Alaska Fisheries Science Center

National Marine Fisheries Service

U.S. DEPARTMENT OF COMMERCE

Biennial Report for Calendar Years 1994-95

AN IN-HOUSE REPORT, NOT FOR USE OUTSIDE AFSC.

ALASKA FISHERIES SCIENCE CENTER

Seattle, Washington

BIENNIAL REPORT
1994-95

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August 1997

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ALASKA FISHERIES SCIENCE CENTER

The Alaska Fisheries Science Center (AFSC) is the research branch of the National Oceanic and Atmospheric's National Marine Fisheries Service (NOAA-NMFS) responsible for fisheries research in the coastal waters off Alaska and the U.S. West Coast. This region of nearly 3 million square miles includes over 50% of the U.S. coastline and over 70% of the U. S. continental shelf. These waters, including the eastern North Pacific Ocean, Gulf of Alaska, and eastern Bering Sea, support some of the most important commercial fisheries in the world -- walleye pollock, Pacific salmon, and king and Tanner crab--with a total biomass of more than 26 million metric tons. These waters are also the home to some of the world's largest populations of marine mammals and seabirds in the Nation. Marine mammals of particular interest include the Steller sea lion, northern fur seal, Dall's porpoise, and bowhead and beluga whales.

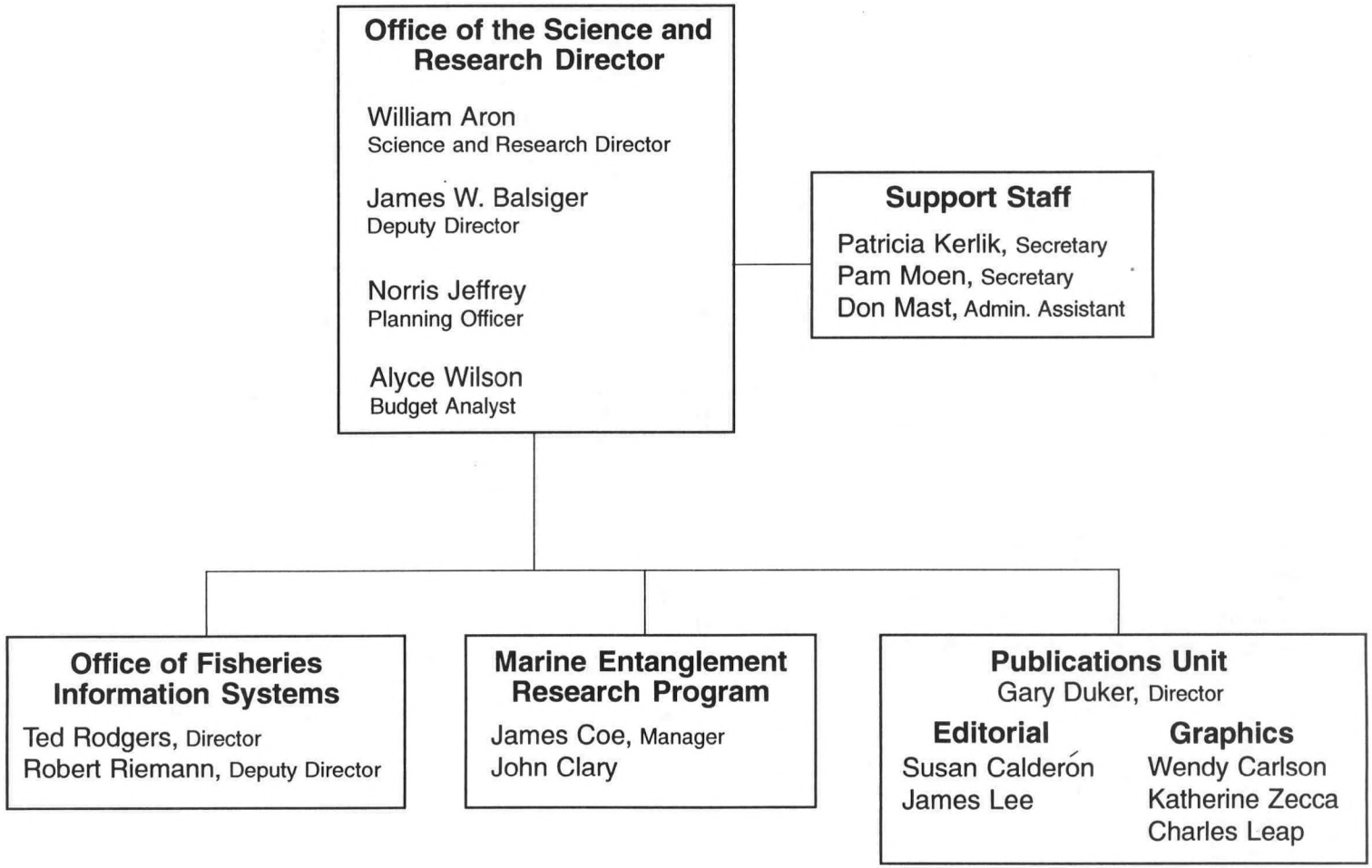
The fishery resources of this region now provide approximately 55% of the volume and 40% of the value of the total U.S. domestic catch. The groundfish complex off Alaska is the most abundant of all fishery resources in the United States. Commercial landings off Alaska in 1995, for example, were greater than for any other state in the Nation in terms of both volume and value, with a total of 5.4 billion pounds and $1.4 billion, respectively.

Scientists of the Alaska Fisheries Science Center conduct field and laboratory research to help conserve and manage of the region's living marine resources in compliance with the Magnuson Fishery Conservation and Management Act, Marine Mammal Protection Act, and Endangered Species Act. Center scientists study the life history of the region's living marine resources. They estimate the size and value of commercial fishery resources, monitor foreign and domestic fishing operations, provide information on protected species, and study the physical properties of freshwater, estuarine, and marine environments. Scientists also interact with their counterparts in Canada, Japan, the U.S.S.R. (Russia), Republic of Korea, Taiwan, and China, and other nations to jointly preserve and conserve the region's living marine resources.

The Alaska Fisheries Science Center is made up of the Auke Bay Laboratory, the National Marine Mammal Laboratory, the Resource Assessment and Conservation Engineering Division, the Resource Ecology and Fisheries Management Division, and the Center Director's Office which includes the Office of Fisheries Information Systems and other support services. Program objectives are carried out at from the Center's Sand Point facilities on Lake Washington, Seattle, at the Auke Bay Laboratory in Juneau, Alaska, the Kodiak Laboratory, Little Port Walter Field Station in Alaska and at the Mark O. Hatfield Marine Science Center in Newport, Oregon.

This biennial report describes some of the major research activities of the Alaska Fisheries Science Center during 1994 and 1995.

CENTER DIRECTOR'S OFFICE
ORGANIZATION CHART
1994-1995



MARINE ENTANGLEMENT RESEARCH PROGRAM

Projects funded by the NMFS Marine Entanglement Research Program (MERP) in 1994 and 1995 addressed the issue of marine debris (persistent solid waste pollution) as required by the Program's authorizing language and by the Marine Plastic Pollution Research and Control Act of 1987 (MPPRCA). The MPPRCA implemented in the U.S Annex V, Regulations for the Prevention of Pollution by Garbage from Ships of the International Convention for the Prevention of Pollution from Ships (MARPOL V). Fiscal Year 1995 was the final year for the NOAA-NMFS Marine Entanglement Research Program.

EDUCATION AND PUBLIC AWARENESS PROJECTS

Public education continued to be a major focus of the MERP. To meet this responsibility a 5-year contract with the Center for Marine Conservation (CMC) continued to operate Marine Debris Information Offices (MDIOs) for the Atlantic, Gulf of Mexico, and Pacific Coast regions. These offices have been overwhelmingly successful at providing to the public educational and resource materials such as printed information, posters, photographs, and video tapes relating to the marine debris issue. During 1994 and 1995, the MDIOs responded to thousands of requests for information from individuals and organizations and distributed nearly 500,000 brochures, teaching aids, and other materials.

