast drum & croaker	16,785	16,785	68,715	16,785	68,715
10. Southest menhaden	890,000	890,000	1,140,000	890,000	1,140,000
11. Southeast/Caribbean invertebrates	112,483	111,641	95,165	112,483	95,165
12. Pacific coast salmon	22,957	33,312	33,312	22,957	33,312
13. Alaska salmon	364,800	296,500	296,500	364,800	296,500
14. Pacific coast & Alaska pelagics	116,800	166,100	559,100	116,800	559,100
15. Pacific coast groundfish	262,657	352,491	465,750	262,657	465,750
16. W. Pacific invertebrates	143	106	135	143	135
17. W. Pacific bottomfish & armorhead	388	626	2,738	388	2,738
18. Pacific highly migratory pelagics	2,077,232	2,003,188	2,033,706	240,438	278,945
19. Alaska groundfish	2,186,684	3,544,525	3,955,025	2,186,684	3,955,025
20. Alaska shellfish	125,744	125,745	113,779	125,744	113,779
21. Nearshore species	283,995	283,995	283,995	283,995	283,995
Total	7,221,727	9,140,330	10,341,744	5,056,811	8,142,371

[1] For row totals; where LTPY is unknown, CPY is substituted; where CPY is unknown, RAY is substituted. RAY is generally for the latest 3-year average, 1992–94.
[2] Unit numbers (1–21) refer to the individual and in-depth reports presented in the full version of OLO '95.

Table 2. Regional Productivity of Fisheries Resources Utilized by the United States

Productivity indicators are expressed in metric tons by long-term potential yield (LTPY), current potential yield (CPY), and recent average yield (RAY). Unknown row totals are substituted as in Table 1.

Region	Entire Range of Stock			Prorated within U.S. EEZ	
	Total RAY	Total CPY	Total LTPY	U.S. RAY	U.S. LTPY
Northeast	777,856	1,330,456	1,289,420	449,734	844,808
Southeast	1,168,531	1,169,346	1,474,344	1,168,531	1,474,344
Alaska	2,732,298	4,025,140	4,423,674	2,733,298	4,423,674
Pacific Coast	462,759	609,948	1,116,207	462,759	1,116,207
Western Pacific Oceanic	2,079,283	2,005,440	2,038,099	242,489	283,338
Total	7,221,727	9,140,330	10,341,744	5,056,811	8,142,371

Status of Stocks

The status of stocks is classified according to the current level of abundance relative to the level that would produce LTPY. Table 3 summarizes the classifications for the 275 stock groups addressed in this report as being 30% below, 27% near, 9% above, and 34% unknown relative to the levels that would produce LTPY. This summary includes 74 stock groups of nearshore resources that are under the purview of coastal states.

Excluding nearshore resources, the remaining 201 stock groups that are under the purview of NOAA Fisheries have been classified as being 36% below, 30% near, 13% above, and 21% unknown relative to the abundance levels that would produce U.S. LTPY (Fig. 5). The 21% unknown category comprises 43 out of 201 stock groups. These 43 stock groups are generally of

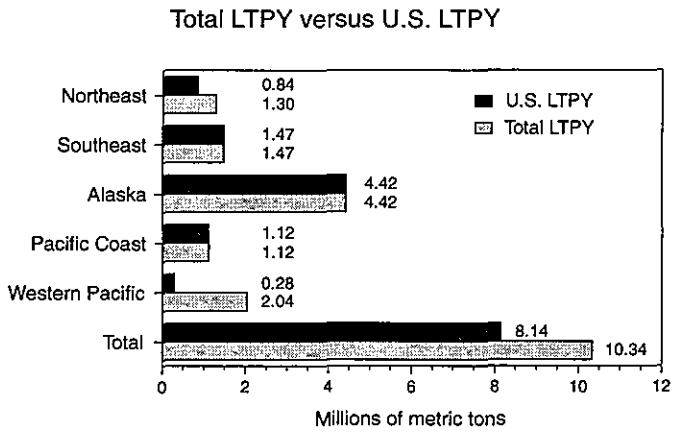


Fig. 2. Total versus U.S. prorated share of fisheries resources.

low abundance and contributed only to 2.7% of U.S. RAY.

There are 158 stock groups whose status is known that fall under the purview of NOAA Fisheries (Units 1-20 in Table 3). In this category, there is a high percentage of stock groups, 46% (involving 73 out of 158 known-stock status), that is below levels that would produce LTPY. The majority of these low abundance cases occurred in Unit 1 (19 stocks of northeast demersal species), Unit 8 (9 stocks of Atlantic and Gulf of Mexico reef fish), and Unit 15 (6 stocks of Pacific coast groundfish). Less pronounced cases of low abundance can be found in all regions, including Alaska. For the remaining stocks (85 out of 158 known-stock status), these have been classified as 38% near and 16% above the levels that would produce LTPY. If it is assumed that stocks near or above levels that would produce LTPY are stocks in healthy condition, it may be stated that 54% of the known-stock status groups are at healthy abundance levels.

Status of Utilization

The status of utilization describes the level of use of a fishery resource as being underutilized, fully utilized, overutilized, or unknown. It compares existing fishing effort with the appropriate levels necessary to achieve LTPY.

Table 4 summarizes the classifications for the 275 stock groups addressed in this report as being 12% underutilized, 34% fully utilized, 23% overutilized, and 31% unknown. This grouping includes 74 stock groups of nearshore resources that are under the purview of coastal states.

Excluding nearshore resources, the remaining 201 stock groups that are under the purview of NOAA Fisheries have been classified as 15% underutilized, 35% fully utilized, 28% overutilized, and 22% unknown (Fig. 6).

There is still a high percentage of stocks, 22%

Table 3. Status of Stock Levels of U.S. Living Marine Resources, 1992–94

Unit[1] / Fishery	Current Status Relative to the Level Producing LTPY				
	Below	Near	Above	Unknown	Total
1. Northeast demersals	19	3	2	1	25
2. Northeast pelagics	1	2	3	0	6
3. Atlantic anadromous	4	0	1	0	5
4. Northeast invertebrates	0	3	2	1	6
5. Atlantic highly migratory pelagics	4	4	0	2	10
6. Atlantic sharks	1	0	1	1	3
7. Atlantic/Gulf of Mexico coastal migratory pelagics	1	3	0	3	7
8. Atlantic/Gulf of Mexico reef fish	9	2	0	17	28
9. Southeast drum & croaker	4	0	0	3	7
10. Southest menhaden	0	2	0	0	2
11. Southeast/Caribbean invertebrates	3	6	0	5	14
12. Pacific coast salmon	2	3	0	0	5
13. Alaska salmon	1	1	3	0	5
14. Pacific coast & Alaska pelagics	3	4	0	0	7
15. Pacific coast groundfish	6	4	4	5	19
16. W. Pacific invertebrates	1	0	0	0	1
17. W. Pacific bottomfish & armorhead	3	3	0	0	6
18. Pacific highly migratory pelagics	2	12	0	1	15
19. Alaska groundfish	6	8	8	3	25
20. Alaska shellfish	3	0	1	1	5
21. Nearshore species	10	14	0	50	74
Subtotal of Units 1-20	73	60	25	43	201
% of Subtotal	36%	30%	13%	21%	
% of 158 "known" stock groups	46%	38%	16%		
Total of Units 1-21	83	74	25	93	275
% of Total	30%	27%	9%	34%	
% of 182 "known" stock groups	45%	41%	14%		

[1] Unit numbers (1-21) refer to the individual and in-depth reports presented in the full version of OLO '95.

(involving 44 out of 201 stock groups), whose status of utilization is unknown. The majority of these 44 unknown stock groups are found in the Southeast region where assessments of coastal migratory species, reef fishes, and invertebrates have been difficult. This category also includes 7 stock groups from Unit 18 occurring in the western Pacific oceanic region where the highly migratory species of tunas move long distances across many national jurisdictions, making assessment of the stocks difficult.

There are 157 stock groups that are classified as being of known-utilization status that are under the purview of NOAA Fisheries (Units 1-20 in Table 4). Of these, 36% (involving 56 out of 157 known utilization-status groups) are overutilized. The majority of these overutilized cases occurred in Unit 1 (18 stocks from the Northeast demersal unit) and Unit 8 (10 stocks in the Atlantic and Gulf of Mexico reef fish unit). For the remaining stocks, they have been classified as 20% underutilized and 44% fully utilized, for a combined total of 64% utilization at under-to-full utilization levels.

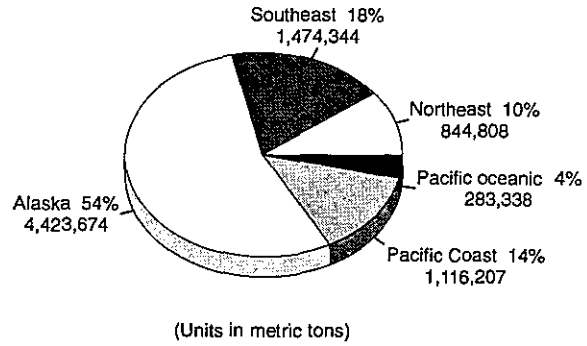


Fig. 3. Regional apportionment of long-term potential yield of the U.S. prorated share of fisheries resources.

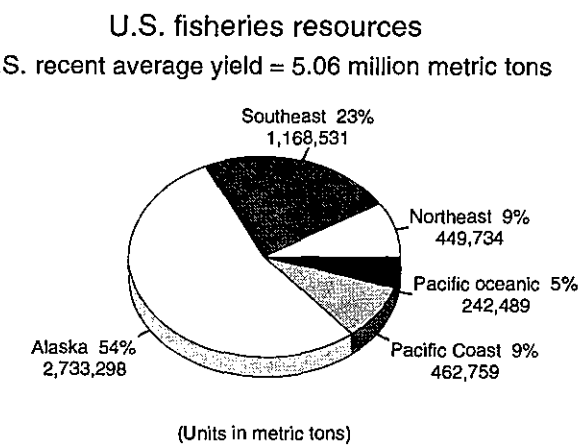


Fig. 4. Regional apportionment of recent average yield of the U.S. prorated share of fisheries resources.

Regional and Species Group Synopses

Northeast Region

The Northeast region's finfish and invertebrates are grouped under demersal, coastal pelagic, anadromous, invertebrate, highly migratory pelagic, and nearshore resources. Their combined U.S. LTPY is 844,800 t (Table 5) out of a total LTPY of 1.29 million t for the region. The lower U.S. LTPY reflects the sharing of transboundary resources with Canada and some Atlantic countries. The U.S. RAY totaled only 449,700 t or 53% of U.S. LTPY because some 33 species, principally groundfish, are overutilized and below the stock levels necessary to produce LTPY. The RAY of 449,700 t excluded 248,000 t of menhaden that were taken at the southern limit of the Northeast region. That amount has been added to the Southeast menhaden data (Unit 10) as it is an integral part of the South Atlantic menhaden stock.

The mixed-species groundfish fishery has traditionally been the most valuable of the region, followed by American lobster and Atlantic sea scallop. Recreational fisheries for species such as cod, winter flounder, mackerel, striped bass, bluefish, and bluefin tuna are also important and contribute greatly to the region's economy.

Principal groundfish and flounders in the Northeast, particularly cod, haddock, and yellowtail flounder, have been severely overfished and their overall abundance in 1994 was the lowest on record. Dogfish and skates, which increased in abundance beginning in the 1970s as groundfish and flounders decreased, currently comprise about 75% of the total fish biomass on Georges Bank and have supported increased catches in recent years. Since 1990, however, their abundances have also begun to decrease. Catches of other

Table 4. Status of Utilization Levels of U.S. Living Marine Resources, 1992–94					
	Degree of Fisheries Utilization of the Resource				
Unit[1] / Fishery	Under	Full	Over	Unknown	Total
1. Northeast demersals	2	4	18	1	25
2. Northeast pelagics	4	1	1	0	6
3. Atlantic anadromous	0	2	3	0	5
4. Northeast invertebrates	0	3	2	1	6
5. Atlantic highly migratory pelagics	0	4	4	2	10
6. Atlantic sharks	0	1	1	1	3
7. Atlantic/Gulf of Mexico coastal migratory pelagics	1	2	1	3	7
8. Atlantic/Gulf of Mexico reef fish	0	2	10	16	28
9. Southeast drum & croaker	0	0	3	4	7
10. Southest menhaden	0	2	0	0	2
11. Southeast/Caribbean invertebrates	0	7	2	5	14
12. Pacific coast salmon	0	3	2	0	5
13. Alaska salmon	0	5	0	0	5
14. Pacific coast & Alaska pelagics	1	6	0	0	7
15. Pacific coast groundfish	5	9	3	2	19
16. W. Pacific invertebrates	0	0	1	0	1
17. W. Pacific bottomfish & armorhead	3	0	3	0	6
18. Pacific highly migratory pelagics	4	2	2	7	15
19. Alaska groundfish	10	13	0	2	25
20. Alaska shellfish	1	4	0	0	5
21. Nearshore species	3	24	7	40	74
Subtotal of Units 1–20	31	70	56	44	201
% of Subtotal	15%	35%	28%	22%	
% of 157 "known" stock groups	20%	44%	36%		
Total of Units 1–21	34	94	63	84	275
% of Total	12%	34%	23%	31%	
% of 191 "known" stock groups	18%	49%	33%		

[1] Unit numbers (1–21) refer to the individual and in-depth reports presented in the full version of OLO '95.

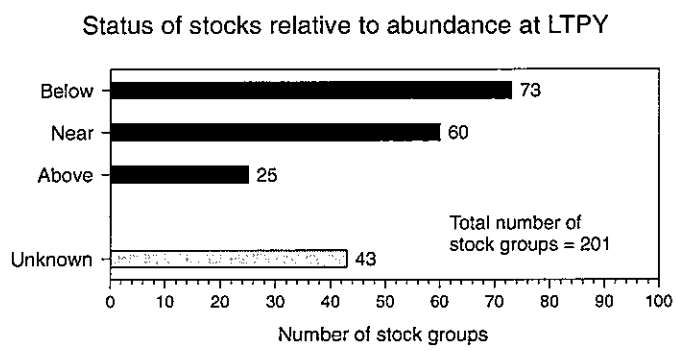


Fig. 5. Number of stock groups classified by their status of stock levels relative to abundance levels that would produce long-term potential yield for stocks under NOAA Fisheries purview.

groundfish have become increasingly important in recent years as preferred species declined. In 1994, the U.S. catch of goosefish exceeded the catch of cod for the first time.

Five species, mainly pelagics, are presently underutilized, and the CPY of the two most abundant of these, Atlantic mackerel and herring, is nearly 522,500 t higher than their RAY. The anadromous striped bass, driven to very low levels of abundance in the early-1980s and subjected to severe catch restrictions beginning in the mid-1980s, was declared fully restored in early 1995. The region's valuable crustaceans and bivalve mollusks, both offshore (e.g., American lobster, sea scallop, surfclam, ocean quahog) and inshore (e.g., blue crab, oyster, blue mussel, hard and softshell clam) are nearly all fully or overexploited.