In 1995, in cooperation with the North Carolina State University Sea Grant Program, the MERP initiated a quarterly newsletter, "Marine Debris Worldwide", dedicated to sharing information on all marine debris issues. Volume 1, Number 1, was mailed to over 800 addressees in June 1995.

Other education and public awareness projects funded by the MERP during 1994 and 1995 included continuing work in the Pacific islands with the University of Hawaii Sea Grant Program and expanding a marine debris outreach campaign in the Caribbean region, in cooperation with the Caribbean Subcommission of the Intergovernmental Oceanographic Commission (IOCARIBE). This latter project was undertaken to help pave the way for MARPOL V Special Area designation of the Wider Caribbean Region (which includes the Gulf of Mexico) and included MERP support, planning, assistance, and attendance of the Third and Fourth Caribbean Marine Debris Workshops in Nassau and the Dominican Republic. The MERP organized, sponsored, and chaired the Third International Conference on Marine Debris in Miami, Florida, in April 1994. A conference summary report titled "Seas

of Debris" was prepared and published in early 1995. The full conference proceedings titled "Marine Debris: Sources, Impacts, and Solutions" is slated for publication in 1996.

MITIGATION PROJECTS

During 1994 and 1995, two continuing projects were supported to directly reduce the marine debris problem: the National Beach Cleanup Campaign and the Debris Removal from Hawaiian Monk Seal Beaches.

The National Beach Cleanup Campaign is the largest single voluntary environmental event in the United States and is cofunded with the Environmental Protection Agency (EPA). During the 1994 cleanup campaign, 139,746 citizen volunteers removed 2.8 million pounds of debris from 5,148 miles of the U.S. coastline. In 1995, 139,929 volunteers collected 2.5 million pounds of debris from 5,870 miles of the U.S. coastline.

The Hawaiian monk seal debris removal project is funded by the MERP through the NMFS Southwest Fisheries Science Center. Research teams working to understand and to protect the endangered monk seals made annual trips to hauling and pupping beaches in the northwest Hawaiian Islands to gather, catalog, and destroy entangling material (approximately 12,000 pounds per year) that had washed ashore in this critical habitat. Since researchers began systematically documenting monk seal entanglements in 1982, over 100 entanglements have been recorded.

Several years' work on development of guidelines for providing adequate port reception facilities for ship wastes culminated in 1995 with the International Maritime Organization's (IMO) publication of its "Comprehensive Manual on Port Reception Facilities". This work was done under contract and in cooperation with the U.S. Coast Guard (USCG).

Initiated in 1992, a project by the National Research Council's Marine Board to determine the level of compliance with MARPOL V in the United States concluded with the publication of "Clean Ships, Clean Ports, Clean Oceans". Funding for this study was provided by the MERP, EPA, USCG, U.S. Navy, and the Maritime Administration. The MERP also set aside funds to support international ratification and implementation of Annex V, and aided in the establishment of a joint World Bank-IMO "Wider Caribbean Initiative on Ship-generated Wastes."

IMPACTS RESEARCH AND MONITORING PROJECTS

Plastic debris and commercial fishing gear lost or discarded at sea entangle marine mammals, seabirds, and fish, disable vessels, and degrade the aesthetic quality of beaches. Since 1985,

the MERP has funded marine debris surveys of Alaska beaches through the AFSC's Auke Bay Laboratory. The presence of trawl webbing, one of the most common entangling items found on Alaska beaches, has declined since 1989. Continuing surveys are determining the geographic extent and significance of this downward trend.

Using methodologies developed in the Alaska surveys, the MERP established a national survey system in 1989 in cooperation with the National Park Service (NPS). Under the program, marine debris accumulations at sites in nine National Seashores have been surveyed quarterly. These sites are located throughout the East, West, and Gulf Coasts and in the U.S. Virgin Islands. The year 1993 was the final year of the cooperative program. During 1994 and 1995, these data were used in a power analysis to determine sample sizes for the design of a permanent National Marine Debris Monitoring Program. This program was launched in 1995 as a volunteer program sponsored by the EPA, CMC, and local entities.

Researchers at the University of Florida continued to study the effects of persistent marine debris on juvenile pelagic loggerhead turtles (*Caretta caretta*). Young turtles are often associated with rafts of sargassum found in oceanic driftlines. The physical forces that establish these communities also concentrate floating marine debris along driftlines. In 1995, data from this project showed conclusively that juvenile loggerhead turtle survival in the wild is reduced by marine debris ingestion and entanglement.

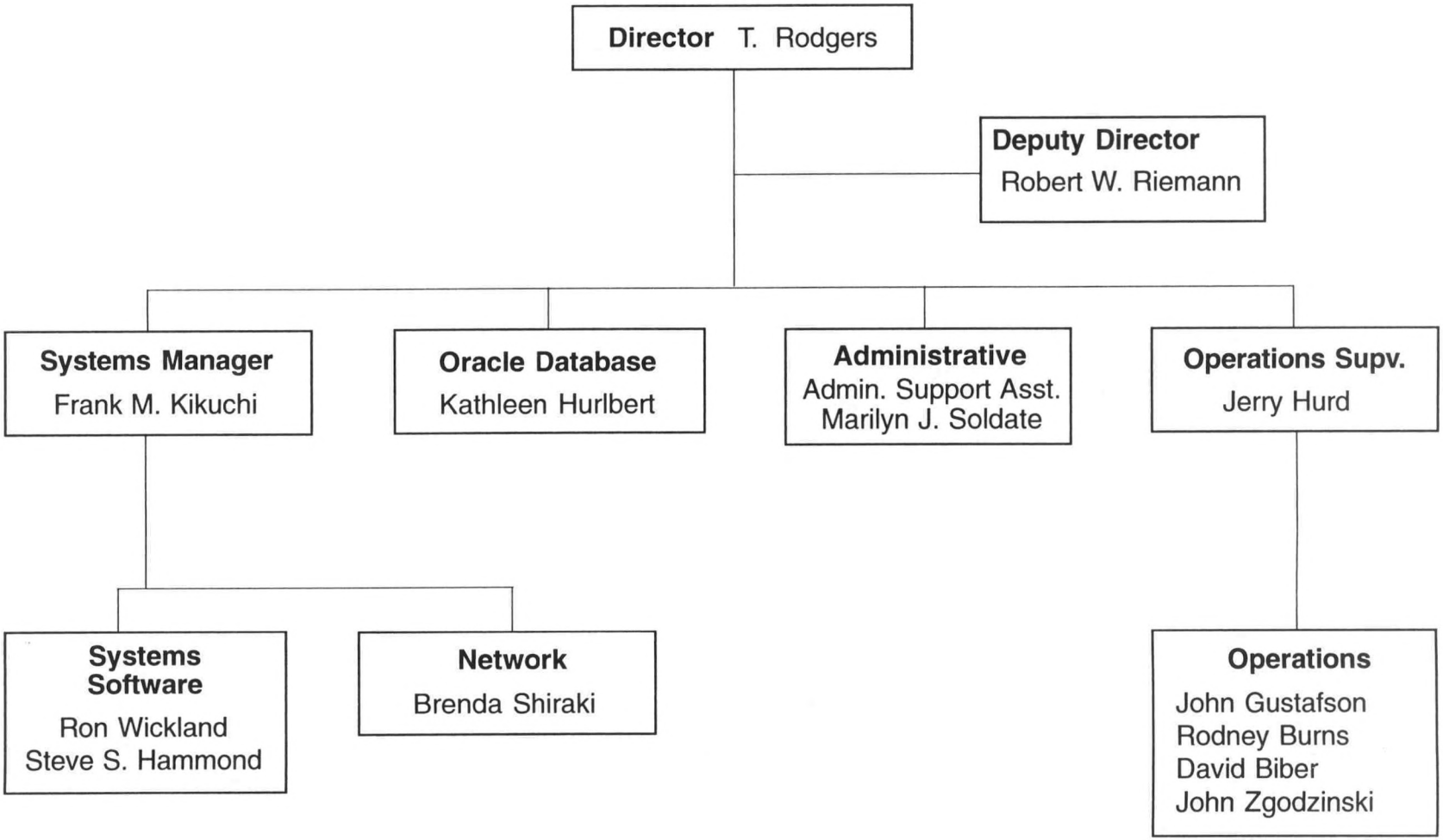
PUBLICATIONS UNIT

The Publications Unit continued to provide editorial and graphics services to AFSC scientists and administrators during 1994-95. In 1994, the Unit's editorial staff reviewed over 70 scientific manuscripts and published 7 AFSC Processed Reports and 20 Technical Memorandums. In 1995, staff reviewed over 80 scientific manuscripts and published 7 AFSC Processed Reports and 11 Technical Memorandums.