Most of the region's fisheries are included in FMPs either in place or under development. Very few FMPs have been successful in preventing overexploitation of their respective species. Amendment #5 to the Northeast Multispecies FMP, enacted early in 1994, was intended to limit commercial fishing effort on groundfish in New England and prevent the issuance of new vessel permits in this overcapitalized fishery. It is now judged to be insufficient in reducing fishing mortality as desired. In light of the serious nature of the collapse of cod, haddock, and yellowtail flounder, the Secretary of Commerce approved an emergency closure of portions of Georges Bank and a moratorium on commercial fishing for haddock, beginning 1 January 1994, which continues in place. The New England FMC is developing Amendment #7 to the Multispecies FMP, with the objective of reducing fishing mortality on these stocks to as near to zero as practicable. Concurrently, Canada continues to maintain severe restrictions on its own groundfish fishery on Georges Bank to promote stock rebuilding.

Amendment #4 to the Sea Scallop FMP controls fishing effort by limiting the days at sea for each vessel, placing a moratorium on new entrants, and imposing a larger dredge mesh-ring size. Along with supplemental measures, it is intended to reduce fishing mortality and move this fishery from overutilization to full utilization. Plans are underway by the New England FMC to develop additional regulatory measures for American lobster that will include limits on numbers of traps, seasonal closures, and overall quotas.

Southeast Region

The Southeast region covers the Gulf of Mexico, Southeast Atlantic, and the Caribbean Sea. Its important resources are Atlantic sharks, Atlantic/Gulf of Mexico coastal migratory pelagics, Atlantic/Gulf of Mexico reef fish, drum and croaker, menhaden, Southeast Atlantic/Caribbean invertebrates, and nearshore resources. The total LTPY of fisheries resources is 1.47 million t and is virtually all available to the U.S. (Table 6). The U.S. RAY is 1.17 million t or 80% of U.S. LTPY.

Menhaden comprise about 75% of both the U.S. LTPY and U.S. RAY. Menhaden are considered fully utilized in both the Gulf of Mexico and Atlantic Ocean, with some growth overfishing in the Atlantic.

Shrimp led the region in value, although composing only 8% of the total Southeast LTPY and RAY. The three major species (brown, white, and pink) are considered fully utilized in both the Gulf of Mexico and Atlantic. Yields are not now closely tied to shrimping effort—about half the current effort in the Gulf could produce about the same long-term average yield.

The highly migratory pelagic species are important components of fisheries in the Northeast and Southeast regions. Bluefin tuna is well below the biomass level required for maximizing long-term yield. The marlins (white and blue) are below as well, although blue marlin appear to be increasing. Swordfish has recently declined to a level below that which would produce maximum long-term yield. Yellowfin tuna is presently fully exploited and near its maximum long-term yield. Bigeye tuna exploitation has recently increased, but current yields are not expected to be maintained.

Large coastal sharks (as a group) may be overutilized, but the status of each species is presently unknown. Due to their life history strategies, sharks may be particularly vulnerable to overfishing.

Spanish mackerel appear to be fully utilized in both the Gulf of Mexico and Atlantic. King mackerel have been overfished in the Gulf, and a stringent rebuilding program has been in place for the last several years. King mackerel in the Atlantic may have some additional yield potential. The status of other coastal migratory pelagic species in the region is unknown.

Reef fish in the Southeast region include

Table 5. Productivity of Fisheries Resources of the Northeast Region, 1992–94

Productivity indicators are expressed in metric tons by long-term potential yield (LTPY), current potential yield (CPY), and recent average yield (RAY)[1]

Unit[2] / Fishery	Entire Range of Resource			Prorated within U.S. EEZ	
	Total RAY	Total CPY	Total LTPY	U.S. RAY	U.S. LTPY
1. Northeast demersals	185,535	183,735	479,335	145,900	402,365
2. Northeast pelagics	165,800	724,300	412,000	115,600	253,920
3. Atlantic anadromous	4,836	4,836	4,836	4,836	4,836
4. Northeast invertebrates	99,500	99,900	72,500	93,568	89,357
5. Atlantic highly migratory pelagics	246,955	242,455	245,519	14,600	19,100
21. Northeast nearshore species	75,230	75,230	75,230	75,230	75,230
Northeast Total	777,856	1,330,456	1,289,420	449,734	844,808

[1] For row totals; where LTPY is unknown, CPY is substituted; where CPY is unknown, RAY is substituted. RAY is generally for the latest 3-year average, 1992–94.
[2] Unit numbers (1–21) refer to the individual and in-depth reports presented in the full version of OLO '95.

Table 6. Productivity of Fisheries Resources of the Southeast/Gulf of Mexico/Caribbean Region, 1992–94

Productivity indicators are expressed in metric tons by long-term potential yield (LTPY), current potential yield (CPY), and recent average yield (RAY)[1]

Unit[2] / Fishery	Entire Range of Resource			Prorated within U.S. EEZ	
	Total RAY	Total CPY	Total LTPY	U.S. RAY	U.S. LTPY
6. Atlantic sharks	9,324	9,213	10,240	9,324	10,240
7. Atlantic/Gulf of Mexico coastal migratory pelagics	17,884	20,127	26,236	17,884	26,236
8. Atlantic/Gulf of Mexico reef fish	31,225	30,750	43,158	31,225	43,158
9. Southeast drum & croaker	16,785	16,785	68,715	16,785	68,715
10. Southest menhaden	890,000	890,000	1,140,000	890,000	1,140,000
11. Southeast/Caribbean invertebrates	112,483	111,641	95,165	112,483	95,165
21. Southeast nearshore species	90,830	90,830	90,830	90,830	90,830
Southeast Total	1,168,531	1,169,346	1,474,344	1,168,531	1,474,344

[1] For row totals; where LTPY is unknown, CPY is substituted; where CPY is unknown, RAY is substituted. RAY is generally for the latest 3-year average, 1992–94.
[2] Unit numbers (6–21) refer to the individual and in-depth reports presented in the full version of OLO '95.

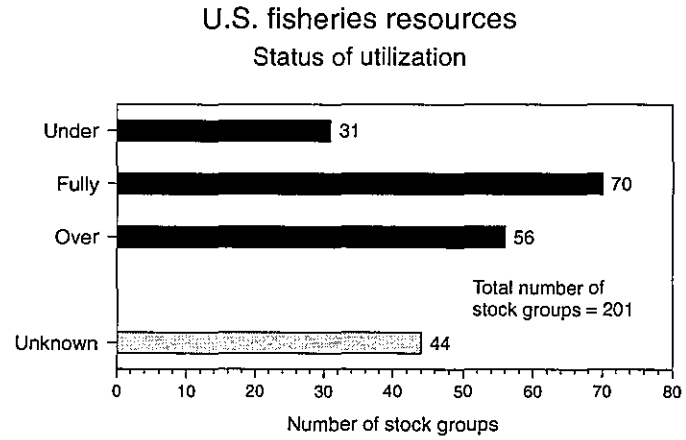


Fig. 6. Number of stock groups classified by their status of utilization for stocks under NOAA Fisheries purview.

over 200 stocks of more than 100 species currently contributing to fishery yield. The status is unknown for many of these stocks, but several of the major species have been assessed. In the Gulf of Mexico, red snapper are overfished, and a stringent rebuilding plan has begun. Success of this rebuilding hinges on the reduction of bycatch of juvenile red snapper in the Gulf shrimp fishery. Red grouper appears to be fully utilized in the Gulf of Mexico. In the Atlantic region, many of the key species are considered overutilized (e.g., vermilion and other snappers, red porgy, several groupers, amberjacks, jewfish). In the Caribbean, Nassau grouper and jewfish are considered overutilized; the status of other species is unknown.

Table 7. Productivity of Fisheries Resources of the Alaska region, 1992–94

Productivity indicators are expressed in metric tons by long-term potential yield (LTPY), current potential yield (CPY), and recent average yield (RAY) [1]

Unit [2] / Fishery	Entire Range of Resource			Prorated within U.S. EEZ	
	Total RAY	Total CPY	Total LTPY	U.S. RAY	U.S. LTPY
13. Alaska salmon	364,800	296,500	296,500	364,800	296,500
14. Alaska herring	52,900	55,200	55,200	52,900	55,200
19. Alaska groundfish					
Bering Sea/Aleutian Islands	1,902,402	3,025,385	3,483,785	1,902,402	3,483,785
Gulf of Alaska	249,582	492,240	451,440	249,582	451,440
Halibut (Alaska)	34,700	26,900	19,800	34,700	19,800
20. Alaska shellfish	125,744	125,745	113,779	125,744	113,779
21. Alaska nearshore species	3,170	3,170	3,170	3,170	3,170
Alaska Total	2,733,298	4,025,140	4,423,674	2,733,298	4,423,674

[1] For row totals; where LTPY is unknown, CPY is substituted; where CPY is unknown, RAY is substituted. RAY is generally for the latest 3-year average, 1992–94.
[2] Unit numbers (13–21) refer to the individual and in-depth reports presented in the full version of OLO '95.

The status of drum and croaker stocks is largely unknown. Many of the smaller species could also be heavily impacted from bycatch of the shrimp fleet; thus weakfish bycatch in the Atlantic is becoming a major management issue. Red drum harvest in the Gulf and South Atlantic EEZs have been prohibited, and harvests in state waters have been reduced for several years due to low spawning levels. All indications are that fishing mortality has been reduced significantly and recovery is expected.

Status information for invertebrates other than shrimp is mixed. Spiny lobster is apparently overutilized in the Southeast region. Spiny lobster status in the Caribbean is uncertain, but possibly overutilized, with growth overfishing. Stone crab appears to be fully utilized, while queen conch may be overutilized.

Alaska Region

The Alaska region dominates in the tonnage of fisheries resources that could be obtained in the long term for the United States. The major resources are salmon, groundfish, Pacific halibut, shellfish, and herring. Their combined U.S. LTPY is 4.42 million t (Table 7). The resources are generally healthy with regional CPY only 9% below LTPY. The U.S. RAY has been steady at about 2.73 million t, or 38% below LTPY. Catches are substantially below long-term potential because many of the resources, particularly flatfish species, are underutilized.

Alaska salmon stocks have produced bumper harvests in recent years. The RAY of 364,800 t is actually 23% above LTPY because salmon runs have been particularly successful. Five species of Pacific salmon (chinook, coho, sockeye, pink, and chum) contribute to the catch.

The development of domestic groundfish fisheries off Alaska has been a great success under the MFCMA. Until its implementation in 1977, Alaska's groundfish fisheries, except for Pacific halibut, were dominated by foreign fishing. Then, within a few years under the new management regime, the U.S. fishery largely replaced the foreign fishing fleet.

For the Bering Sea/Aleutian Islands groundfish, RAY is 1.9 million t (Table 7). The major species groups harvested are walleye pollock, Pacific cod, flatfishes, Atka mackerel, rockfish, and sablefish. Except for Greenland turbot, all flatfish species are high in abundance and in excellent condition. Walleye pollock and Pacific cod abundances are much lower than their recent high levels, but are still close to the levels that would produce LTPY.

For the Gulf of Alaska groundfish, RAY is 249,600 t. The major species groups harvested include walleye pollock, Pacific cod, sablefish, flatfishes, and slope rockfish. Overall abundance of groundfish in the Gulf has been relatively stable, except for walleye pollock, which is down.

Pacific herring stocks are producing slightly below their LTPYs. Shrimp resources are down

throughout Alaska. King crab resources are depressed, but Tanner crab stocks are still relatively high.

In addition to the general groundfish complex, Pacific halibut is a groundfish species that has supported an important traditional fishery for both the U.S. and Canada. This resource is fully utilized and managed by the International Pacific Halibut Commission. Abundance peaked in 1989 and has been declining steadily at about 10% per year since.

Pacific Coast Region

The Pacific coast fisheries resources have a combined U.S. LTPY of 1.12 million t (Table 8). The major species are salmon, coastal pelagics, groundfish, Pacific halibut, and nearshore resources. The U.S. RAY is 462,800 t or only 41% of LTPY. The lower RAY is due mainly to lower abundances of coastal pelagic species (Unit 14) and groundfish (Unit 15) and underutilization of some species. Most stocks are fully utilized or overutilized.

All five species of Pacific salmon are fully or overutilized. The RAY of 23,000 t is 69% of its LTPY. Depressed production is partly due to ocean conditions that have been generally unfavorable for salmon off the Pacific coast since the late-1970s. Some stocks are depleted and have triggered ESA designations.

Coastal pelagic fishes are low in abundance, and all, except jack mackerel, are fully utilized. Jack mackerel is one of the few underutilized Pacific coast species. The RAY of 64,000 t is only 12% of LTPY. The Pacific sardine population has been increasing after decades at low abundance levels.

The groundfish fishery harvests a vast array of bottom-dwelling species from Washington to California. The RAY of 262,500 t is 56% of LTPY. The large difference between RAY and LTPY is due to a variety of factors and the diversity of this fishery complex. Some species are overexploited, some have experienced periods of low recruitment, and some are underutilized. Pacific whiting dominates the commercial catch, accounting for 72% of the groundfish catch. Rockfishes and lingcod also support popular recreational fisheries. Certain stocks, such as Pacific ocean perch, are in need of rebuilding following overutilization and a period of poor recruitment. Shortbelly rockfish is substantially underutilized.

Table 8. Productivity of Fisheries Resources of the Pacific Coast Region, 1992–94

Productivity indicators are expressed in metric tons by long-term potential yield (LTPY), current potential yield (CPY), and recent average yield (RAY) [1]

Unit [2] / Fishery	Entire Range of Resource			Prorated within U.S. EEZ	
	Total RAY	Total CPY	Total LTPY	U.S. RAY	U.S. LTPY
12. Pacific coast salmon	22,957	33,312	33,312	22,957	33,312
14. Pacific coast pelagics	63,900	110,900	503,900	63,900	503,900
15. Pacific coast groundfish	262,657	352,491	465,750	262,657	465,750
19. Halibut (Pacific Coast)	200	300	200	200	200
21. Pacific Coast nearshore species	113,245	113,245	113,245	113,245	113,245
Pacific Coast Total	462,759	609,948	1,116,207	462,759	1,116,207

[1] For row totals; where LTPY is unknown, CPY is substituted; where CPY is unknown, RAY is substituted. RAY is generally for the latest 3-year average, 1992–94.
[2] Unit numbers (12–21) refer to the individual and in-depth reports presented in the full version of OLO '95.

Pacific coast shellfish resources are diverse and important both commercially and recreationally. Shrimp, crab, clams, and abalone fisheries are relatively small in terms of tonnage landed, but they contribute substantially to the value of Pacific coast fisheries due to the high prices they command. Most shellfish species are fully utilized.

Recreational fisheries are important along the Pacific coast and especially so in southern California. A wide variety of species are taken, and the recreational catch of some greatly exceeds the commercial catch. Many are nearshore resources. Gamefishes such as albacore, tuna, billfishes, rockfish, and salmon are highly prized. Recreational crabbing, clam digging, and abalone diving activities are also significant.