In 1994, the Unit's staff designed, produced, and managed the in-house production of the book, "Marine Mammals and the *Exxon Valdez*". The Unit also designed and produced the 1992-93 AFSC Biennial Report and four issues of the AFSC *Quarterly Report* during each calendar year.

Graphics personnel provided critical support in four areas - presentation graphics, computer graphics, scientific illustration, and photography. Posters, slides, and other presentation materials were designed and produced for national and international scientific symposia. Maps and other detailed illustrations were created consistently for use in scientific publications.

OFFICE OF FISHERIES INFORMATION SYSTEMS
ORGANIZATION CHART
1994-95



OFFICE OF FISHERIES INFORMATION SYSTEMS

The years 1994 and 1995 were transition years for the Center's Office of Fisheries Information Systems (OFIS). During this period the old UNISYS or Burroughs B7000 series of computer systems first installed during 1979 at the Montlake Laboratory was replaced by a new state-of-the-art Control Data CD9460 computer system. The acquisition and installation of the Control Data CD9460 computer system manufactured by Silicon Graphics Inc. was just one part of an agency-wide effort (known as IT-95) to upgrade the computing and data processing needs of the National Marine Fisheries Service (NMFS). The CD9460 computer system at the Alaska Fisheries Science Center (AFSC) at Sand Point was made fully operational during 1994. The CD9460 installed at the AFSC is one of ten installed at various other NMFS research centers in support of the Nation's fisheries research and management programs. All systems operate under the IRIX UNIX operating system.

The CD9460 installed at the AFSC had an initial on-line disk storage capacity of 22 gigabytes, two 150 megaherz CPUs and 128 megabytes of memory. The computer is also support by 0.5 inch tape drives, 8 mm cartridge tape drives, 0.25 inch QIC tape drive. Software for the CD9460 includes the ORACLE database system, FORTRAN, COBOL, C++, BASIC, IMSL, SPSS, MINITAB, SAS, Splus and the econometric package SHAZAM.

As part of the transition to the new CD9460 computer system a 40 Kva DELTEC UPS (Uninterruptible Power Supply) with a LIEBERT Power Distribution system was installed during 1994. Late in 1995 a 100 Kva ONAN diesel motor generator was also installed to ensure an uninterrupted power source for the CD9460 computer system.

The regional wide area network (WAN) was modified during '94-'95 to include 56 kilobit dedicated data lines from the Sand Point campus to the Center's Auke Bay Laboratory located in Auke Bay, Alaska, the Kodiak Island Facility of the Center's Resource Assessment and Conservation Engineering Division, the NMFS Alaska Regional Office, and the North Pacific Fishery Management Council at Anchorage. A Sand Point campus fiber optic backbone linking computer systems to the Internet was also installed.

AUKE BAY LABORATORY

Research at the Auke Bay Laboratory (ABL) was reorganized in 1995 into five programs: Stock Identification and Assessment, Marine Fisheries Assessment, Marine Salmon Interactions, Ocean Carrying Capacity, and Habitat Investigations. The first two programs focus almost exclusively on research to solve fishery management problems, particularly those of international mixed-stock Pacific salmon (*Oncorhynchus* spp.) fisheries and Alaska groundfish fisheries, with emphasis on the sablefish (*Anoplopoma fimbria*) and rockfish (*Sebastes* spp.) fisheries in the Gulf of Alaska. The next two programs focus on Pacific salmon research, particularly on the migration, growth, and survival of the young salmon after they enter the marine environment. The Habitat Investgations Program focuses on the effects of natural and man-caused environmental perturbations on key species and habitat, with the emphasis in recent years on the effects of the *Exxon Valdez* oil spill.

STOCK IDENTIFICATION AND ASSESSMENT STUDIES

ABL's research to identify and assess fish stocks focuses on information needed to implement the Pacific Salmon Treaty between the United States and Canada and to understand which salmon stocks are intercepted in high-seas fisheries. In addition, new research focuses on identifying and assessing stocks of rockfish caught in the Alaska longline and trawl fisheries.

Under the Pacific Salmon Treaty, the Stock Identification and Assessment Program provides information to the Pacific Salmon Commission (PSC) on management and allocation issues of long-standing concern to the two nations. ABL staff serve on four bilateral technical committees and on the Research and Statistics Committee. Technical support provided by ABL staff also assists U.S. negotiators in seeking agreements on salmon fisheries in northern British Columbia and Southeast Alaska, and the Yukon River. Research at ABL includes stock identification, stock assessment, and interception analysis for fisheries that occur in boundary areas, transboundary rivers, and coastwide.

The other major program objective is to identify the origin of salmon caught in high-seas fisheries in U.S. and international waters and to gain knowledge of ocean distributions and migrations of maturing salmon. Achieving this goal requires considerable international cooperation. ABL staff work closely with other U.S. scientists and conduct collaborative studies with Russian, Japanese, and Chinese scientists to add baseline information from Asian salmon stocks to North American databases.

AUKE BAY LABORATORY
ORGANIZATION CHART
1994-1995

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Deputy Director J. Greenough
Office Auto Asst F. Mynarski

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- C. Guthrie
- S. Hawkins #
- C. Kondzela

Interceptions Analysis
- *J. Pella
- M. Masuda

Transboundary Rivers
- *J. Eiler

Marine Salmon Interactions
**W. Heard

Auke Creek Studies
- *S. Taylor

Marine Recruitment
- *A. Wertheimer
- A. Celewycz
- D. Mortensen
- J. Thedinga

Southeast Chinook Studies
- *R. Martin
- J. Joyce
- F. Thrower
- B. Weinlaeder

Marine Fisheries Assessment
**Vacant

Groundfish Analysis
- *J. Fujioka
- M. Clausen
- S. Fowler
- J. Heifetz
- J. Karinen
- N. Maloney
- T. Rutecki
- M. Sigler

Marine Resource Ecology
- *B. Wing
- R. Haight
- K. Krieger

Ocean Carrying Capacity
**J. Helle

Environmental Factors
- *S. Ignell

Retrospective Studies
- *H. Jaenicke
- M. Hoffman #

Salmon Distribution
- *R. Carlson
- J. Orsi
- M. Sturdevant

Habitat Investigations
**S. Rice

Environmental Studies

Anadromous Fish Habitat
- * M. Murphy

Benthic Ecology
- * C. O'Clair
- L. Freese

Mining and Entanglement
- * S. Johnson
- R. Stone #

Physiology/Pathology
- * A. Moles

Restoration
- * K. Koski
- M. Lorenz

EVOS

Benthic Ecology
- * M. Babcock
- C. Brodersen

Herring Oil Impacts
- * M. Carls
- L. Ewing #
- D. Fremgen #

Oil Chemistry
- * J. Short
- P. Harris
- L. Holland
- M. Larsen
- J. Lunasin #
- B. Nelson

Pink Salmon Oil Impacts
- * R. Heintz
- R. Bradshaw
- J. Maselko

Program Support

Administration
Admin Officer - S. Masters
Mangmt Serv - A. Anderson
Off Auto Asst - C. Morris
Procurement - H. Stitt

Information Services
Computer/LAN - J. Lynk
- E. Risley
- M. Masters

Copy Editor - S. Kraft
Librarian - P. Johnson

Facility Maintenance
Construction/Maintenance - T. Dress
- G. Ewing

**Program Manager
*Task/Project Leader
Other than FTP
EVOS - Exxon Valdez Oil Spill Studies

Genetic Stock Identification and Assessment

Over the last several years, the ABL genetics laboratory has obtained tissue samples to establish genetic baselines for Southeast Alaska chinook (*Oncorhynchus tshawytscha*), sockeye (*O. nerka*), chum (*O. keta*), and pink salmon (*O. gorbuscha*) stocks and for pink, sockeye, and chum salmon stocks from northern British Columbia. To date, ABL scientists have collected genetic samples of chinook salmon from 30 separate spawning grounds, chum salmon from 70 spawning grounds, sockeye salmon from 74 spawning grounds, odd-year pink salmon from 120 spawning grounds, and even-year pink salmon from 97 spawning grounds.

The analysis of these samples will contribute to a genetic database for chum, sockeye, chinook, and pink salmon stocks throughout the North Pacific region that can be useful in stock separation. To assist in this effort, scientists from the Russian Academy of Sciences in Vladivostok, the KoTINRO laboratory in Petropovlosk-Kamchatski, and the Chinese Academy of Sciences in Harbin have been hosted at ABL every year since 1991 to develop genetic baseline information on Asian pink, chum, sockeye, and chinook salmon stocks. Major goals were to identify stocks in high-seas bycatches, to determine migration routes in the Bering Sea and North Pacific Ocean, and to assist Russia and China in developing genetic stock identification methods for managing their fisheries. Such information is also useful for enforcement purposes; ABL has responded to several requests from NMFS Enforcement Division agents to examine high-seas salmon catches.

Research is currently underway to develop genetic information for managing rockfish fisheries. Little is known about these 35+ species in the North Pacific Ocean. Genetic characters can be used to determine species and, potentially, stocks of commercially harvested species.

Related work is continuing on the development of multiattribute stock separation methods that combine genetic information (including mitochondrial DNA), parasite incidence, and scale characteristics.

Chum Salmon Interception Analysis

In cooperation with other State and Federal agencies, a North Pacific genetic database was developed for chum salmon. This baseline was used to analyze chum salmon caught in the 1994 Bering Sea trawl pollock fishery ("B" season) to determine which stocks were being caught. Samples were collected by the NMFS' Observer Program and shipped to ABL for analysis. The first year was predominately a test to determine the feasibility of obtaining high-quality tissue samples by this method. The sample quality was excellent; the genetic analysis of the tissues showed that of the total sample (n = 457), 47% were from Asian stocks, 33% Alaskan, 14% British Columbian, and 6% Washington State. The

distribution and size of the sample were not designed to extrapolate these figures to the total chum bycatch. Sampling from the 1995 "B" fishery was designed to provide a sample that will represent the total chum bycatch; those samples are still being analyzed.

ABL staff also began simulation analyses using the Southeast Alaska-northern British Columbia chum salmon genetic baseline. Data was gathered from the Alaska Department of Fish and Game (ADF&G) and the Canada Department of Fisheries and Oceans concerning run sizes and stock groupings of interest to fishery managers. These tests are designed to determine the accuracy and precision of stock composition estimates from simulated mixed-fishery samples.

Salmon Stock Assessment Using Radio Tags

The Taku River, a large, turbid transboundary river, is an important producer of Pacific salmon. Salmon returns are jointly managed by the U.S. and Canada under the Pacific Salmon Treaty. Since 1984, ABL has conducted radiotelemetry studies on adult salmon returning to the drainage. In addition, ABL developed a remote tracking system with a satellite up-link for collecting and retrieving telemetry data from isolated sites. This system was used effectively during these studies. In 1994, studies on the Taku River were completed and equipment was removed from the drainage. Since then, ABL has begun to extend this program to the Stikine and Yukon Rivers. In 1995, a feasibility study was conducted on Stikine River chinook salmon. Adult chinook salmon returning to the drainage were captured near the river mouth. Forty fish were tagged with radio transmitters to determine tagging response, movement patterns, and to obtain cursory information on spawner distribution. Potential sites for remote tracking stations were also located on both the Stikine and Yukon Rivers in preparation for possible work in these drainages. Additional work was also conducted to refine the telemetry systems used by ABL. Modified tracking stations were operated throughout the winter under severe environmental conditions to test operating parameters, and a GPS (Global Positioning System)-linked tracking system was developed to standardize telemetry data collected during aerial surveys.

MARINE FISHERIES ASSESSMENT

The Marine Fisheries Assessment Program conducts groundfish studies in the Gulf of Alaska and makes recommendations to the North Pacific Fishery Management Council (NPFMC) for allowable biological catch (ABC) levels of sablefish (*Anoplopoma fimbria*), slope rockfish; such as Pacific ocean perch (*Sebastes alutus*), shortraker rockfish (*S. borealis*), and rougheye rockfish (*S. aleutianus*) as well as pelagic rockfish, such as dusky rockfish (*S. ciliatus*). Sablefish and rockfish comprise a major portion of the groundfish

fishery in Alaska, with the ex-vessel value of sablefish alone well in excess of $100 million. Proximity to Alaska groundfish resources and their habitat allows ABL scientists to conduct field research to better understand these species and to improve our ability to assess their abundance and productivity. Research centers on tracking the abundance and distribution of the various species and understanding their life histories and population dynamics.