Western Pacific Oceanic Region

The vast area that encompasses this region stretches across the central and western Pacific Ocean and includes the Hawaiian Islands and the U.S. territories of American Samoa, Guam, and the Northern Marianas. These are tropical and subtropical island waters with a large diversity of species but relatively low sustainable yields due to limiting ocean nutrient availability. Though the magnitude of the fisheries may be relatively small (U.S. LTPY is only 283,300 t and U.S. RAY is 242,500 t, Table 9) when compared to certain larger mainland fisheries, seafood and fisheries are valued highly and important culturally and socially in Hawaii and the Pacific island territories. Additionally, certain transboundary fisheries hold considerable international interest with high collective importance and value to Pacific Rim nations and U.S. fleets fishing within

Table 9. Productivity of Fisheries Resources of the Western Pacific Oceanic Region, 1992–94

Productivity indicators are expressed in metric tons by long-term potential yield (LTPY), current potential yield (CPY), and recent average yield (RAY) [1]

Unit [2]/ Fishery	Entire Range of Resource			Prorated within U.S. EEZ	
	Total RAY	Total CPY	Total LTPY	U.S. RAY	U.S. LTPY
16. W. Pacific invertebrates	143	106	135	143	135
17. W. Pacific bottomfish & armorhead	388	626	2,738	388	2,738
18. Pacific highly migratory pelagics	2,077,232	2,003,188	2,033,706	240,438	278,945
21. W. Pacific nearshore species	1,520	1,520	1,520	1,520	1,520
Western Pacific Total	2,079,283	2,005,440	2,038,099	242,489	283,338

[1] For row totals; where LTPY is unknown, CPY is substituted; where CPY is unknown, RAY is substituted. RAY is generally for the latest 3-year average, 1992–94.
[2] Unit numbers (16–21) refer to the individual and in-depth reports presented in the full version of OLO '95.

and beyond the U.S. EEZ. Fishery resources include highly migratory pelagic fishes, bottomfishes, nearshore reef fishes, and invertebrates. The region also supports protected species such as the Hawaiian monk seal, green sea turtle, and blue, fin, and sperm whales.

The highly migratory stocks (tunas, billfishes, swordfish, sharks, and others) range the high seas and often occur beyond U.S. fisheries management jurisdiction. Tunas provide the major catch component and are species that migrate across multiple jurisdictions in the Pacific. The combined LTPY of these stocks throughout their migratory range is over 2.0 million t, while the prorated U.S. LTPY is only 278,900 t. Of the 15 stock groups of highly migratory pelagics, 12 stocks are near the levels that would produce their LTPYs, two are below LTPY, and one is of unknown status.

Western Pacific bottomfishes (snappers, jacks, grouper, emperors) are harvested from a variety of rock and coral habitats around Hawaii and western Pacific island territories. About 90% of the catch is taken in the main Hawaiian islands, where stock assessments indicate some important species are only at 10–30% of original stock levels, and overutilization is of concern. But when the resources are considered across the region, the U.S. LTPY of 2,700 t is seven times higher than U.S. RAY because stocks in the northwestern Hawaiian Islands, American Samoa, and Marianas are underutilized.

Pelagic armorhead has been harvested by foreign fleets on the summits and slopes of submerged seamounts along the southern Emperor-northern Hawaiian Ridge since 1968. Of these undersea mountains, the only group under U.S. jurisdiction is the Hancock Seamounts, where armorhead fishing has been prohibited since 1984 to allow the stock to recover after catch rates declined to low levels. The U.S. has never fished armorhead, but because of its fishery potential, the resource is regulated under a Seamount Groundfish FMP. This stock is currently in a recovery stage.

The most important invertebrate fisheries in the western Pacific are for spiny and slipper lobsters. They are primarily fished in the northwestern Hawaiian Islands. This fishery began in 1977 and reached its peak during the mid-1980s, but has since declined. The primary cause of the decline is thought to be a general reduction in lobster productivity and recruitment since 1989, stemming from mesoscale oceanographic changes. Since 1991, emergency closures, a limited entry regime, and a closed season was adopted to rebuild the stocks. The lobster LTPY is now much lower than during the 1983-89 period, but the stock is recovering.

Nearshore Resources

For the purposes of this report, "nearshore fishery resources" are those coastal and estuarine species under the purview of coastal states and for which NOAA Fisheries does not have direct responsibility. Many of these coastal and estuarine species provide the basis for important commercial and recreational fisheries. They vary widely in species diversity and abundance. Many are highly-prized gamefish. Others are small fishes used for bait, food, and industrial products. Those of greatest interest include invertebrate species like crabs, shrimps, abalones, clams, scallops, and oysters.

Because the composition of nearshore resources is diverse and management is spread out among the many coastal states and other local authorities, a comprehensive treatment of them has not been attempted in this report.

It is difficult to assess the condition of many of the country's nearshore resources. A high percentage are of unknown status. No firm estimate exists for LTPY nor CPY. Thus, the RAY of 284,000 t (Table 1) has been used to indicate minimum amounts for CPY and LTPY. The RAY itself has been underestimated and excludes landings of large-scale nearshore fisheries like anchovy, sardine, herring, and invertebrate resources which are reported in other unit chapters.

Marine Mammals

The amended MMPA of 1994 requires the Secretary of Commerce and the Secretary of Interior to develop stock assessment reports (SARs) for all marine mammal stocks that are found within U.S. waters. NOAA Fisheries is responsible for assessing and managing 155 stocks of cetaceans and pinnipeds. The U.S. Fish and Wildlife Service has authority for stocks of North Pacific walrus, Alaska polar bear, West Indian manatee, and Alaska and California sea otters. SARs for all stocks are divided into three separate regions—Alaska, Pacific including Hawaii, and Atlantic including the Gulf of Mexico.

The MMPA requires an SAR to include, among other things, information on how the stock was defined, a minimum abundance estimate, the stock's current and maximum net productivity rate, current population trend, a calculation of PBRs, an assessment of whether incidental fishery takes are "insignificant and approaching zero mortality and serious injury rate," and an assessment whether the level of human-caused mortality and serious injury is likely to reduce the stock to below OSP or whether the stock should be classified as a "strategic stock." SARs are to be reviewed annually for strategic stocks and for stocks for which new information is available, and at least once every three years for all other stocks. The 1994 amendments also require that take reduction teams be formed for each strategic stock and charges them with developing plans to reduce takes to below the PBRs. Strategic stocks are those 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 anthropogenic mortality exceeds the estimated replacement yield.

Of the 163 marine mammal stocks managed under the MMPA, 54 are classified as strategic (Table 10). These include 4 stocks that are depleted under the MMPA, 4 that are listed as threatened and 24 as endangered under the ESA, 17 for which the total annual mortality exceeds PBR, and other stocks where information on stock status or fisheries related mortality is uncertain. In addition, 2 of 10 stocks of eastern tropical Pacific dolphin are listed as depleted under the MMPA.

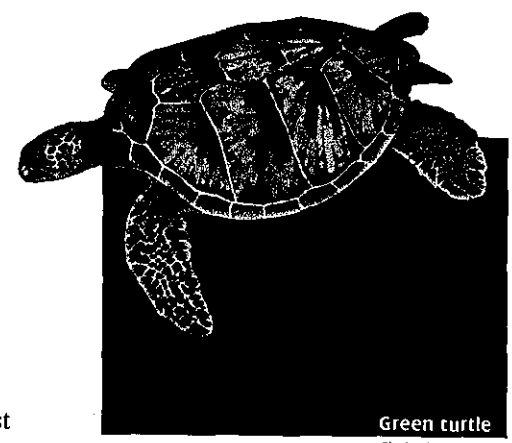
With regard to population trends, of the 163 marine mammal stocks in U.S. waters, there is sufficient long-term population information to describe trends for only 55 stocks (33%), and the status of the remaining 108 stocks (66%) is unknown. Of those for which information is available, 8 (5%) are declining, 24 (15%) are known to be stable, and 23 (14%) are believed to be increasing (Table 10). The new regime established by the 1994 MMPA amendments, once implemented by NOAA Fisheries and the USFWS, will contribute to the long-term database needed to detect and evaluate trends for all marine mammal stocks.

Table 10. Status and Trends of Marine Mammals and Sea Turtles

Unit[1]	Decreasing	Stable	Increasing	Unknown	Total	Strategic Status	MMPA/ESA Status[2] E, T, D
22. Alaska Region	2	10	5	18	35	9	6,2,1
23. Pacific Region	4	13	13	36	66	16	9,2,2
24. Atlantic Region	2	1	5	54	62	29	9,0,1
% of Total	5%	15%	14%	66%	163		
25. Sea Turtles[3]	2	2	2	4	10		7,3,0

[1] Unit numbers (22-24) refer to the individual and in-depth reports presented in the full version of OLO '95.
[2] E = Endangered, T = Threatened, D = Depleted
[3] Five stocks of sea turtles from the Pacific side and five from the Atlantic side.

Sea Turtles



Green turtle
Chelonia mydas

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. Limited stock assessment data exist for about one-half of these species. All sea turtles are listed either as endangered or threatened under the ESA (Table 10). The Kemp's ridley, hawksbill, and leatherback turtles are listed as endangered throughout their ranges. The loggerhead and olive ridley turtles are listed as threatened throughout their U.S. ranges, as is the green turtle, except the Florida nesting population which is listed as endangered.

The large Pacific population of green sea turtles at French Frigate Shoals in the Hawaiian Islands is thought to be increasing, but there is continuing concern about the tumor-associated fibropapilloma disease. Efforts continue to investigate the cause of the disease and halt its advance among green sea turtles in both Hawaiian and Florida waters.

Issues of National Concern

The management of living marine resources is complex and involves many biological, economic, social, and political factors. Each region and fishery discussed in this report, and even those fisheries that are currently well managed and yielding near their long-term potential for the national benefit, must continually adjust and adapt to ever-changing conditions. To increase long-term benefits from currently overutilized and depleted resources, the difficult issues and practices which have resulted in overutilization and resource depletion must be confronted.

In each of the 21 fishery and 4 protected species units of the full OLO '95, major issues affecting the resources and their management are raised. Although each resource unit has unique features, there are common themes that are significant to many, if not all, units. These are discussed below.

Resource Conservation and Utilization

The primary concern of fishery management is conservation—the protection and wise use of the Nation's living marine resources. Management strategies must consider which stocks are overutilized and too low to produce LTPY. Table 3 indicates that 46% of the stocks under NOAA Fisheries purview whose abundance status is known (73 out of 158 stock groups) are below the abundance levels that would produce LTPY. Similar compilations indicate that 36% of the stocks (56 out of 157 stock groups) are overutilized (Table 4).

The list of stocks that are overutilized or below the levels required to produce LTPY includes some of the our most valuable fishery resources, such as New England groundfish, Atlantic sea scallops, Gulf of Mexico shrimp, several pelagic highly migratory stocks (including Atlantic bluefin tuna and swordfish), some Pacific salmon stocks, some rockfish off Alaska, and Alaska king crab. Many nearshore stocks (including several oyster populations, bay scallops, abalones, Pacific striped bass) are also overutilized.

The Northeast region has the worst case for overutilized stocks. Three historically important groundfish species (cod, haddock, and yellowtail flounder) on Georges Bank off New England are presently among the most depleted stocks in U.S. waters. Haddock and yellowtail flounder are classified as "collapsed" by virtue of their current low abundance (biomass of spawners is about 10% of the mid-1970s levels) due to prolonged excessive fishing pressure. The cod stock is in imminent danger of collapse, and portions of Georges Bank were closed to fishing beginning 1 January 1994 to reduce fishing mortality on these species and promote stock recovery.

All five species of Pacific salmon (chinook, coho, sockeye, pink, and chum), from Washington, Oregon, and California, may be considered overutilized and depleted. However, the main causes for their decline appear to be changing ocean conditions and habitat alterations, although intense fishing pressure from competing user groups exacerbate the problem.

Most shellfish resources off Alaska are depressed, and Alaska king crab is depleted in the eastern Bering Sea. Rockfish resources, particularly Pacific ocean perch, were overutilized by foreign fleets in the 1960s, but have since stabilized at historical long-term abundance levels.

In the Gulf of Mexico, the king mackerel was severely depleted because of excessively high catches in the late 1970s and early 1980s. It now supports catches about 36% of LTPY. Red snapper, traditionally the most important reef fish in the Gulf of Mexico, is taken mainly as incidental catch in the shrimp fishery, and currently supports catches only about 21% of LTPY. Red drum was subjected to intense fishing in the 1980s in response to consumer demands for "blackened redfish" and currently provides catches at about 46% of the long-term potential.

Other examples of overutilization can also be found throughout the country. Many are disproportionately impacted by fishing owing to their low numbers in relation to more abundant target species. In recent years, there has been growing awareness of Federal actions to mitigate overutilized situations. All Federal FMPs now require numerical overfishing levels to be specified according to sound population dynamics principles. Catches are normally restricted to help rebuild overfished stocks. Despite a vigilant watch for overutilization, resources do decline—some naturally, some through habitat change, and some through excessive fishing efforts—not all are controllable.

Many U.S. marine fisheries, including both the overutilized and fully utilized stocks, are overcapitalized. As generally understood, this means

that there are more fishing vessels and gear trying to catch fish than are necessary to harvest the resource efficiently. Such overcapitalization is a major factor contributing to overutilization of a resource. Where fisheries are overcapitalized and performing poorly in economic terms, short-term economic concerns tend to receive undue weight relative to the steps needed to cut back harvests and achieve long-term biological and economic goals. The excess capital may maintain pressure to increase catch limits beyond potential yield levels, deplete the resource, and once depleted, prevent its recovery. Many of the other issues discussed in this report are complicated by overcapitalization. For example, excess numbers of boats exacerbate fish allocation and bycatch problems.

Economic theory and experience in most U.S. and worldwide fisheries indicate that overcapitalization is an inevitable consequence of management schemes that allow free access to fisheries. U.S. fisheries managers have recently established access controls for more fisheries. Individual transferable quota (ITQ) management plans have been approved and/or implemented for three fisheries: the Atlantic surf clam fishery, the Alaska sablefish fishery, and the Alaska Pacific halibut fishery. Additional controls on access, including ITQs, are under consideration by all FMCs.

A few abundant resources, such as some pelagic stocks in the Northeast region, jack mackerel off California, and flatfishes off Alaska, are currently underutilized. A much larger fishery yield can potentially be obtained from these stocks, but market conditions or bycatch limitations has kept the harvest low.

Shifting fishing pressure from overutilized to underutilized stocks may relieve pressure on stressed stocks and aid in the rebuilding of depleted stocks. However, the habitat of the stocks often overlap, and effective harvesting strategies must be developed to fish one stock while not jeopardizing the other.

Bycatch

The incidental take of nontarget species in fishing operations reflects the fact that species do not live in pure, discrete, exploitable patches, but as members of intermixing communities. Groundfish fisheries have notoriously visible bycatch problems. The fisheries, whether conducted with trawl gear, longlines, or pot gear, catch and discard large volumes of animals that are of the wrong size, wrong species, wrong maturity stage, or are otherwise unwanted. For instance, as much as 60–80% of the rock sole caught in recent years in the Bering Sea were discarded because they are not the valuable roe-bearing female fish. According to a recent United Nations report examining bycatch amounts worldwide, 20–40% of the world's catch may have been discarded routinely.

Mitigation of bycatch problems is complex. The problem is partly biological and partly technological. While some technological innovations can work to reduce bycatch, such as the use of turtle excluder devices to minimize impacts on sea turtles in shrimp fisheries, most problems of bycatch are not as simple to resolve. In many cases, catches of high abundance species threatens low abundance species; thus the catch of more dominant species may have to be severely restricted.

Bycatch levels and control measures have occupied the attention of most fisheries management actions of all regional FMCs. Even when apparent solutions are found, the dynamics and abundance of marine species change in time and area, which can shift the character of the problems and require continuous adjustments to their solutions.

Habitat

Habitat loss and degradation affects mostly inshore and estuarine ecosystems. The primary threats come from alteration of freshwater flows, wetland loss, and destructive fishing methods. Diminution in freshwater volume and flow rates stem from damming and diversions of major rivers and impact nearshore ecosystems adapted to seasonal discharges of freshwater. Logging contributes to siltation and can destroy salmon spawning habitat upriver and impede their migratory paths.

Loss of aquatic plant-based habitat (e.g., coastal wetlands or eelgrass and kelp beds) resulting from development (e.g., marinas, docking facilities) adversely affect a variety of food webs that are important to adults and juveniles of many marine and anadromous species. Dredging and disposal of dredged material in estuaries and bays also cause significant habitat impacts.

Destructive fishing methods can also damage habitat and coral reefs. In the past, extremely damaging fishing practices that employed explo-

sives or poisons were prevalent in some Pacific islands. These are now almost universally outlawed, but poaching by these methods remains a problem in remote regions of the western Pacific islands.

Nonindigenous Species

Many introductions of foreign (i.e., non-native) aquatic species are intentional, and made to enhance fisheries productivity or to establish organisms of cultural importance as people immigrated to new regions. However, new species may bring along undesired effects. They may compete with native species, dilute genetic integrity, or carry new diseases to the system.

The introduction of the Pacific oyster, *Crassostrea gigas*, from Japan to the U.S. Pacific coast, which now comprises much of the aquaculture production in that area, is an example of introduction that went well. Other cases are less fortunate. The discovery of nonindigenous shrimp species in South Carolina waters during the 1980s is an example of the more common consequence of accidental introductions from aquaculture sources. Pacific black tiger prawn, *Penaeus monodon*, and Pacific white shrimp, *Penaeus vannamei*, that escaped aquaculture ponds brought new diseases to the native stocks. The Pacific white shrimp, in particular, is known to sometimes harbor infectious hypodermal and hematopoietic necrosis virus and other diseases that can devastate native shrimp stocks.

While there are benefits to be gained from species introductions, the dangers of such activities are now better appreciated, and numerous regulations have been enacted to control them. In most application reviews, the risks from intentional introductions are compared to the benefits before introductions are allowed. Even so, unforeseen adverse impacts from introductions can occur.

Unintentional introductions are increasing even as intentional introductions have declined. Unintentional aquatic introductions include the release of ornamental organisms from the aquarium trade and the accidental release of cultured species. Potential problems have been found in Florida and Hawaii where there are abundant native aquarium-trade species. Thus far, the problems has not become widespread.

Another mechanism of unintentional introduction is salmon net-pen escapes. Atlantic salmon cultured in net pens in the Atlantic Northeast and Pacific Northwest do escape and may spawn with natural salmon runs, leading to erosion of local genetic integrity. Double-mesh nets and the use of sterile animals (triploidy) are possible ways to reduce impacts of net-pen escapes.

Nonindigenous organisms may be difficult to eradicate once they become established. The effects of introductions are impossible to predict. Slowing the spread of nonindigenous marine species and reversing the impacts of introduced species are conservation problems of growing significance.

Transboundary Jurisdiction

The fact that many living marine resources often cross the boundaries between states and with other nations complicates even the most comprehensive fisheries exploitation and management regime. Effective oversight of these species requires coordination, cooperation, and agreement among all interested parties. Stocks located largely within the waters of more than one state are, to an increasing extent, managed by interstate compacts. One example of successful interstate management is the recovery of Atlantic striped bass, highlighted in OLO '93. After striped bass were reduced to very low abundance in the 1970s, a plan was developed by the Atlantic States Marine Fisheries Commission (ASMFC) which called for a series of tight fishing restrictions during 1981–90, followed by a gradual relaxation of controls as remedial measures began to take effect. This effort culminated in a declaration in January 1995 of full stock restoration.

Stocks located primarily within Federal waters are managed by plans prepared by regional FMCs and implemented and enforced by NOAA Fisheries. Stocks whose distribution overlaps the jurisdiction of more than one regional FMC require the participation of multiple FMCs.

Most stocks that extend beyond the U.S. EEZ are managed wholly or in part under international conventions. In the Atlantic, highly migratory bluefin tuna and swordfish fall under the jurisdiction of the International Commission for the Conservation of Atlantic Tunas. Regulation of these particular species is difficult since international consensus on catch levels for these high-valued fish is not always reached nor agreed on. Further, enacted measures must always be equally enforced by all nations to be effective.

Another example of a transboundary stock issue occurs on Georges Bank off New England. In 1984, a World Court decision resolving the U.S.-Canada maritime boundary dispute awarded each country part of the bank. The resulting "Hague Line" gave each country custody over the fisheries in their respective waters and the stocks distributed over the entire bank. In spite of the obvious need for joint management of important cod, haddock, pollock, yellowtail flounder, and sea scallop stocks, each country has so far exercised separate control on fisheries in their respective zones. The lack of bilateral management agreements has added to the complexity of rebuilding these overfished stocks. Recently, both countries have again taken independent actions to restrict fishing on Georges Bank.

Off the Pacific coast, anchovy and sardine straddle the border with Mexico, and several important groundfish stocks extend across the border into Canadian waters. Highly migratory tuna and billfish also cross international borders, and some range Pacific-wide. While international exchange of scientific information has been historically good, progress on joint management has been slow. In the absence of cooperative international management regimes, most stocks are regulated by individual coastal nations.

In some cases, foreign fisheries targeting migrating U.S.-origin stocks outside the U.S. EEZ can undermine Federal management of those stocks. One example is the interception of U.S. pollock stocks that occurs in the international zone of the central Bering Sea, known as the "Donut hole" area. Several international meetings were convened to address the problem, and temporary agreement was reached among all affected parties to cease fishing in the zone during 1992–95. In another positive development, an international treaty was signed and ratified in late 1995 to manage the Aleutian Basin pollock resources.

Salmon on both the Atlantic and Pacific coast begin life in freshwater and migrate to the open ocean to feed and mature before returning to their natal streams to spawn. During this period, salmon are subject to fishing pressure outside U.S. waters. Heavy exploitation of U.S.-origin Atlantic salmon in the commercial fisheries off Greenland has recently been reduced through measures implemented by the North Atlantic Salmon Conservation Organization (NASCO). Off the Pacific coast, some U.S.-origin salmon are intercepted by Canadian fishermen while migrating through Canadian waters, and some sockeye and pink salmon originating in Canada's Fraser River are caught by U.S. fishermen while transiting U.S. waters. The always-contentious allocation of expected catches from stocks originating from each country to fishermen of both nations is handled by the U.S.-Canada Pacific Salmon Commission. In the Pacific Ocean, high-seas salmon driftnet fishing is now banned under a United Nations General Assembly Resolution and by the North Pacific Anadromous Fish Commission.

Marine Mammals and Protected Species

The cumulative effects of commercial fishing activities with regard to marine mammal status are still largely unknown. One important interaction is competition for fish. Sea lions in Alaska, for example, eat juvenile pollock, while the fishing fleet targets adult pollock. Thus, while direct competition is minimized, there is concern that commercial fisheries may disrupt prey availability either through bycatch of small pollock or from general disruption of the underlying food web.

The release of fish-processing waste can alter the feeding behavior of some marine animals. Sea lions and killer whales learn to feed on fish waste discharged by processing vessels and shore-based plants. This creates an artificial dependency that may not be beneficial to the long-term well being of the animals.

Direct interactions with fishing gear can be fatal to some marine mammals, but direct kills have generally been few. Other direct interactions that can interfere with normal marine mammal behavior are less well understood, but may be important in the vicinity of critical habitats and rookeries.

Of course the other side of this issue is that marine mammal competition for fishery resources may reduce fishery yields. The relationship between such predation and fishery yield is complex and difficult to quantify, but marine mammal consumption probably has a significant effect on some fisheries.

Many protected marine mammal and sea turtle stocks are listed as endangered or threatened under the ESA or depleted under the MMPA (Table 10). Developing and implementing management strategies to minimize the adverse impact of human activities on these animals and

aiding their recovery, while not unnecessarily restricting commercial and recreational fisheries, is a major challenge.

Contaminants

Toxic contaminants in estuarine and marine habitats originate from a variety of sources, including industrial and sewage treatment plants, urban and agricultural runoff, and air pollution. These contaminants include toxic metals and such organic chemicals as chlorinated hydrocarbons and petroleum compounds.

Elevated concentrations of these contaminants can be found in bottomfish and shellfish from a number of urban and industrialized sites in many coastal areas. For example, bottomfish species from a number of chemically contaminated areas in the vicinity of such major cities as Boston, New York, Los Angeles, and Seattle exhibit liver cancers and other lesions that are associated with the process that leads to liver cancer. While cancers are the most dramatic of the lesions observed, early degenerative or proliferative conditions are much more prevalent and are found in animals from moderately as well as heavily contaminated sites. Others may suffer various types of reproductive impairment such as inhibited spawning ability and reduced viability of eggs and larvae.

Little is known about contaminant effects on marine mammals, although studies continue on the effects of DichloroDiphenylTrichloro-ethane (DDT) and Polychlorinated Biphenyls (PCBs) on California sea lions. Toxic effects range from sublethal changes, such as slower growth, to death.

There is also widespread public concern about large oil spills in the marine environment. A large spill can cause extensive loss of plants and wildlife, commercial and recreational uses, and property values. The 1989 *Exxon Valdez* oil spill in Prince William Sound, Alaska, is a recent example.

Chemicals, microbial pathogens, and marine toxins are potential contaminants to seafood. In most U.S. coastal areas, the human health risks projected from current levels of marine environmental contamination in marine seafood products are either negligible or undetectable. However, fish and shellfish from some areas, such as near Boston Harbor and San Pedro Bay near Los Angeles, have been known to contain elevated levels of toxic chemicals that could be potentially harmful to human health.

Another major type of pollution, discharges of infectious microorganisms from agricultural and domestic sources, can contaminate clams, oysters, and other shellfish species. This potential risk to humans has resulted in the closing of vast coastal waters to shellfish aquaculture and harvesting; however, with present management practices, the risk remains relatively low.

Marine biotoxins, such as paralytic shellfish poisoning (PSP) and domoic acid or amnesiac shellfish poisoning (ASP), adversely affect fisheries by jeopardizing the safety of some of their products. PSP results from the consumption of mollusks infected with specific strains of dinoflagellates. Domoic acid outbreaks have occurred in a variety of seafood products and caused huge losses to the seafood industry. For example, in the fall of 1991, an outbreak of domoic acid poisoning in Monterey Bay, California, moved up the coast and to Oregon and Washington. Like PSP, the primary route of human exposure to domoic acid is from eating affected mollusks (e.g., razor clams), although the viscera of Dungeness crab is also known to accumulate high levels of the acid. The mechanism by which the acid is accumulated is not clear. Biotoxins occur naturally, but the apparent increase in their occurrence may be related to coastal development, including nutrient enrichment.

Marine Debris

Marine debris pollutes all of the world's oceans, but the problem hardly begins there. Close to 80% of the debris is washed, blown, or dumped from shore. This debris casts a broad shadow over marine and littoral animals, plants, and perhaps even entire ecosystems. Biological studies tell us that waterborne litter entangles wildlife and masquerades as a food source, smothers beaches and bottom-growing plants, and provides a surface for colonizing small organisms that travel on marine debris to distant shores, perhaps with adverse ecological consequences. Entanglement is the most obvious of all biological impacts. Northern fur seals entangled in net webbing were spotted as early as the 1930s. Only fleeting glimpses of entangled animals are possible from planes and ships. Many die and sink or are eaten by predators

without detection; others remain submerged and hidden beneath the ocean surface. At least 135 species of marine vertebrates and eight invertebrates have been reported entangled in marine debris. The list now includes most of the world's sea turtle species and more than 25% of marine mammal species.

Ingestion of some marine debris can be a serious threat. Sea turtles mistake clear plastic bags for jellyfish, a favorite natural food. Ingested debris damages the digestive tract, causes starvation by blocking food, may be toxic, and in general is a serious source of mortality.

For centuries, we have used the oceans as dumping grounds for waste. Trash was simply heaved overboard from ships; much of it still is. At present, two global conventions combat marine debris pollution from sea-based sources: the London Dumping Convention (LDC) and the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78). Land-based sources of marine pollution are beginning to be addressed globally in follow-up meetings to the 1992 U.N. Conference on Environment and Development. The U.S. is party to these fora and takes an active role in mitigating marine debris problems. Education and promotion of awareness of the issue and its many solutions seem the best ways to combat this widespread phenomenon.

Adequacy of Scientific Information and Assessments

The status of fishery resources has been classified as unknown for 34% of the stocks covered in OLO '95. Most are nearshore resources (50 out of 74 nearshore stock groups). The figure may give an overly negative impression of our knowledge of national LMRs. However, they accounted for only 4.7% of U.S. RAY (238,000 t out of 5.06 million t) during 1992–94. In turn, this means that the status is known for the stocks that produce more than 95% of the U.S. catch.

But sound, scientifically based fisheries management requires more than the ability to classify the status of stocks. Relatively precise estimates of actual abundance, fishing mortality, and potential yield (e.g., CPY and LTPY) are more desirable. To improve on these estimates, more effective research and data sets will be needed.

Many potential benefits from LMRs may not be achieved because of insufficient data. When the status of LMRs is unknown or imprecisely known, it is necessary to harvest more conservatively to guard against accidental depletion. Some groundfish fisheries in the eastern Bering Sea and Gulf of Alaska are examples of such a cautious strategy. On the other hand, the lack of precision in assessments of fishery resources has rather unfortunately been used in some cases to argue that the evidence of overutilization was not strong enough to justify restricting a fishery. This argument has led to the depletion of many historically abundant stocks.

Uncertainty about the relationship between marine mammals and fisheries now threatens both. In the example of Steller sea lions off Alaska, the sea lion population has declined substantially, and the scientific basis to determine if the fishery is negatively impacting them remains incomplete.

It is also important to note that the status of stocks is unknown for 65% (112 out of 173 stock groups) of the marine mammal and sea turtle groups reported here. Trend data are similarly lacking.

In addition to uncertainties in the status of stocks and abundance estimates or trends, there are critical gaps in our knowledge about ecosystem effects on LMRs. These gaps include the effects of environmental variability and change, including climate, functional habitat alteration, and long-term environmental degradation. Also included are gaps in knowledge about multispecies interactions.

Outlook

The ocean environment is particularly complex. Such factors as wide temperature fluctuations, frequent storm events, and global ocean warming, to name a few, combine to create a highly variable environment that affects resource populations. What is lacking is good information and scientific knowledge on the quantitative interrelationships of the major species and the components of marine ecosystems.

A wide range of human activities affect LMRs. Ever-intensifying fishing efforts and deployment of more powerful and sophisticated fishing gear and electronic fish-finding equipment have resulted in gross overfishing of some resources. Associated with fishing is "bycatch," the situation

in which nontarget species are taken in fishing operations. These problems have caused management to move toward "controlled access" to fishing whereby catch quotas would be allocated to individual fishing vessels instead of granting free and open access to all vessels. This move towards the allocation of quota share to individual vessels is gradually achieving wider acceptance by both managers and fishermen.

Today, another major issue is mitigation to protect endangered or threatened species. The use of riverine waters for irrigation, power generation, and consumptive uses by large urban areas has compromised freshwater flows and the survival of Pacific salmon runs. The people and the courts have become more involved with mitigation of the issues, and some rather extreme options, as in the case of the removal of the two Elwha River Dams on the Olympic Peninsula of Washington State, are being contemplated.