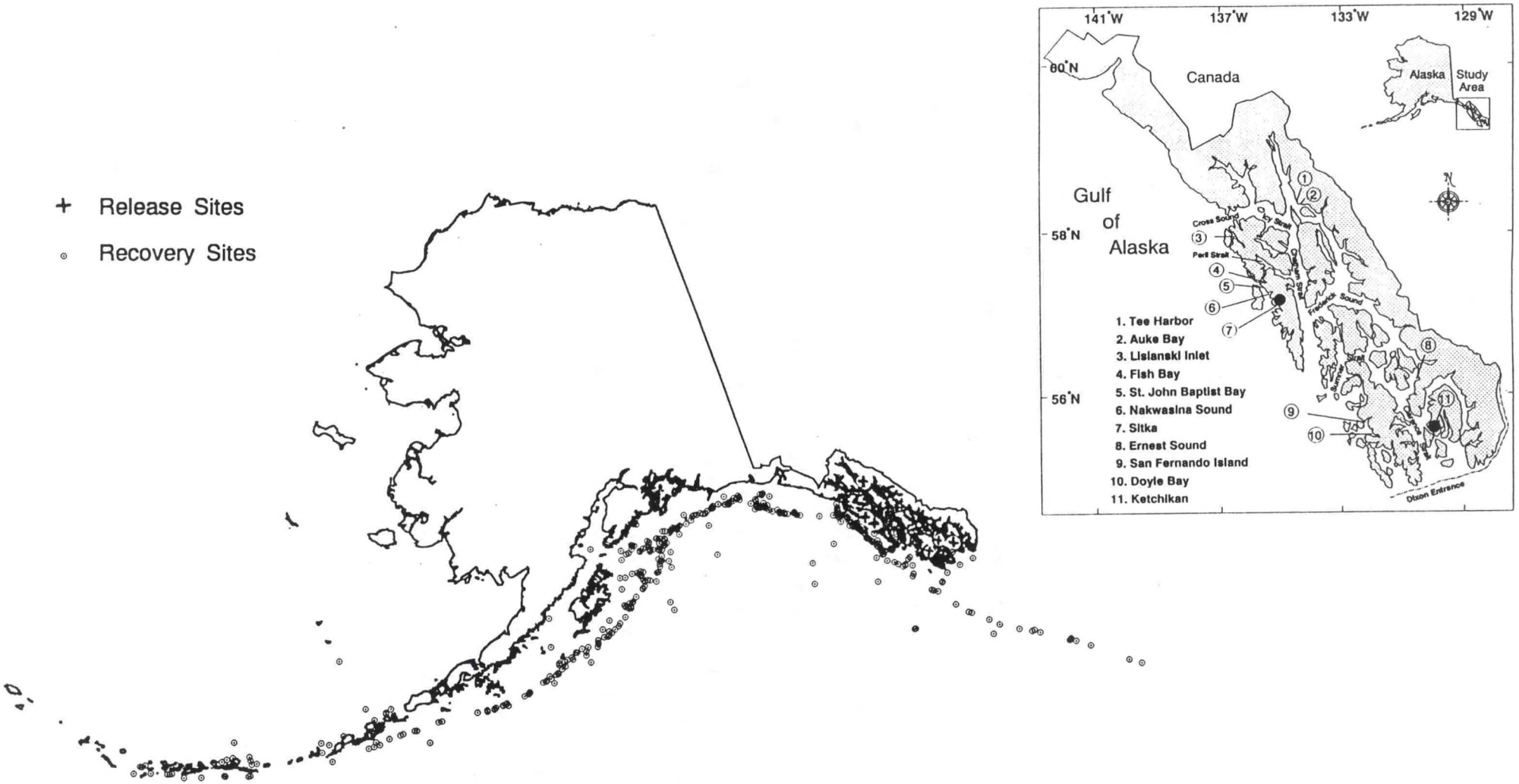
Assessment Surveys

Annual longline surveys, which provide basic information used in assessing the abundance of sablefish in the Gulf of Alaska, were continued in 1994 and 1995. In prior years, both U.S. domestic and U.S.-Japan cooperative longline surveys were conducted, but in 1995 the cooperative survey was discontinued. Staff from ABL and the Center's Resource Assessment and Conservation Engineering (RACE) Division have coordinated the planning and execution of these surveys in the past. Beginning in 1995, ABL took lead responsibility for planning the sablefish longline survey. ABL staff members participate in the Center's trawl surveys that occur triennially, with the last survey occurring in 1993.

Current trawl surveys do not adequately track abundance of most rockfish. Because of their responsibility to recommend ABCs for rockfish, ABL staff work with other AFSC scientists on studies aimed at improving the Center's rockfish assessment capabilities. Evaluation of data collected from work aboard commercial rockfish trawlers indicate that relative abundance of shortraker and rougheye rockfish might be improved by modifying the current survey nets to sample rougher sea bottoms and increased sampling in their habitat. Sampling experiments to evaluate survey design of Pacific ocean perch have been developed. To explore an alternative to trawl surveys for assessing rougheye and shortraker rockfish, observations made in 1993 from a manned submersible of the interactions of rockfish and sablefish with survey longline gear were evaluated in 1994. The results showed that capture reduced local populations of rougheye and shortraker rockfish, but they left open the question of whether a longline survey would be a feasible alternative to a trawl survey. The experiment will continue at least through 1997.

Biological Research on Sablefish and Rockfish

A blind test of ageing of otoliths recovered from known-age sablefish to validate age reading methods was conducted with the Center's Age Reading Task. This study was possible because of the recovery of sablefish tagged as known-age juveniles as early as 1985. Continued recoveries of sablefish tags and the sablefish tagging database are used to estimate interarea movement rates and age of recruitment to the fishery. The use of a low-breaking-strength, small-mesh gillnet for sampling young-of-the-year sablefish in the ocean was tested and shown to work well.



Results of tagging juvenile sablefish (20-60 cm FL) with Floy tags for several years indicates extensive movements of fish from southeast Alaska to the central Aleutian Islands and south as far as southern California. About 30,000 juvenile sablefish were tagged and released at 11 sites in southeast Alaska (most at St. John the Baptiste Bay, Sitka, and Ketchikan) over a period of 10 years (see inset). Recoveries of about 1,000 tags were made by commercial fisheries and research vessels at fishing sites along the shelf edge in the Gulf of Alaska, the Bering Sea, and the eastern Pacific Ocean. Contact Tom Rutecki at (907) 789-6051 or at trutecki@abl.afsc.noaa.gov for further information.

Studies of rockfish stock structure are being pursued as the rockfish fisheries become more intense and appropriate management becomes more critical. ABL staff initiated the development of DNA genetic techniques for rockfish at the University of Alaska Fairbanks's Juneau Center for Fisheries and Ocean Sciences by providing funding and sampling support. Analyses of electrophoretic genetic samples of shortraker and rougheye rockfish from the eastern and western Gulf of Alaska indicate genetic differences between the two areas. Information was also collected on the ages when Pacific ocean perch, dusky rockfish, and other rockfish mature. This information is needed to compute the fishing rates recommended by the NPFMC, which are based on spawning biomass per recruit.

Fishery Management Activities

ABL staff participate in the NPFMC stock assessment and fishery evaluation process by serving on the Groundfish Plan Teams, providing assessments and evaluating other assessments. Allowable biological catch recommended for the 1995 and 1996 fisheries for sablefish, slope rockfish, and pelagic rockfish were adopted by the NPFMC. Staff members were active in presenting and explaining to various industry groups or agencies the assessment of Pacific ocean perch, which was subject to controversy for the 1995 fishery. The 1995 sablefish assessment recommended substantial reductions for the 1996 fishery.

Fishery Analyses

A model to evaluate alternative apportionments of sablefish harvested by area was developed and has been especially useful with the management of the individual fishing quota (IFQ) fishery for sablefish. IFQs are area-specific and in proportion to the respective total allowable catch for each area. The optimal allocation of area-specific quotas is highly dependent on the geographic contribution of recruitment, of which little is known. An age-structured population model for sablefish was developed and evaluated and will be incorporated in future assessment analyses of sablefish. This model will provide considerably more information for supplementing the survey data for estimating population changes and reducing interannual changes in ABC due to survey variability.

MARINE SALMON INTERACTIONS

The Marine Salmon Interactions Program has six principal objectives: 1) Maintain research and technology development sufficient to produce more chinook salmon for

Alaska fisheries, including determining unique biological features of specific Southeast Alaska stocks; 2) Determine the effects of the *Exxon Valdez* Oil Spill (EVOS) on pink salmon including impacts of crude oil, if any, on survival, migration behavior, genetics, and to develop steps necessary for potentially restoring damaged resources; 3) In cooperation with the University of Alaska Fairbanks, increase our knowledge and understanding in variations of life history traits in Pacific salmon including interspecific hybrids; 4) Determine natural straying rates of wild and hatchery salmon and the effects of different variables on homing fidelity; 5) Increase scientific understanding of growth and distribution of young juvenile salmon in near-shore marine environments, particularly how growth and distribution relate to environmental factors and abundance of young salmon, and how these factors help determine the eventual number of adult salmon; and 6) Restore the depressed Auke Lake sockeye salmon run to perpetuate this stock and provide for urban-area sport fishing opportunities.

Research is carried out at three year-round field facilities; two on Baranof Island at Little Port Walter (LPW) and Osprey Bay and one at Auke Creek near ABL. In addition, studies on the abundance, growth, and distribution of young salmon in the marine environment are conducted throughout Southeast Alaska using the NOAA ship *John N. Cobb.*

Chinook Salmon Research

In a cooperative effort with the ADF&G, Division of Sport Fish, and others, studies since 1976 at LPW have focused on developing technology to enhance broodstock development, ocean survival, and egg production of chinook salmon, with the purpose of improving the resources and fisheries for this species in the Southeast Alaska region. Initially, this research involved biological comparisons of two stocks from the Unuk and Chickamin Rivers in the Behm Canal area of Southeast Alaska. A third stock was added to these comparative studies in 1988 from the King Salmon River. Maintaining three separate anadromous stocks of the same species at one location is a unique research undertaking and is unparalleled in Pacific salmon biological studies.