Urbanization has led to habitat alterations in rivers and estuaries, as well as coastal zones. Along with urbanization has come alteration of freshwater flows, erosion, introduction of toxic chemicals and other contaminants into the waters, introduction of nonindigenous species, and degradation of the marine habitats essential to the survival of LMRs.

Many demographic trends suggest that these conditions and threats are not likely to change in the immediate future. Some 50% of the U.S. population reportedly lives within a 2- or 3-hour drive of major freshwater systems (the Great Lakes) or the ocean. As the national economy grows, there will be further development at the land-sea interface. The human desire to live within sight of the ocean has never abated and, increasingly, urban dwelling areas are being developed on or near the shorelines.

There are also many natural changes in the dynamics of the ecosystem that may exacerbate the aforementioned issues. For instance, global warming research over the past two decades now shows widespread impacts on living marine resources. Articles in recent issues of major scientific publications such as *Science*, indicate subtle yet progressive warming of Pacific coastal waters and consequently an eradication of certain species that would have been found in these waters a half-century ago. The foregoing suggests that it is necessary to have a far better understanding of how human activities, in concert with short- and long-term climatic changes, can compromise LMR viability.

Thus far, the utilization and management of the Nation's LMRs have been approached mainly from a resource-by-resource point of view. As information on multispecies relationships, ecosystem interactions, and environmental influences becomes more available, management approaches can move toward more explicit considerations of human activities on all components of the ecosystem. The goal is to move toward utilization of living marine resources for their combined ecological, recreational, commercial, and other aesthetic values. These optimal values and uses are no simple matter to define, let alone achieve. Thus the task will remain a formidable challenge for the fisheries, scientists, and managers.

Generally, the outlook for the welfare of the Nation's LMRs is "guarded" with a need to remain vigilant. The unprecedented decline in the Northeast groundfish fisheries, the precarious state of some Pacific Northwest salmon stocks, and declines in some marine mammal populations are situations that need special attention. While many of our marine resources remain in good condition, they must be attentively managed and conserved under a suite of Federal laws and international treaties. The science of the marine environment and the resources found there must be improved, because without reliable scientific knowledge, resource utilization and management must continue in a very conservative and narrow scope. ❑

FEATURE ARTICLES

OUR LIVING OCEANS • 1995

Introduction

This article describes the biology, history and development of Pacific Northwest salmon and their fisheries, and identifies issues of special concern that have caused some of the salmon stocks to be listed under the Endangered Species Act. The status of Pacific coast salmon stocks and the Alaska salmon stocks are described completely in Units 12 and 13, respectively, of the full version of OLO '95.

Salmon have played an important role in the culture and commerce of the Pacific Northwest since time immemorial. Six species are traditionally called Pacific salmon: Chinook salmon, *Oncorhynchus tshawytscha*; sockeye salmon, *O. nerka*; coho salmon, *O. kisutch*; chum salmon, *O. keta*; pink salmon, *O. gorbuscha*; and the cherry or masou salmon, *O. masou*. All but the Asian cherry salmon are found in the northeast Pacific Ocean and spawn in rivers of the Pacific Northwest. All Pacific salmon spawn only once in their lives, and all species are considered to be anadromous, i.e., they migrate from saltwater to freshwater to spawn. The catch history for each species is shown in Figures 7 to 11.

Pink Salmon

The pink salmon has the smallest body size of all North American Pacific salmon, averaging 1.0–2.5 kg at maturity. Pink salmon are sometimes called "humpback" salmon or "humpies" because the males develop a large dorsal hump at maturity. It is the most abundant species of Pacific salmon and the least dependent on freshwater. Thus, depending on whether Pacific salmon evolved from a freshwater or marine ancestor, pink salmon may be considered either the most primitive or the most highly evolved species.

Pink salmon commonly spawn around the north Pacific Rim from North Korea to Puget Sound, Washington. Spawning has been reported as far south as Monterey Bay, California, but the southernmost runs regularly occur in Puget Sound. Most pink salmon spawn in the lower sections of coastal rivers and creeks, though some spawn in brackish water. The young salmon or fry migrate to sea immediately after emerging from their gravel beds and, during extensive offshore North Pacific migrations, grow to full size and return to spawn at age 2.

Because of this rigid two-year life cycle, populations that spawn in even years and odd years are reproductively isolated even if they spawn in the same stream. In fact, odd-year pink salmon in North America are more closely related to odd-year pink salmon in Asia than to even-year pink salmon that spawn in the same North American streams. In Puget Sound and southern British Columbia, most pink salmon spawn in odd years.

Chum Salmon

Chum salmon, also called dog salmon, is the second most abundant and the second largest Pacific salmon at maturity, averaging 4.6 kg. Like pink salmon, chum salmon spend little time in freshwater. Most adults enter freshwater when they are fully mature and spawn and die within a few days of freshwater entry. Also like pink salmon, chum salmon usually spawn in the lower reaches of rivers and rarely ascend streams above any barriers that require leaping, although some in the Yukon River (Alaska/Canada) migrate over 2,000 km upstream to spawn. Chum salmon juveniles also migrate to sea immediately after emerging from the gravel and undertake extensive oceanic migrations. However, unlike pink salmon, chum salmon do not always mature at the same age: a few mature at age 2, some at age 3, but in the Pacific Northwest, most mature at age 4.

Pacific Northwest
Salmon
PINK • CHUM • CHINOOK • COHO • SOCKEYE

Chinook Salmon

Chinook or king salmon is the least abundant species of Pacific Northwest salmon and has the largest body size at maturity, with fish as large as 57 kg (126 lb). The species has two distinct life history patterns which are characterized as "stream-type" or "ocean-type" rearing.

Adult stream-type chinook salmon tend to enter freshwater in the spring or summer when they are still bright silver in color and not fully mature. They typically migrate to headwater areas and hold in pools until the fall when they spawn. Juveniles predominantly remain in freshwater for one or more years before migrating to the sea. At

sea, the stream-type chinooks make extensive high-seas migrations.

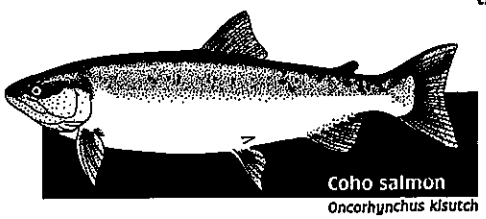
Ocean-type chinook salmon tend to spawn in the larger mainstem rivers at lower elevations than stream-type fish. Adults generally enter freshwater in the fall and spawn within a month or two of freshwater entry. Ocean-type juveniles rear in freshwater or estuaries for a few months after emergence from the gravel and then migrate to sea as subyearlings. At sea they tend to remain in the area of the continental shelf where they are more vulnerable to shore-based fisheries.

Because of the great differences in their life histories, freshwater habitat has a much larger influence on the survival of stream-type chinook salmon than on that of ocean-type chinook salmon. Stream-type chinook salmon are also less suitable for hatchery rearing because the extended freshwater holding periods of both adults and juveniles require extensive facilities. Consequently, stream-type fish, which was once the dominant life-history type in Washington, Oregon, and California, has declined far more than ocean-type chinook salmon in the region.

Coho Salmon

Coho salmon has a less diverse life history than chinook salmon, and it is more dependent on freshwater habitat than ocean-type chinooks. In the southern part of its range, juveniles spend their first year in fresh water before migrating to sea. In more northerly areas, they may spend 2 years in freshwater. Like ocean-type chinook, coho salmon tend to remain relatively close to shore, where they are harvested in commercial and recreational troll fisheries.

A small percentage of the fish, mostly males, return to spawn at age 2 after spending one summer in the ocean, but the majority of coho mature at age 3. Coho salmon tends to spawn in the headwater areas of streams that are smaller than those used by chinook salmon, and coho juveniles rear for their first year in backwaters and side channels before migrating to sea as yearlings. Erosion and sedimentation resulting from logging has degraded much of the coho salmon spawning habitat, and channelization of coastal streams for agriculture and flood control has severely reduced the available rearing habitat of coho salmon in many areas.



Coho salmon
Oncorhynchus kisutch

Sockeye Salmon

Sockeye salmon has the most complex life history of North American Pacific salmon. The species usually spawns in river systems that contain lakes. Runs of sockeye salmon in a single river system can include separate races that spawn upstream and downstream from a lake, as well as beach spawners that spawn within the lake itself. There are also resident populations of sockeye, known as kokanee, that never migrate to sea.

After hatching and emerging from the gravel, sockeye fry migrate to lake waters where they live from 1 to 3 years before migrating to sea. The fish mature after spending from 1 to 5 years in the ocean.

At maturity, the male sockeye salmon develops a pronounced dorsal hump and an exaggerated hooked jaw, and both sexes turn bright red with a green head. In North America, the sockeye salmon is the third most abundant Pacific salmon species, after pink and chum salmon. However, the sockeye salmon is the least abundant salmon species in the Pacific Northwest, as its largest populations are found in Canada and Alaska.

History

Salmon played a central role in the culture of Indian tribes of the Pacific Northwest prior to the arrival of Europeans. Its abundance, as well as that of other fish and game, permitted a human population density that was unequaled elsewhere in North America. The reliability of runs and the relative ease of capture of migrating salmon permitted a degree of affluence among tribes of the Pacific Northwest, which is amply reflected in their art, commerce, and culture.

The early Indians used hook and line, traps, weirs, jigs, spears, and a variety of nets to harvest salmon. Large river systems like the Sacramento, Columbia, and Fraser had many salmon runs returning at different times. Consequently, salmon were available for harvest nearly year round.

Within Puget Sound, the coastal Salish people developed a fishing method called reef netting that targeted Fraser River sockeye salmon on their homeward migration. This method involved guiding the migrating salmon over a net suspended between two canoes and then raising the

net. Reef netting was labor-intensive but highly productive, and is still in limited use today.

In 1855 and 1856, the U.S. Government negotiated treaties with native tribes in the Pacific Northwest when land was opened for new settlement. In these treaties, Indians were guaranteed the right "to fish in common" at their traditional fishing locations with the nonnative settlers.

When the early Europeans arrived on the west coast of North America, they also began to harvest salmon for subsistence and limited commerce at local markets as fresh fish and for export as salted and dried fish. In 1864, the Hume brothers started a salmon cannery on the Sacramento River in California. Three years later, they opened their first cannery on the Columbia River, and the commercial salmon fishery rapidly expanded.

Early canning production focused entirely on chinook salmon. Chinook catches peaked on the Columbia River in 1883 when 630,000 cases of salmon, representing nearly 20,000 t of fish, were packed. The salmon were caught in freshwater with weirs, traps, fish wheels, seines, and gillnets. As the chinook runs began to decline, the industry also targeted other Pacific salmon species. Total harvest peaked in 1911 when about 22,500 t of salmon were taken from the Columbia River. Nearly every accessible river in California, Oregon, and Washington with a significant run of salmon had at least one cannery on it.

In Puget Sound, the canning industry targeted sockeye salmon from the Fraser River in Canada. Salmon migration routes brought a significant portion of Fraser River fish through U.S. waters in the San Juan Islands and in the waters off Point Roberts at the U.S.-Canada border. The canneries initially obtained a large part of their fish from the Indian reef-net fishery, but as more efficient gear was introduced, the Indians were almost completely displaced from the commercial fishery.

In the 1890s, traditional reef-net sites were taken over by fish traps, which were often owned by the canneries and were much more efficient than the traditional Indian gear. Gillnetters and purse seiners began to harvest fish before they reached the traps. When boats became motorized in the early part of the 20th century, they were able to fish the runs as they entered the Strait of Juan de Fuca, and to follow the runs through Puget Sound.

At that time, the Indians lacked the financial resources necessary to enter these capital-intensive fisheries and mostly were restricted to subsistence fishing near river mouths on reservation land. In the early-1900s, concern arose over declining salmon abundance, and the states began to restrict salmon fishing seasons. The ocean troll fishery rapidly expanded thereafter for a number of reasons: the introduction of powerboats made the offshore fishery feasible, gear was relatively inexpensive, and the fishery was initially exempt from license requirements and closed seasons because it operated outside state jurisdiction.

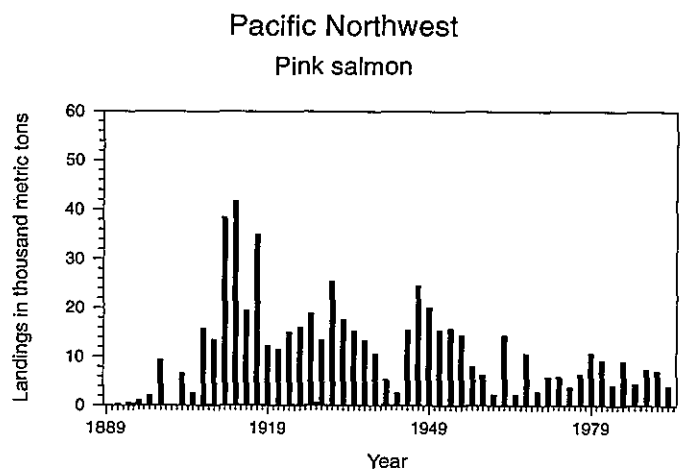


Fig. 7. Historical landings of pink salmon.

With the additional gear types and participants, salmon runs continued to decline. States began to pass further restrictions on fishing, but many restrictions were aimed more at allocation than at conservation.

In the 1930s, Washington and Oregon banned fixed gear, such as fishwheels and traps, for salmon. Most fishwheels and traps were owned by canneries, and the less efficient gillnet and recreational fisheries had more public support than the cannery operators. Since then, there has been a trend to eliminate more efficient gear types and to allow expansion of effort in the remaining fisheries. California eliminated all nontribal salmon gillnetting in the 1950s, and Oregon did the same in state coastal rivers. Presently, the only legal gear in the ocean salmon fisheries is hook and line, but gillnetting is still permitted in the Columbia River and by Indian tribes in estuaries and fresh water. Purse seining, gillnetting, and reef netting are all permitted in Puget Sound.

In 1974, a Federal court presided over by Judge George Boldt ruled that the treaty phrase "to fish in common" entitled the treaty tribes to half of the available harvest from salmon stocks that passed through traditional Indian fishing grounds. The State of Washington had argued that when it had become a state, its authority to manage fisheries and commerce within its boundaries superseded Indian treaties negotiated by the Federal government when Washington was a territory. The Court also ruled that tribal fishing rights had precedence over any other salmon fishing privileges that all others had.

The Boldt decision mandated reallocation of a major portion of the salmon resource and thus a subsequent downsizing of the non-Indian commercial fishery. Since 1974, treaty tribes in the Pacific Northwest have been allocated an increasing share of the salmon resource and have assumed a significant role in management of the stocks.

As Pacific Coast settlement progressed, freshwater salmon habitat has been lost. In California, sedimentation caused by hydraulic mining in the mid-1800s nearly extirpated salmon runs in the American, Feather, and Trinity Rivers. Throughout California, Oregon, and Washington, logging, flood control projects, and diversion of water for agriculture reduced the amount of available habitat and degraded much of what was left. On the Fraser River in British Columbia, rockslides and debris from railroad construction caused a blockage of the river at Hells Gate that prevented most fish passage in 1914 and contributed to the decline of upper Fraser River populations. From the early-1900s through the 1960s, construction of dams for hydropower, irrigation, and flood control continued to progressively block fish passage and reduce salmon habitat despite requirements that the larger dam projects include construction and operation of hatcheries as mitigation for their impacts on salmon.

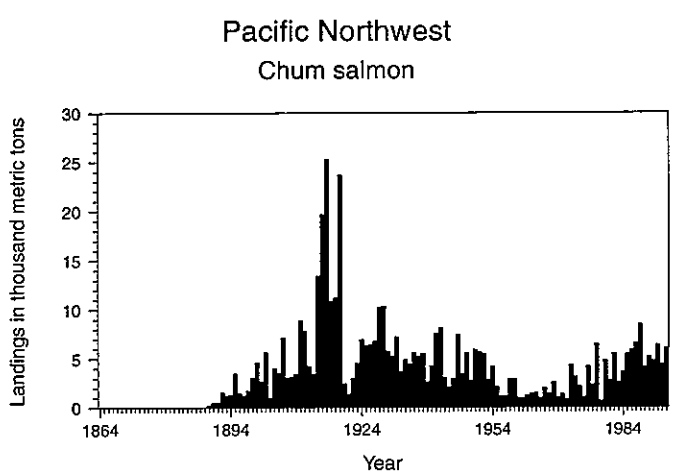


Fig. 8. Historical landings of chum salmon.

Present Fisheries

Recreational

Currently, recreational salmon fisheries operate in fresh water, salt water, and in estuaries: all are restricted to hook-and-line gear and target primarily chinook and coho salmon. Recreational fisheries in state waters are managed by the states, while those in the ocean are managed by the Pacific Fishery Management Council.

In the ocean and Puget Sound, anglers fish from private skiffs and commercial passenger fishing vessels by either trolling or drifting with bait. In California, most fish taken in the ocean recreational fishery are chinook salmon. In Oregon and Washington, coho salmon are usually targeted, but in all three states, both species are taken whenever regulations allow. Within Puget Sound, some pink salmon are taken by trolling in the recreational fishery, and a chum salmon fishery has developed in recent years that is primarily catch-and-release using light tackle or flies. In fresh water, most recreational fishing is done from boats or river banks using light tackle.

Commercial

Nontribal commercial fisheries remain offshore, in Puget Sound, and in the Columbia River. In the ocean, all fish are taken by trolling with hook-and-line. A commercial salmon troller typically uses 6 wire lines with up to 6 "spreads" or pieces of terminal gear on each line for a total of 36 lures fishing simultaneously. In recent years, ocean regulations have been adopted restricting the number of spreads on each line in an effort to make the commercial fisheries more selective. Commercial troll fisheries target chinook and coho salmon, though they take a few pink salmon incidentally.

Most troll catches are marketed as premium fresh or frozen products, as the fish taken in saltwater are bright silver and unmarked by nets. In Puget Sound, commercial fishing is conducted with gillnets and purse seines, in addition to troll gear. The fleets target Fraser River sockeye and pink salmon runs, which tend to school during their return migration, making them more vulnerable to net gear. Some also target hatchery-reared coho salmon runs that have earlier run timing than the natural spawning populations of coho. They also take large numbers of Puget Sound pink salmon in odd years and any other salmon that are encountered.

Tribal

In Puget Sound and off coastal Washington, many treaty tribes engage in commercial, ceremonial, and subsistence salmon fishing. Tribal commercial fisheries use the same gear types as nontribal commercial fisheries, and, though primarily commercial, some fish are kept for personal use. Tribes also operate fisheries in estuaries and in fresh water, targeting salmon and steelhead (the sea-run form of rainbow trout). The majority of these fisheries use gillnets, although dip nets and weirs also still are used. As a general rule, fish taken in fresh water are used for subsistence and ceremonial purposes, though harvest in excess of subsistence needs is often sold.

In the Puget Sound area and on the coast of Washington, many treaty tribes participate in the fishery management process through the Northwest Indian Fisheries Commission. On the Columbia River four treaty tribes belong to the Columbia River Inter-Tribal Fish Commission. The decline and loss of many upper Columbia River salmon stocks have made it difficult for upriver tribes to receive their allotted share of the harvest.

In California, three tribes fish the Klamath River basin: The Yuroks harvest salmon in the Klamath River estuary with gillnets, the Hoopa Valley Tribe operates a subsistence gillnet fishery in the Trinity River (a Klamath tributary), and the Karuks have a subsistence dipnet fishery at Ishi Pishi falls on the mainstem Klamath River. These tribes differ from the treaty tribes of Washington and Oregon in that no treaty was ever negotiated with the U.S. Government that guaranteed them perpetual fishing rights.

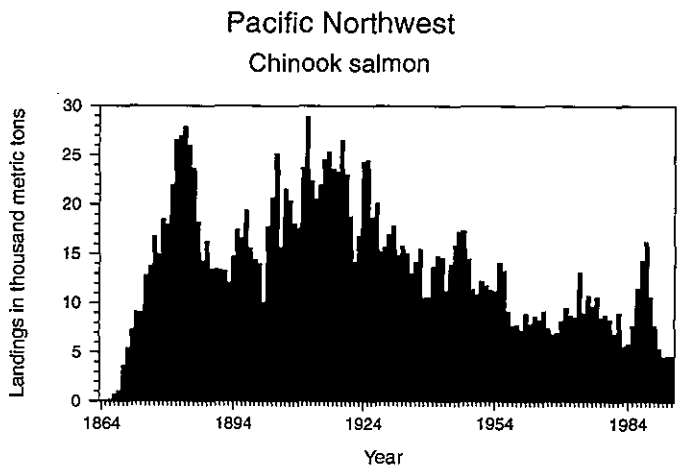


Fig. 9. Historical landings of chinook salmon.

Management

Pacific salmon management involves several national and international jurisdictions. In 1955, the International North Pacific Fish Commission (INPFC) was established by convention by the United States, Japan, and Canada to develop agreements for harvesting and conserving Pacific salmon on the high seas. INPFC sponsored extensive research programs to determine ocean distribution and migration pathways of all species of Pacific salmon and made recommendations on high-seas salmon fishing. Research sponsored by the INPFC included pioneering work on tagging, scale pattern analysis, genetic stock identification, and parasite analysis. The organization was dissolved in 1993 and its obligation was assumed by the North Pacific Anadromous Fish Commission (NPAFC). The NPAFC has four members: the three original INPFC nations and Russia.

The International Pacific Salmon Fisheries Commission was established in 1936 by treaty between the U.S. and Canada to allocate harvest of Fraser River fish and to restore stocks of sockeye and pink salmon in the Fraser River. In 1985, this organization was replaced by the Pacific Salmon Commission (PSC) as established by the U.S.-Canada Pacific Salmon Treaty. The PSC, through its Fraser River Panel, manages sockeye and pink salmon fisheries in treaty waters and allocates harvest as jointly agreed. The PSC also has the authority for in-season regulation of salmon fisheries within treaty areas based on

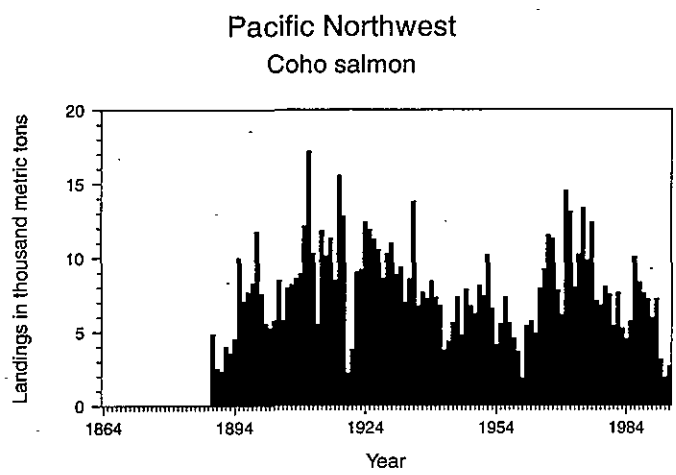


Fig. 10. Historical landings of coho salmon.

information collected during the season.

In Washington, Oregon, and California, ocean salmon fisheries are managed by the Pacific Fishery Management Council under a framework management plan. Each year, the Council reviews the status of key stocks and evaluates management recommendations. The Council adopts recommendations for ocean fisheries seasons and submits them to the U.S. Secretary of Commerce for approval. NOAA Fisheries implements ocean fishing regulations and, with Council advice, provides in-season management. States and tribes monitor landings in the commercial and recreational fisheries, but the U.S. Coast Guard and NOAA Fisheries are also involved in enforcement.

Issues of Concern

Allocation

Pacific salmon fisheries are managed to meet annual spawning escapement goals. Each year, a forecast is made for most stocks and, given expected abundance levels and legally mandated tribal allocations, a set of fishery openings and quotas is designed to meet escapement goals for the most critical stocks. Disputes over allocation of harvest have been common between gear types within the commercial fisheries, between commercial and recreational fishing interests, between states, and between tribal and nontribal fisheries. While most allocation issues are addressed through the management process, disputes over tribal and nontribal allocation have been negotiated or resolved primarily outside of the management arena, in the courts.

The current fishery management structure operates under the MFCMA which was passed after the 1974 Boldt decision had allocated 50% of the harvest to treaty tribes in Washington. Implementing this allocation has been difficult because most tribal fisheries have traditionally operated in terminal areas (i.e., in rivers and estuaries) making tribal fishermen the last in line to physically harvest salmon. For salmon to reach tribal fisheries, they must first escape all the preterminal fisheries.

Prior to the Boldt decision, preterminal fisheries were harvesting salmon at rates that probably exceeded the harvest rates necessary to achieve the long-term potential yield, and they still have the capacity to overexploit all salmon stocks. To reduce the ocean harvest enough to allow terminal fisheries 50% of the total harvest, preterminal fisheries had to reduce fishing by more than 50%. This has required profound reductions in nontribal fishing fleets.

In Puget Sound, the State of Washington and the tribes have undertaken a number of programs to minimize impacts on preterminal fisheries. Large hatchery programs were developed to increase coho salmon production and the number of fish available for harvest, and fishery openings were provided exclusively for tribal fishing. Hatchery programs have selected broodstocks with early run timing to allow fisheries to target hatchery fish while avoiding naturally produced fish. This policy is also intended to minimize the impacts of hatchery straying on natural populations of coho salmon. In the southern part of Puget Sound and Hood Canal, coho salmon are reared for an extended period in saltwater net-pens prior to release in an attempt to keep fish near terminal areas to enhance recreational and tribal fisheries.

Tribes on the Klamath River in California were not included in the Boldt decision because the Hoopa Valley reservation originally was established by presidential order rather than by treaty. Consequently, there was no treaty language guaranteeing tribal fishing rights on the Klamath River. California banned gillnetting in fresh water in 1956 and asserted that the state had the authority to regulate fisheries on Indian reservations. It was not until 1979 that a Federal court recognized the right of Indians to fish commercially on

reservations in the Klamath basin. However, the court decision did not specify tribal allocations.

The lack of agreement over tribal allocations in the Klamath basin has complicated the management of ocean salmon fisheries in southern Oregon and northern California. In 1992, the Yurok tribe argued that because they had surrendered no aboriginal rights by signing a treaty, they were entitled to at least as large a share of the harvest as treaty tribes. In 1993, the U.S. Departments of Commerce and Interior issued a legal opinion supporting the Yurok claim, and ocean salmon fisheries in southern Oregon and northern California have subsequently managed to provide a 50% allocation of Klamath River chinook salmon to the tribes.

Habitat

Habitat degradation and loss is a constant threat to salmon survival and persistence. The impacts generally increase from north to south and have affected each species of Pacific salmon in proportion to its dependence on freshwater habitat. Toward the southern end of the Pacific salmon range, impacts have been the greatest. In California's central valley, which once contained over 6,000 miles of salmon spawning and rearing habitat, because of dam construction for flood control, hydropower, and irrigation, less than 200 miles of habitat remain today, and the remaining habitat continues to decline in quality. Dams have interrupted the movement of gravel downstream, so as floods wash spawning gravel downstream, it is not replaced by new gravel from upstream. The construction of levees to reduce flooding has also reduced contributions of spawning gravel from stream banks which once resulted from shifts in the river's channel. Bank protection programs have eliminated much of the shaded nearshore habitat where young salmon once reared, and irrigation diversions entrain fish into agricultural fields and canals.

In the coastal rivers of northern California and Oregon, logging and agriculture have had several detrimental impacts on salmon. Logging has increased sedimentation in coastal streams, filling in pools and increasing the proportion of fine sediments in spawning gravel, which can suffocate incubating eggs. Past logging practices did not leave buffer strips of timber along streams to provide shaded habitat and large woody debris. Shaded habitat maintains lower water temperatures and large woody debris plays an important role in pool formation in smaller streams where coho salmon live. In lower portions of coastal streams, river bottoms have been channeled to reclaim the floodplains for agriculture and grazing. This has greatly reduced the meandering of streams which used to produce the side channels and backwater areas utilized by young coho salmon.

In the Columbia River basin, development of hydropower resources has entailed construction of 11 dams on the mainstem Columbia River and several more on the Snake River. Fish passage facilities were provided on most dams for adult fish migrating upstream to spawn, and fish guidance and bypass structures were added to pass downstream migrants around the turbines. However, the fish passage facilities have been less effective than anticipated and are still being refined.

Reservoirs created by hydroelectric dams inundated most mainstem spawning habitat, and impassable dams cut off headwater areas that historically contained many miles of spawning habitat. Impounded reservoirs also created habitat for salmon predators and increased the time that it takes smolts to complete their downstream migration. To improve survival of juvenile fish on their downstream migration, NOAA Fisheries and the U.S. Army Corps of Engineers instituted a transportation program whereby smolts are collected at the upper dams and loaded onto barges for transportation past all downstream reservoirs and dams. While this program has been successful in improving the survival of downstream migrants, the abundance of several upper basin runs of salmon has not increased.

On the Olympic Peninsula of Washington, the headwaters of most rivers lie inside the Olympic National Park, where they are protected and remain in relatively pristine condition. However, the lowlands through which these rivers flow fall outside the park and have been extensively logged with concurrent habitat degradation. Particularly noteworthy is the Elwha River, which was once one of the largest producers of salmon on the Olympic Peninsula. It was unique in that it supported all five species of Pacific salmon, in addition to steelhead, *O. mykiss*; coastal cutthroat trout, *O. clarki*; and the Dolly Varden, *Salvelinus malma*, and bull trout, *S. confluentus*. The chinook salmon produced by the Elwha River were the largest salmonids on the Olympic Peninsula with

fish reportedly taken that were over 45 kg.

From 1910 to 1912, a dam was constructed for hydropower 8 km from the mouth of the Elwha, and no provisions were made for fish passage. In 1927, a second impassable dam was constructed 14 km above the first one. Thus, for over 80 years all natural salmon spawning in the Elwha has been restricted to the lower 8 km of the river where the habitat continually has declined owing to interruption of the flow to spawning gravel from the headwaters. In 1992, the U.S. Congress passed the Elwha River Ecosystem and Fisheries Restoration Act with the goal of removing the two dams and fully restoring the Elwha River Ecosystem. The cost of removing the dams has been estimated from $147 to $203 million, with the majority associated with removing and stabilizing accumulated sediments behind the dams.