In 1994, 144,588 age-1 chinook salmon smolts from the three stocks were released at LPW. In the same year, 2,134 adult chinook salmon returned to the station from earlier smolt releases and 1,739 adults were caught in commercial and recreational fisheries. Over 1.2 million eggs were collected and roughly 0.8 million of these went to larger production facilities including Gastineau Hatchery in Juneau, and Deer Mountain and Whitman Lake Hatcheries near Ketchikan.

Chinook salmon research at LPW included comparative off-station releases of smolts in 1992, 1993, and 1994 to measure the effects of this displacement on survival and homing fidelity. One aspect of these studies is to determine if near-shore predators are adversely

impacting smolt survival. The experimental design measures these parameters in replicate smolt groups released both in the Inner Bay of LPW and at a location 4 miles east of the station near the middle of Chatham Strait. Other research included moving chinook salmon smolts into marine net pens in the spring for 6 to 8 weeks before release to measure any effect on ocean survival.

Studies at Osprey Bay

In a cooperative program with staff at the University of Alaska Fairbanks, School of Fisheries and Ocean Sciences Juneau Campus, research at Osprey Bay documented the relationship between juvenile growth rates and age-at-maturation of chinook salmon as well as behavioral traits in backcrosses of first-filial-generation, interspecific, Pacific salmon hybrids. The hybrid work, undertaken in cooperation with the University and the Western Regional Aquaculture Consortium (WRAC), a coast-wide organization of universities and other fisheries concerns, measured survival, seawater tolerance, growth, and age-at-maturation of different groups reared to maturity in captivity. This project has identified several hybrid crosses that display high growth rates, early seawater tolerance, and low rates of maturation.

Does Oil Exposure Have Long-Term Effects on Pink Salmon?

The Auke Bay Laboratory's Marine Salmon Interactions and Habitat Investgations Programs teamed up with ADF&G in a cooperative study to measure the effects of oiled incubation gravel on pink salmon. Evidence from Prince William Sound, the site of the 1989 *Exxon Valdez* oil spill, indicates the possibility of both short- and long-term damage to oiled pink salmon streams. This study has several components and is conducted at LPW and Osprey Bay. It involves incubating pink salmon embryos at a variety of oil exposure levels and measuring survival rates, histological effects, oil uptake in the fry, possible genetic damage, and the impact of oil, if any, on homing fidelity. The study involves a sophisticated experimental system that simulates the natural intertidal spawning environments of Prince William Sound and includes comparison with both upstream and intertidal pink salmon stocks. Also included in the study are a variety of tagging and marking treatments to determine if coded-wire tagging has an impact on homing in pink salmon.

Sockeye Salmon Restoration Based on Age-0 Smolts

Many sockeye salmon spend at least 1 year in fresh water before migrating to sea as smolts. This presumed freshwater requirement made the species an unlikely candidate for artificial enhancement. Recently, however, the occurrence of age-0 sockeye salmon

smolts with limited freshwater residency has been documented in many Alaskan river systems. As a result, there is increasing interest in the possibility of utilizing this life history feature as a tool for rehabilitation and enhancement. This concept is receiving attention from several Pacific rim nations and may have future impact on sockeye salmon programs in several countries.

Studies at the Auke Creek experimental hatchery near ABL focus on the use of age-0 smolts to rehabilitate a badly depressed run of sockeye salmon in the Auke Lake system. Although there are no natural age-0 smolts in this system, experimental releases of these smolts over several years have helped rebuild the weak sockeye salmon run. In 1985, fewer than 400 adult sockeye returned to Auke Creek. By 1993-95 the run had increased to 5,000-9,000 fish, with roughly one-half of these adults derived from experimental groups of age-0 smolts. Planning is under way with ADF&G's Sport Fish Division to reopen a controlled recreational fishery for sockeye salmon at the mouth of Auke Creek.

Distribution and Growth of Juvenile Salmon in Marine Waters

Analysis of pink salmon scales collected by ABL scientists has shown that early marine growth is positively related to survival but negatively related to size at maturity. In other words, good early growth of young pink salmon in marine waters results in better survival rates but smaller fish when they return as adults, and when this early growth is poor, the number that survive is decreased but the returning adults are larger.

These studies on the early life of salmon in marine waters are closely coordinated with the new Ocean Carrying Capacity Program at ABL. The research staff is currently using the NOAA ship *John N. Cobb* to sample juvenile salmon throughout the inside waters of Southeast Alaska, and plans are underway to extend use of this vessel into coastal oceanic waters under favorable weather conditions. The distribution of the young salmon and their use of the near-shore habitat provide insight on the capacity of the near-shore environment for supporting the needs of young salmon. Scales from juvenile salmon collected from these cruises are used to forecast future year-class abundances. Studies are also examining the relationships of spring zooplankton production to the growth and survival of juvenile pink and chum salmon. This work includes developing index methodologies that can be readily adapted by enhancement operations for monitoring zooplankton for timing releases of hatchery salmon.

OCEAN CARRYING CAPACITY PROGRAM

Over the past 20 years, body size has decreased and the age-of-maturity has increased in a number of North American and Asian salmonid stocks. These changes are associated with large increases in salmonid production and increasing evidence for an inverse relationship between body size and abundance of salmon in the ocean. In response to this evidence, the North Pacific Anadromous Fish Commission (NPAFC) called for research on the "critical issue of the impact of change in the productivity of the North Pacific Ocean on Pacific salmon" by studying factors affecting: 1) current trends in ocean productivity and their effects on salmonid (*Oncorhynchus* spp.) carrying capacity, and 2) changes in the growth, size at maturity, oceanic distribution, survival, and abundance of Pacific salmon.

The Ocean Carrying Capacity (OCC) Program of ABL was formed in 1995 as the first U.S. effort specifically designed to address the NPAFC concerns. An implementation plan, developed in early 1995, identified the key scientific questions for the carrying capacity issue and a research strategy needed to address these questions. This research strategy has three major components: juvenile salmonid research in coastal Alaskan waters, immature and maturing salmonid studies in offshore waters, and retrospective studies.

Juvenile Salmonid Research in Coastal Alaskan Waters

A major objective of the OCC Program is to learn the ocean migration patterns of young salmon and to examine how survival and growth of juvenile salmon at sea relates to ocean conditions in their environment. In pursuit of this objective, ABL staff during 1995 participated in two high- seas research cruises to sample juvenile salmon and document oceanographic and biological features of their surroundings.

During March-April of 1995, an ABL staff member participated in the cruise of the F/V *Anita-J*, a 120-foot trawler chartered by the Canada Department of Fisheries and Oceans, Pacific Biological Station (PBS), Nanaimo, B.C. The cruise sampled young salmon with a surface trawl from off northern Vancouver Island to northern California and operated 200-800 miles offshore. Samples were taken of juvenile and maturing sockeye, pink, and chum salmon, and all those sampled had been actively feeding. Thermal gradients were found to define salmon distribution with sockeye found only in waters colder than 8°C, and pink and chum found together in waters up to 10°C.

During October of 1995, ABL staff participated again in a joint cooperative research cruise with PBS on the Canadian research vessel *W. E. Ricker*, and sampled young salmon with surface beam trawls and made oceanographic observations in coastal and shelf waters of the Gulf of Alaska from Southeastern Alaska to Kodiak. Juvenile pink, chum, and

sockeye salmon were taken, all found over continental shelf or coastal depths. All young salmon were feeding, and other marine fishes (e.g., juvenile sablefish and rockfish) were found with them. Most young salmon were found near the Alaska Coastal Current, which may play a major role in transport of juvenile salmon to the north and west in the Gulf of Alaska. In addition to ABL and PBS, visiting scientists participated from the University of Washington's Fisheries Research Institute (FRI) and KoTINRO, Kamchatka, Russia.