Puget Sound has also experienced a great deal of habitat modification. The coastal areas were extensively logged, and many coastal forests are being harvested for the second or third time. The area has rapidly become urbanized, and the population is growing faster in many rural areas than it is in the cities. In several rivers, summer flows are reduced due to agricultural diversions, and the flows of other streams are intermittent because of pumping from the aquifers for domestic water supplies. Industrialization and shipping have produced problems with contamination in Puget Sound, which, while usually not directly lethal to salmon, weakens their resistance to disease and their ability to avoid predators. Production of salmon in Puget Sound has been maintained at relatively stable levels through extensive hatchery programs for chinook and coho salmon and through less extensive programs for chum salmon.

Artificial Propagation

Historically, loss of natural salmon production to water development and hydropower projects has been mitigated by hatchery construction. Hatcheries also have been built for fisheries enhancement. The first Federal fish culture facility on the U.S. west coast was a salmon hatchery on the McCloud River in California, opened in 1872 by the U.S. Commission of Fish and Fisheries. Since then hatcheries have proliferated coastwide. Currently, hatcheries probably account for the majority of chinook and coho salmon production in California, Oregon, Washington, and Idaho, although the ratio of hatchery to natural production has not been estimated on a coastwide basis. Hatcheries initially were viewed as the salvation of salmon stocks and fisheries in the face of habitat destruction and degradation, but they have come under increasing scrutiny in recent years.

Production of natural populations may be depressed through competition with hatchery smolts for food and habitat, and predation of natural fry by larger hatchery smolts. Juvenile hatchery fish often are larger than naturally produced juveniles because of earlier spawn timing and more favorable growing conditions in the hatchery. When huge numbers of hatchery smolts are released into rivers with native fish, they can reduce the availability of prey for the natural fish. The influx of hatchery fish also can disrupt the territorial behavior of naturally produced juveniles, causing them to emigrate prematurely from rearing areas. In addition, coho salmon rear for a year in freshwater before release, and when they are released from the hatcheries, may prey upon naturally produced fry emerging from the gravel.

Hatchery populations also tend to be more productive than naturally spawning populations. Some fisheries in the Columbia River and in Puget Sound are managed for hatchery production. This means that stocks are harvested at rates that natural populations cannot sustain. If natural stocks are subjected to the same harvest rates in mixed-stock fisheries, they will be eliminated. In the mainstem of the lower Columbia River, this has already occurred with coho salmon. In Puget Sound, the Washington Department of Fish and Wildlife has attempted to protect natural stocks by selecting hatchery broodstock with earlier run timing than the natural populations and by timing commercial fisheries in terminal areas to target hatchery stocks. Whether this is sufficient to protect wild populations remains to be seen.

One of the greatest criticisms of hatcheries is the impact they may be having on the genetic structure of natural populations. Hatcheries have been operated by a large number of public agencies as well as a few private organizations, and there has been no comprehensive program to manage the genetic makeup of hatchery stocks.

Several practices in artificial propagation give rise to these criticisms. Over the years, hatchery broodstock and gametes have been transferred over broad geographic areas. There is concern that this movement of fish between hatcheries may

have disrupted the genetic structure of natural salmon populations in North America. There is also some evidence that propagation of fish in hatcheries over many generations has resulted in domestication of some stocks, and that fish adapted to an artificial environment are less fit for life in the wild. Thus, when hatchery fish stray from the hatchery and spawn with wild fish they may decrease the fitness of the natural populations. Attempts to minimize interaction between natural and hatchery fish by actively selecting fish with dissimilar life histories means that when hatchery fish do spawn with natural fish, their progeny are even less likely to survive.

A relatively new aspect of artificial propagation is the increasing role of commercial aquaculture. Along the Pacific coast there have been several attempts at ocean ranching, which involves operating a hatchery that releases fish to the wild with the idea of harvesting the mature fish when they return to the hatchery. Most ocean ranching operations have been unsuccessful, but the same model is being used successfully in Alaska for pink salmon enhancement.

A more successful approach has been farming, or net-pen rearing, of salmon. Salmon farming involves rearing the fish entirely in captivity, usually in floating net-pens. The production of farmed salmon on a global scale has been steadily increasing since the late-1970s, and in 1994, global production of farmed salmon exceeded the total commercial fishery production of Alaska. While most farmed salmon are Atlantic salmon, *Salmo salar*, chinook and coho also are raised.

From a market standpoint, farmed salmon have several advantages over salmon harvested in the fisheries: production is predictable and relatively stable, while natural production may fluctuate widely; fresh fish can be supplied year-round, while most wild salmon fisheries are highly seasonal; and fish quality is more consistent than in the commercial catch. As the industry continues to improve domesticated strains of salmon and to develop better feeds, the attractiveness of farmed salmon should continue to increase as its capital cost decreases.

Endangered Species

The Endangered Species Act (ESA) considers a species to be endangered if it is in danger of extinction throughout all or a significant portion of its range and threatened if it is likely to become endangered in the foreseeable future. The ESA also allows listing distinct population segments as unique "species." Because of declines in a number of individual salmon populations, NOAA Fisheries has received several petitions to list runs of salmon and anadromous trout for protection under the ESA.

Because the ESA does not define the term "distinct population segment," NOAA Fisheries has developed a policy to define this term for Pacific salmon. According to this formula, a salmon population (or group of populations) can be considered distinct only if it constitutes an evolutionarily significant unit (ESU). In order to qualify as an ESU, a population segment must be enough isolated reproductively from other population segments to allow genetic differences to occur, and it must comprise a significant component of the evolutionary legacy of the species as a whole. Currently, Snake River spring/summer chinook salmon are listed as threatened, and Sacramento River winter run chinook salmon, Snake River sockeye salmon, and Snake River fall run chinook salmon have been listed as endangered under the ESA. NOAA Fisheries has proposed listings for Umpqua River coastal cutthroat trout, and Klamath Mountains Province steelhead trout.

Because of the large number of petitions received, the agency has undertaken coastwide ESA status reviews of all species of Pacific

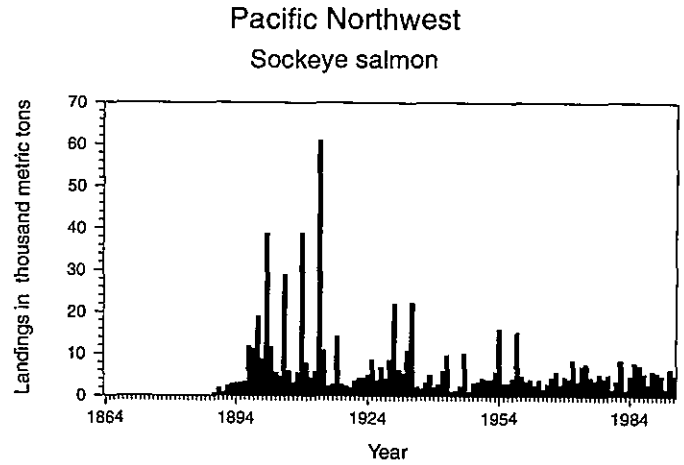


Fig. 11. Historical landings of sockeye salmon.

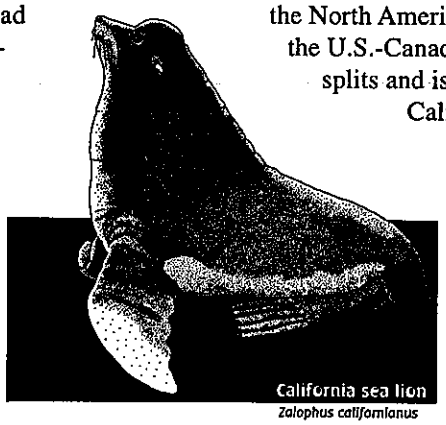
salmonids. The process involves determining the boundaries of the ESUs that comprise each species and the status of each ESU. Completion of these comprehensive status reviews should streamline the process of reviewing future petitions for listing salmon runs under the ESA.

Marine Mammal Interactions

Pacific salmon stocks have had highly publicized interactions with other protected species. Prior to the passage of the MMPA, seals and sea lions were routinely shot by fishermen. Populations of marine mammals were kept at low levels, and their interactions with the fisheries were relatively minor.

The MMPA has been extremely successful in restoring some species, notably the northern elephant seal, the harbor seal, and the California sea lion. Populations of seals and sea lions have increased in some areas to the point where they are now causing problems for fisheries. For several years there have been complaints from the marine commercial and recreational fishing industries that California sea lions have become a substantial source of noncatch mortality associated with ocean fishing.

The most visible example has been at the Ballard Locks on the ship canal near downtown Seattle, Washington. The locks are a popular gathering place for tourists and locals alike, and all salmon and steelhead migrating upstream to Lake Washington must pass through the locks or through the fish ladder located there. In recent years, up to 20 young male California sea lions, collectively named "Hershel," have congregated at the locks to take advantage of the concentration of salmonids during their spawning migration. Steelhead runs in Lake Washington have declined precipitously in this time, and it has been estimated that the sea lions may be killing as much as two-thirds of the run each year. Attempts to deal with the sea lions have been unsuccessful: loud noises to frighten them away only resulted in sea lions overcoming their fear of loud noises. Several sea lions were trapped and relocated to California, only to return. After extensive review, NOAA Fisheries finally announced plans to use lethal removal as a method of last resort, but there has been tremendous public outcry in defense of the sea lions.



California sea lion
Zalophus californianus

Marine Environment

Pacific salmon spend much of their lives and achieve the vast majority of their growth in the marine environment, yet relatively little is known about how variability in the marine environment affects their growth and survival. However, with improvements in our capability for global data collection and remote sensing, patterns in oceanographic features on larger spatial and temporal scales are emerging.

One well-known environmental feature of the U.S. Pacific coast is the periodic appearance of El Niño, a disturbance in the upper layers of the ocean originating in the eastern tropical Pacific Ocean and producing abnormally warm surface waters off the coasts of California, Oregon, and Washington. This surface warming is associated with reduced upwelling and reduced productivity of coastal waters, and with a corresponding production decline in many fisheries, including those of chinook and coho salmon.

Productivity in the eastern North Pacific now appears to be driven substantially by changes in the entrainment of the North Pacific West Wind Drift Current. This current, which originates as an extension of the Kuroshio Current, approaches the North American continent in the vicinity of the U.S.-Canada border. There the current splits and is diverted southward into the California Current along the U.S. west coast and northward into the Alaska Gyre in the Gulf of Alaska. When more of the West Wind Drift is diverted to the south, the California Current is strengthened. This is associated with colder water and with increased productivity off the west coast of the contiguous United States. When more of the West Wind Drift is entrained into the Alaska Gyre, the California Current is weakened and productivity decreases. At the same time, a strengthened Alaskan Gyre is associated with warmer temperatures and increased productivity in the Gulf of Alaska.

Changes in the entrainment of the West Wind

Drift are driven by changes in global atmospheric circulation patterns and seem to occur on decadal scales. Since about 1977, conditions have favored entrainment of the West Wind Drift into the Alaska Gyre most of the time. The changes in productivity associated with this change in ocean currents have affected different salmon species in different ways. All salmon stocks in Alaska have benefited from increased productivity in the Alaska Gyre.

Pacific Northwest sockeye, chum, and pink salmon all migrate far offshore and to the north, and have benefited from increased productivity in the Alaska Gyre. Chinook and coho salmon from California and Oregon tend to remain in coastal waters, and they have suffered from reduced productivity in the California Current system.

Chinook and coho salmon from the Columbia River northward tend to remain in coastal waters, but migrate still further north. The effects on these stocks have varied depending on the migration pathway and feeding grounds of individual stocks. Chinook salmon from the upper Columbia River tend to migrate far to the north and have maintained their productivity. Coastal stocks of chinook and coho salmon from Washington and northern Oregon and those from Puget Sound also tend to migrate to the north, but not as far as upper Columbia chinook. These stocks have experienced declines in productivity, but not as severe as those of stocks to the south. Attempts to evaluate the effects of any management impacts on Pacific salmon will always be confounded by variability in the marine environment.

Discussion

Salmon fisheries have always been a prominent feature of the cultural heritage of the Pacific Northwest. For thousands of years Northwesterners have identified with the fish, and with the activity of fishing for them. Now the future of both fisheries and fish seems to be in question.

While salmon fisheries in Puget Sound have maintained their total landings in recent years, nontribal fisheries have been severely reduced since the Boldt decision. Tribal fisheries have benefited from the Boldt decision and have increased their take from a minor fraction of the landings to a major component. Within Puget Sound, fisheries are presently supported primarily by species that have relatively little dependence on freshwater habitat, on production originating from the Fraser River in Canada, and on hatchery production of chinook and coho salmon.

Nontribal fisheries in the Pacific Northwest face difficult times. Landings have been reduced recently to protect spawning escapements. Nontribal commercial fisheries have also seen their share of the harvest decrease as a result of recent changes in allocation. Recent record landings of Alaska salmon and the increasing production of farmed salmon have driven prices down and undermined the toehold that Pacific Northwest commercial fisheries have traditionally maintained in the market. With additional constraints likely to result from recovery efforts for endangered species, the economic viability of these fisheries is doubtful.

The plight of Pacific salmon is particularly compelling because their dependence on fresh water to complete their life cycle has always made them very visible, available, and vulnerable. The challenges they overcome on their spawning migrations are inspiring, yet it is this same dependence on fresh water that currently threatens them. There are still some healthy natural pink and chum salmon populations in the Pacific Northwest, but it is increasingly difficult to find healthy natural populations of species that spend more of their lives in fresh water. The human population in the Pacific Northwest continues to increase, and people are also dependent on fresh water. The challenge we face with preserving these magnificent fish is to protect the needs of the species while accommodating the needs of the people. ❑

Marine Mammal Protection Act

• Keeping Pace with Wildlife Conservation •

Introduction

When the Secretary of the Interior produced his 1945 report on the "Fishery Resources of the United States," he noted that whale stocks worldwide were at an all time low. In that report, Remington Kellogg reported that the U.S. whaling industry had at one time engaged some 735 vessels and 40,000 people, representing an investment of $40 million and an annual harvest worth $8 million. However, in 1943, this fishery was reduced to only 3 vessels and employed 59 people; capital investment was less than $1 million and the annual harvest worth only $44,000. This dramatic turn was representative of the decline of whaling worldwide and largely due to overharvesting.

The next three decades saw increases in some marine mammal populations (e.g., gray whales, humpback whales, California sea lions), while others declined (e.g., Hawaiian monk seals, Steller sea lions). These developments were coincident with the decline of many commercially valuable fisheries resources. In response, scientists and resource managers began to focus their attention on alternatives to traditional single-species conservation regimes. The growing recognition of the need for ecosystem-level resource management was reflected in legislative actions of the 1970s and 1980s, including: the Marine Protection, Research, and Sanctuaries Act; the Coastal Zone Management Act; the National Environmental Policy Act; the Marine Mammal Protection Act; the Endangered Species Act; and the Magnuson Fisheries Conservation and Management Act. In recent years discussion of holistic multispecies management and the sustainable use of renewable resources has included the issue of maintenance of biodiversity. A key concern was the potential effect of resource utilization on the diversity and stability of ecosystems. This is particularly true for marine ecosystems, where community structure has been significantly altered by the depletion of principal prey and predator species.

From its inception in 1972, the Marine Mammal Protection Act (MMPA) has reflected the need for ecosystem-based management in its primary goal—"to maintain the health and stability of marine ecosystems." Three explicit charges are to: 1) maintain animal stocks at optimum sustainable population (OSP) levels as functioning elements of their ecosystems, 2) restore depleted stocks to OSP levels, and 3) reduce incidental mortality and serious injury to "insignificant levels approaching a zero mortality and serious injury rate." The legislative record of the MMPA frequently refers to another implicit goal, which is to minimize interference with commercial fishing enterprises while meeting the other goals.