In October-November of 1995, ABL staff were joined for a third time with staff from the PBS for a study of the distribution of juvenile Pacific salmon from the Gulf of Alaska southward to Oregon (140°W, 45°N). The chartered vessel F/V *Columbia* surveyed from Cape Spencer, Southeast Alaska, to Oregon while the Canadian research vessel *W. E. Ricker* surveyed from Kodiak to Southeast Alaska. Both vessels worked together for a while off Southeast Alaska. The *Columbia* used a midwater rope trawl fishing 5-20 m below the surface that proved more effective at catching salmon than the surface beam trawl used by the *W. E. Ricker*. Although previous studies indicated that juvenile salmon would be present in the oceanic areas of the northeastern Pacific in the early winter, the *Columbia* captured juvenile salmon only while working on the continental slope and continental shelf in the Gulf of Alaska. The cruise track did not include continental shelf areas south of Alaska. During the cruise of the *Columbia*, juvenile salmon were sampled for genetic stock composition (tissues for enzymatic and DNA electrophoresis), body composition (fat and water content), growth characteristics (scales and otoliths), and food habits (stomach contents). Associated fishes in the catches were kept for food habit studies to assess the potential to be either salmon forage, competitors, or predators. Oceanographic profiles of salinity, temperature, dissolved oxygen, and zooplankton samples for species composition and isotope analyses were taken to describe or identify the specific habitat of the juvenile salmon.

Immature and Maturing Salmonid Field Studies in Offshore Waters

The OCC program includes support for contracted research on high seas salmonids by the FRI. This work is also focused on NPAFC research priorities and is comprised of three tasks: 1) international cooperative high-seas sampling and tagging; 2) ocean ecology, stock assessments, and carrying capacity research; and 3) scale pattern analyses to determine age, growth, and stock origins of salmon.

Scientists from FRI participated in a variety of Japanese research cruises to the central North Pacific Ocean, Bering Sea, and Gulf of Alaska during the summers of 1994 and 1995. Salmonids caught on longlines were tagged, marked with oxytetracycline for experimental age and growth validation research, and released. Age, weight, length, scale samples, and stomach contents data were taken from salmonids caught in research gillnets and summarized by oceanographic region. Analyses of these data indicate that there is limited capacity for crustaceous zooplankton to provide energy for salmon production in

the North Pacific Ocean. Bioenergetic modeling of pink salmon using high-seas field data showed that at a constant ration salmonids have much better growth in the cooler water temperatures of the Bering Sea than in the warmer waters of the Transition Domain of the central North Pacific Ocean.

Trends in salmonid abundance and growth by major ocean production region were examined using a time series of scale measurement data from salmonids caught on the high seas. Pairs of otoliths and scales from individual salmonids collected during various research cruises were used to study the development of growth indices for juvenile salmon in the ocean. These data were also used in a joint U.S.-Japan study on the relationships between fish size, scale growth, and rates of protein synthesis (determined by RNA-DNA analysis) in chum, pink, and sockeye salmon caught on the high seas.

Retrospective Studies

Four retrospective studies were initiated in 1995. The first study involves an analysis of long-term trends (over seven decades) in growth and abundance of salmonids using scales from the Kvichak and Karluk River systems in Alaska. This study is designed to identify climatic and biological factors affecting the growth of salmonids in the freshwater and marine environment over these decades and develop inferences about possible limits to the carrying capacity of sockeye salmon in the North Pacific Ocean. The strength of this study lies in the long time-series of data which spans several shifts in ocean environmental conditions and several historic highs and lows in Alaskan salmonid abundances.

The second study examines geographical variability in the growth and size of Alaskan pink and chum salmon. Various data sets consisting of body size, number of eggs per female (including egg size where available), and growth measurements were collected from salmon returning to hatcheries situated around the Gulf of Alaska, from research facilities, and from samples collected from commercial fish harvests. Some chum salmon data sets included scale collections. Three analyses are underway: 1) statistical analyses of body size, egg size, and age at maturity between stocks and years to examine whether any geographic, temporal, or stock-specific variation of growth is apparent; 2) growth analyses of chum salmon scale patterns to test independently growth patterns found in analysis ; and 3) compare records (morphological, life-history) from ocean-ranched brood stocks with contemporary records of ancestral populations to test for divergence after 15-20 years of domestication.

Stream surveys and biological sampling of Olsen Creek chum salmon in Prince William Sound were resumed in 1995. Unlike the first two studies, this third study is very limited in scope. It provides, however, an opportunity to renew a historical study on growth and maturation from the chum salmon population that provided the first evidence for the

importance of oceanographic conditions in the second marine season to age of maturation and growth.

The last study is a historical review and evaluation of research findings of Karluk sockeye salmon. The sockeye salmon using the Karluk River and Lake system on Kodiak Island have intrigued fishery biologists for over 100 years. At one time they had the greatest adult return per lake surface area, and the lake ranked among the highest in primary productivity. The diversity of age groups is second to none: Karluk sockeye spend from 0 to 4 years in freshwater and from 1 to 4 years in the ocean. But it was the precipitious decline in the abundance of Karluk sockeye salmon that stimulated extensive debate among biologists and led to numerous research papers. The total run peaked in 1901 with 5.6 million sockeye. By the 1920s it had declined to about 2.3 million, then to 1.2 million in the 1940s, 700 thousand during the 1950s and 1960s, and to a low of only 175 thousand in 1971. Since then, the run increased to an average of 1.3 million from 1985 - 1993. Much of the data that has been collected over the years has never been analyzed and published. Series of biological data of over 80 years duration are extremely rare. The Karluk sockeye salmon data, therefore, provide invaluable records of long-term fluctuations in size-at-age, age-at-maturity, and fecundity, which can then be compared with fluctuations in marine and freshwater conditions. Our objectives for this study were to locate, summarize, and evaluate all the published reports and unpublished data concerning Karluk sockeye salmon, and assemble this information into one comprehensive, peer-reviewed publication and establish an electronic database to make the data and reports readily available to other researchers.

HABITAT INVESTIGATIONS

The Habitat Investigations Program provides resource managers with the best scientific information to support their management decisions for species harvests and habitat protection. Research focuses on natural and human activities that affect marine and anadromous species. Since March, 1989, the *Exxon Valdez* oil spill (EVOS) has dominated habitat issues in Alaska as well as our research priorities. Since the settlement of the EVOS litigation, ABL has initiated work in support of the EVOS Trustee Council's efforts at restoring damaged resources and habitats. Over one-half of the funding provided by the EVOS Trustees and over one-half of the research effort in the Habitat Investigations Program are directed toward EVOS research and habitat restoration.

Maintaining fish habitats is vital to maintaining Alaska's fisheries. Alaska's economy is based on such resource extraction industries such as oil, logging, mining, and fisheries. The activities of these industries alter fish habitats, sometimes irrevocably. No amount of careful fishery management can sustain a fishery in the face of habitat degradation. The challenge is to understand fish habitat requirements and to manage extraction industries in

such a way as to avoid loss of the more vital habitats. Unlike fish habitat in the waters of much of the United States, Alaska has not been altered irrevocably. With good management based on sound research, we can understand the effects of single threats to fish habitat and take appropriate action.

In addition to oil spill-related studies, several smaller research projects were conducted during 1994-95: These studies focused on important Alaskan habitat issues for which limited funding is available at present, and which will increase in importance in the coming years as both development and fishing pressures come to bear on the resources and habitat. Ongoing studies examine indicators of habitat degradation, restoration of anadromous fish habitats, changes in abundance of derelict fishing gear on Alaskan beaches, impacts of mining operations on nearshore habitats, and effects of fishing pressure on Dungeness crab populations.