The MMPA has been reauthorized several times and amended in response to advances in our understanding of marine mammal population dynamics evolving legal, political, and economic landscape surrounding marine wildlife conservation and management. In this regard, the most recent amendments include mandates to undertake studies of the Bering Sea and Gulf of Maine ecosystems and direct research toward multi-species interactions between pinniped populations and the fisheries. With each reauthorization, however, the fundamental conservation goals of the Act have prevailed.

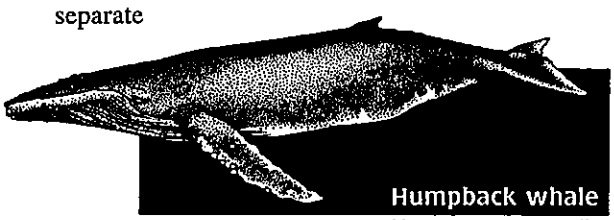
1994 MMPA Amendments

The most significant recent event affecting the conservation and management of U.S. marine mammals was the enactment on April 30, 1994 of Public Law 103-238, the Marine Mammal Protection Act Amendments of 1994. These amendments supersede the 5-year exemption from the MMPA for most commercial fisheries enacted by the 1988 MMPA amendments. During this 5-year exemption period NOAA Fisheries developed a regime for the long-term management of marine mammal/fisheries interactions. The regime is based on a scientific rationale for determining how many marine mammals may be incidentally taken; it reflects sound principles of wildlife management; and it is consistent with and implements the intent of the legislative act. Two aspects of the revised MMPA are discussed below: Stock Assessment Reports (SARs), which represent the starting point for evaluating the status of U.S. marine mammals at the beginning of the new regime; and the Potential Biological

Removal (PBR), a concept that establishes a quantitative process for setting levels of take such that marine mammal stocks will equilibrate within their optimal population size.

Regional Stock Assessment Reports

The amended MMPA requires the Secretary of Commerce and the Secretary of the Interior to jointly develop SARs for all marine mammal stocks found within waters of U.S. jurisdiction. This does not apply to stocks having a remote possibility of occurring regularly in U.S. waters. The U.S. Fish and Wildlife Service (USFWS) has sole authority for stocks of Pacific walrus, Alaska polar bear, West Indian manatee, and Alaska and California sea otters, while NOAA Fisheries is responsible for the remaining cetaceans and pinnipeds (155 stocks, including 10 eastern tropical Pacific dolphin stocks). SARs are assigned to three separate



Megaptera novaeangliae

regions—Alaska, Pacific including Hawaii, and Atlantic including the Gulf of Mexico. Three regional scientific review groups were established to review the SARs and identify areas of uncertainty and research needed to address them. They also advise the Secretaries on issues that affect the conservation of marine mammal stocks and their interactions with the commercial fisheries. The review groups are composed of 10–12 persons with expertise ranging from marine mammal population dynamics and modeling to commercial fishing technologies to represent a balance of regional, conservation and industry expertise, interests, and concerns.

The MMPA requires SARs to include how listed stocks are defined, minimum abundance estimates, current and maximum net productivity rates, current population trends, calculations of PBRs, and assessments of whether incidental fishery takes are "insignificant and approaching zero mortality and serious injury rate." Additional requirements include an assessment as to whether the level of human-caused mortality and serious injury is likely to reduce the stock to below OSP, or whether the stock should be classified as a "strategic stock." SARs are to be reviewed annually for "strategic stocks" and for stocks for which new information is available. Stocks not otherwise considered are to be reviewed at least once every 3 years.

Strategic stocks are those that are listed as endangered or threatened under the ESA, or declining and likely to be listed in the foreseeable future. Strategic stocks also include those designated as depleted under the MMPA (i.e., below OSP), and those for which human-caused mortality exceeds the estimated PBR. When implemented by NOAA Fisheries and USFWS, the new MMPA mangement regime will contribute to the long-term database needed to detect and evaluate trends for all U.S. marine mammal stocks.

The 1994 Amendments require that take reduction teams be formed for each strategic stock and charges these teams with developing a take reduction plan to reduce takes to below the PBR. Plans for strategic stocks must be submitted to the Secretary within 6 months of the convening of a team. Team membership includes representatives of Federal and state agencies, appropriate regional fishery management councils, interstate fisheries commissions, academic and scientific organizations, environmental groups, all commercial and recreational fisheries groups and gear types that impact the stock, Alaska Native organizations or Indian tribal organizations, and others as the Secretary deems appropriate.

The Potential Biological Removal Process

The 1994 MMPA amendments established, for the first time, the fundamental concept for calculating PBRs or sustainable removal levels for marine mammal stocks. Section 117 defines PBR to mean, "the maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while allowing that stock to reach or maintain its OSP. The PBR is the product of the following factors:

(a) the minimum population estimate of the stock, N_{MIN},
(b) one-half the maximum theoretical or estimated net productivity rate (R_{MAX}) of the stock at a small population size,
(c) a recovery factor (F_R) of between 0.1 and 1.0."

NOAA Fisheries interprets the PBR approach as an extension of precautionary resource management. The primary intent is to respond to the greater degree of uncertainty that is associated with assessing and reducing marine mammal mortality from incidental fisheries takes, as compared to mortality from directed harvests.

Advantages of the PBR approach are that it is not based on any particular population model, it allows conservative management to proceed when lacking detailed information, it provides an incentive to improve information on stock size by increasing precision (i.e., lowering coefficients of variation, CVs), it is based on readily measurable quantities, and it focuses on achievable goals.

Recognizing that the authorizing legislation provided only limited guidance for implementing the PBR process, and the need to establish quantitative criteria for calculating PBRs that could be consistently applied across regions, NOAA Fisheries, in consultation with the USFWS and the Marine Mammal Commission, convened a series of workshops and meetings in 1994. Guidelines for calculating PBRs for marine mammal stocks, including quantitative criteria for making those calculations, were developed. Once parameter values for the three PBR elements (N_{MIN}, R_{MAX}, and F_R) were identified, their performance was evaluated using statistical simulations to explore the behavior of hypothetical populations under a range of precision about these input variables. The simulations indicated optimal parameter values that met the MMPA goals of the recovery of depleted stocks and maintenance of stocks within OSP with 95% probability within 20–100 years (Fig. 12). For example, it was found over a range of abundance estimate CVs, from 0.2 to 0.8, that using the 20th percentile of the abundance estimate for N_{MIN} was sufficient to allow populations to recover to or remain within OSP. This occurred in the absence of problems such as biased estimates of abundance or mortality, while meeting both the 20-year and 100-year criteria. Further simulations called "robustness trials" were undertaken to explore the effects of unknown bias or other problems with input parameter valuess, including underestimation of mortality by as much as 50%. Simulations indicated that a F_R value of 0.50 (for pinnipeds and for cetaceans), in combination with the 20th percentile of the abundance estimate, resulted in all populations equilibrating near OSP within the specified time period.

Minimum Population Estimate

The minimum population estimate (N_{MIN}) is defined in the 1994 MMPA amendments as an estimate of the number of animals in a stock that:

(a) is based on the best available scientific information on abundance, incorporating the precision and variability associated with such information; and,
(b) provides reasonable assurance that the stock size is equal to or greater than the estimate."

Consistent with these definitions, N_{MIN} is calculated such that a stock of unknown status would achieve and be maintained within OSP with 95% probability. Population simulations demonstrated that this goal can be achieved by defining N_{MIN} as the 20th percentile of a log-normal distribution based on an estimate of stock abundance:

$$N_{MIN} = N/\exp(0.842 * (\ln(1+CV(N)^2))^{1/2})$$

where N is the abundance estimate and $CV(N)$ is the coefficient of variation of the abundance estimate. This is equivalent to the lower limit of a 60% 2-tailed confidence interval.

If abundance estimates are believed to be biased, appropriate correction factors are applied to obtain unbiased estimates of N. In such cases, the coefficient of variation for N includes uncertainty in the estimation of the correction factor. Where direct counts of animals are available, such as for many pinniped stocks, these direct counts are used as the estimate of N_{MIN}. Other approaches can also be used to estimate N_{MIN} provided the same level of assurance that the stock size is equal to or greater than that estimate is maintained.

Maximum Rate of Increase

One-half of the maximum rate of increase (R_{MAX}) is defined in the MMPA as "one-half of the maximum theoretical or estimated 'net productivity rate' of the stock at a small population size." The term "net productivity rate" means "the annual per capita rate of increase in a stock resulting from additions due to reproduction, less losses due to natural mortality."

Consistent with a risk-adverse approach, these default values are near the lower range of

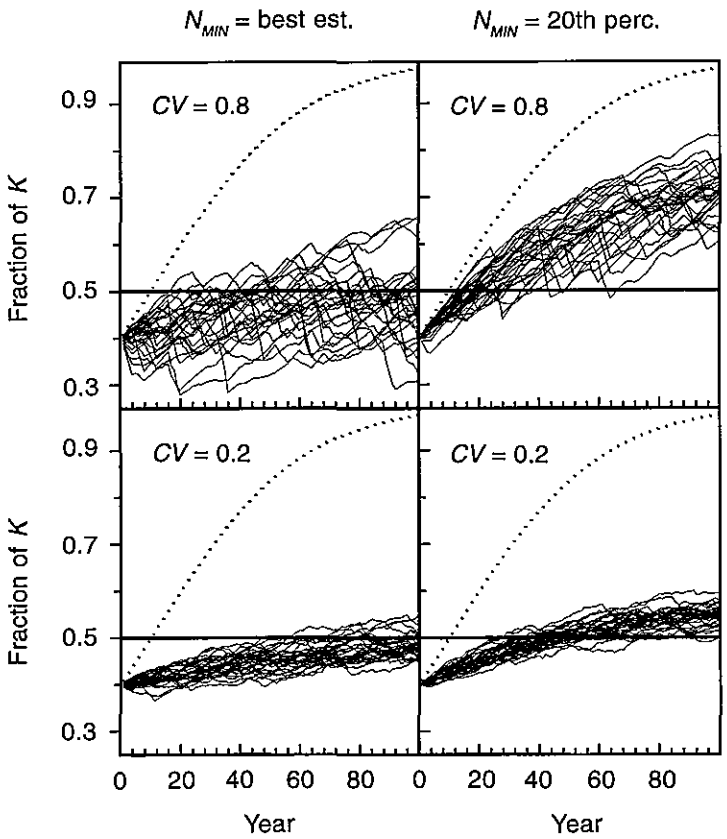


Fig.12. PBR Simulations. A sample of 30 cetacean populations simulated for 100 years for 4 different cases. PBR is calculated as the product of N_{MIN}, ½ R_{MAX} (0.02), and F_R (1.0), and is recalculated from a "new" abundance estimate every 4 years. The simulations assume that the entire PBR is taken each year as incidental fisheries mortality. The thick solid line represents a fraction of *K* (carrying capacity) of 0.5. Populations above that line are within their Optimum Sustainable Population level (OSP), whereas populations below that are considered depleted under the MMPA. Each population starts at a fraction of 0.4 *K*. The dotted line represents the trajectory of a population with no incidental fisheries mortality. The two panels on the left represent simulations using a best estimate of abundance (or point estimate) for N_{MIN}—the majority of the simulated populations are depleted after 100 years. The two panels on the right represent simulations using the 20th percentile of the abundance estimate for N_{MIN} (the lower 60% 2-tailed confidence limit), representing the strategy for calculating PBR adopted by NOAA Fisheries. In these panels, at least 95% of the simulated populations are within OSP after 100 years. The two upper panels represent simulations where the abundance estimate is relatively imprecise (*CV*=0.8), and the two lower panels represent simulations where the abundance estimate is relatively precise (*CV*=0.2).

measured or the theoretical maximum values that are thought to be plausible for a wide range of species (i.e., 0.12 for pinnipeds and sea otters and 0.04 for cetaceans and manatees). When reliable stock-specific information is available on R_{MAX}, such as an observed rate higher than the default, substitutions for these default values can be made in calculating PBR.

Recovery Factor

The MMPA defines the recovery factor (F_R), as being within the range from 0.1 to 1.0. Adding F_R to the definition of PBR ensures the recovery of populations to their OSP levels. This does not significantly increase the time necessary for endangered, threatened, or depleted populations to recover. Values of F_R less than 1.0 allocate a proportion of expected net production toward population growth and compensates for uncertainties that might prevent population recovery. These may include biases in the estimation of N_{MIN} and R_{MAX}, or errors in the determination of stock structure.

While values for N_{MIN} and R_{MAX} are adopted from strict criteria as starting points for calculating initial PBRs, the value of F_R can be "tuned." Tuning requires that reasonable assurance in the form of scientific justification or other reliable information is employed to ensure that the estimates of abundance, mortality, and R_{MAX} are not severely biased. Further, coefficients of variation of the abundance and mortality estimates must fall within accepted ranges.

Simulation studies demonstrate that to achieve the conservation goal of encouraging the recovery of stocks that are depleted (below OSP), the default F_R for depleted and threatened stocks and stocks of unknown status should be no greater than 0.5. The recovery factor of 0.5 for depleted or threatened stocks, or stocks of unknown status, was determined by the assumption that the coefficient of variation of the mortality estimate is equal to or less than 0.3. If the CV around the mortality estimate is greater than 0.3, the recovery factor must be further decreased to achieve stock recovery to OSP with 95% probability. F_R for stocks listed as endangered is assigned as 0.1.

Stocks known to be within OSP (e.g., as determined from quantitative methods such as dynamic response or back-calculation), stocks of unknown status that are thought to be increasing, or stocks taken primarily by aboriginal subsis-

tence hunters that are not known to be decreasing, can have higher F_R values. These values may be up to and including 1.0, provided that there have been no recent increases in the levels of mortality.

The recovery factor is also used to accommodate additional information and allow for management discretion as appropriate and consistent with the MMPA goals. For example, if human-caused mortalities include more than 50% females, the recovery factor could be decreased to compensate for the greater impact of this mortality on the population (or increased if the mortalities are less than 50% female). Similarly, declining stocks, especially ones that are threatened or depleted, can be given lower recovery factors; the value of which may depend on the magnitude and duration of the decline.

Alternatively, recovery factors can be increased in some cases. If mortality estimates are known to be relatively unbiased because of high observer coverage, then it may be appropriate to increase the recovery factor to reflect the greater certainty in the estimates. For example, in the case where the observer coverage was 100% and the observed fishery was responsible for virtually all fishery mortality on a particular stock, the recovery factor for a stock of unknown status might be increased from 0.5 to 0.75. This action reflects reduced concern about bias in mortality, but continued concern about biases in other PBR parameters and possible errors in determining stock structure. Recovery factors of 1.0 for stocks of unknown status are reserved for cases where there is assurance that N_{MIN}, R_{MAX}, and the kill are unbiased, and where the stock structure is unequivocal or those cases where the population is not known to be adversely affected by human interactions. Where stocks are not known to be adversely affected by human activities, but whose status is unknown, recovery factors up to 1.0 are appropriate.

Throughout 1994 and the spring of 1995, NOAA scientists identified several opportunities for continuing or new research that would advance and assess the performance of the PBR-based regime for managing takes of marine mammals. NOAA Fisheries published the final versions of the SARs in the summer of 1995 and will conduct follow-up PBR workshops. ❑

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