Exxon Valdez Oil Spill Studies

The *Exxon Valdez* oil spill and its long-term impact on Prince William Sound (PWS) still dominate habitat research in Alaska. Seven years after the spill, oil is still present in some locations and the alteration of the fisheries may still be related to the spill. The crash of PWS salmon and herring stocks in 1993 suggests subtle, long-term damages that are difficult to understand. Impacted members of the fishing industry have demanded further broad-based studies. ABL research focuses primarily on hydrocarbon issues: monitoring oil in the environment and evaluating the toxicity of oil to living marine resources, such as finfish and mollusks. In 1994 and 1995, the EVOS Trustee Council funded seven ABL studies: 1) technical support in hydrocarbon analysis and database management; 2) monitoring of restoration and recovery of oiled mussel beds; 3) effects of the oil spill on nearshore vertebrate predators; 4) monitoring of hydrocarbon load in subtidal sediments; 5) determination of genetic aberrations in pink salmon incubated in oiled substrates; 6) the effects of oil exposure on straying of salmonids and; 7) the impact of oil exposure on herring reproduction.

ABL scientists provide technical support in hydrocarbon analysis, interpretation, and management of the extensive hydrocarbon database. In 1994 and 1995, ABL chemists analyzed 1,700 marine sediments and tissues for hydrocarbons by gas chromatography and mass spectrometry for Trustee Council-supported restoration projects. The chemical analyses are evaluated and entered into the Trustee Council's database, in which tens of thousands of analyses are currently stored. The data are made available and interpreted to all resource agencies, principal investigators, and interested parties upon request. Results of a nationwide Biennial Quality Assurance Study, organized by the National Institute of Standards and Technology, continuously ranks ABL with the Nation's best laboratories for hydrocarbon analysis.

The persistence of substantial amounts of petroleum hydrocarbons under mussel beds in PWS and the Gulf of Alaska is a continuing source for petroleum hydrocarbons to enter the food chain when consumed by nearshore predators. Concentrations over 10,000 μg/g in sediments have been found underlying some mussel beds. Oil concentrations are diminishing over time. Mean 1993 concentrations in sediments were 48% of the mean 1992 concentrations. In 1994, ABL, the Alaska Department of Environmental Conservation, and the village of Chenega conducted a project to determine the feasibility of mussel bed restoration by removing the oiled sediments from contact with the overlying mussels. Twelve mussel beds in five different locations were cleaned. Ninety tons of mud, sand, and mussels were moved by hand. One year later, oil concentrations in mussels and sediments at cleaned mussel beds were dramatically lower. Multi-agency studies in the future will assess the impacts of oiled mussels on nearshore predators.

ABL conducted preliminary sampling of the intertidal region for mussels, *Mytilus trossulus*, between 11 and 22 July 1995 within two study areas: Montague Island and Knight Island (Herring Bay and Bay of Isles). Sea otter abundance in the Montague Island study area had not declined appreciably following the *Exxon Valdez* oil spill, whereas sea otter abundance in the Knight Island study area had declined after the spill. The objectives were to obtain preliminary mussel density estimates and size frequency distribution information from 1) rocky (including bedrock, boulder, and cobble areas) and 2) unconsolidated or mixed substrates (including various mixtures of sand, granules, and pebbles) at both study areas for statistical power analysis. This information will be used to determine sample size for the 1996 sampling season. Preliminary observations from field collections and laboratory counts indicate that variability in mussel density may be greater on rocky than on unconsolidated (mixed) shores. Because rocky substrates tended to occur on more steeply sloping shores, invertebrate predators from the lower intertidal zone could, during high tide, move up into the mussel zone and prey upon all but the highest *Mytilus*. By contrast, on shores with unconsolidated substrates, the slope of the shore tended to be substantially gentler and invertebrate predators were probably less able to move into and forage in the mussel zone at high tide.

ABL sampled subtidal and low intertidal sediments at eight locations in the northern Gulf of Alaska in July 1994 to determine the subtidal distribution and concentration of oil from the EVOS in the subtidal region in comparison with that in the low intertidal zone. No *Exxon Valdez* oil was found in sediments from 0 m at assessment sites. One intertidal sediment sample showed evidence of *Exxon Valdez* oil, but the polynuclear aromatic hydrocarbon (PAH) analyte distribution in that sample may have resulted from a combination of hydrocarbons from other sources. One-half of the subtidal sediment samples collected at one station (Windy Bay, 6-m depth) showed polynuclear aromatic hydrocarbon composition patterns similar to *Exxon Valdez* oil. Petroleum hydrocarbons at the 20 m depth were chiefly (47% of all 20-m assessment samples) from the "Katalla" source.

Investigators from ABL found reduced growth rates among pink salmon that incubated in gravel contaminated with crude oil. These long-term damage studies on pink salmon eggs and alevins demonstrated effects never before documented such as delayed effects on growth, size of returning adults and reduced eggs survival in spawn of fish exposed as eggs. Reductions in growth rates were observed 4-6 months after the oil exposures ended, demonstrating potential for oil to cause long-term effects that may ultimately influence survival and reproduction. The experiments to determine if incubating in oil could affect reproduction began in 1993 and are planned to end after the third generation has finished incubating in 1998. The experiments are designed to assess the genetic basis for any long-term damage. The experiment consists of incubating the first generation of pink salmon in oiled gravel, spawning them when they mature, incubating their offspring in a clean environment, and spawning the offspring when they mature. In 1994 and 1995, the initial phase was completed; the first-generation offspring incubated during the winter of 1995-96.

Several trends were observed among the returning adult pink salmon, suggesting that oil may reduce marine survival, size, sperm activity, and homing fidelity. These are intriguing results given that the experiment was not designed to test these sorts of differences among treatment groups. A more detailed study of the effects of incubating in oiled gravel on subsequent straying of returning adults was begun in late 1995 with results available in 1997.

A three-part study on Pacific herring (*Clupea harengus pallasi*) conducted in 1994 and 1995 was designed to 1) Determine if exposure to oil of reproductively ripe herring would cause genetic damage in progeny; 2) Determine impacts on herring eggs exposed to oil during incubation; and 3) Survey Prince William Sound herring stocks for evidence of reproductive impairment due to the *Exxon Valdez* oil spill. In the 1994 tests, herring exposed to oil showed an accumulation of hydrocarbons in their tissues, an inducement of detoxification activity, and a suppression of immune activity. Increased prevalence of viral disease was noted as well. Exposure of the adults did not cause genetic damage in their offspring. Oil-exposed eggs hatched earlier than unexposed eggs with reduced size, swimming, and survival rate and increases in physical abnormalities and genetic changes. Despite the induction of genetic damage to herring exposed to oil in the laboratory, evidence of reproductive impairment in wild herring stocks was not detected. This may have been due to the large natural variability in herring reproduction.

Use of Flatfishes as Indicator Species

Studies were completed in 1994 and 1995 to determine the feasibility of juvenile flatfishes as sensitive indicators of altered habitat and pollution. Juvenile flatfishes such as rock sole, yellowfin sole, and halibut were found to have strong preferences for substrate of narrow grain sizes. These preferences are so strong that juveniles will select oil-contami-

nated sediments of the preferred grain size over clean sediments of greater or lesser size. Only at the highest concentrations of oil would the fish select habitat outside the preferred grain size or alter burrowing behavior. Fish reared on oil-contaminated sediments had reduced growth after only 30 days. The exposure to the oil also altered the liver and gill tissue and the prevalence of several species of parasites in the fish.

Restoration of Anadromous Fish Habitats

Scientists from ABL are helping to restore Juneau's Duck Creek, one of 20 streams listed by the Alaska Department of Environmental Conservation as impaired by urban development. ABL scientists are working in a partnership with Trout Unlimited, the ADF&G, the U.S. Forest Service, other agencies, and private citizens to develop a comprehensive restoration plan for the Duck Creek basin. Restoring Duck Creek will provide a valuable example of the feasibility to restore other impaired streams, increase anadromous fish populations, and familiarize the public with the many values of their urban streams. Coho salmon emigrating from Duck Creek in 1994 had lower survival rates than those emigrating from a neighboring clean stream. Experiments are underway to evaluate the source of such differences. In particular, the role of water quality on egg-to-fry development and survival was tested by observing the development of coho salmon larvae reared under both field and laboratory conditions.

Surveys of Stranded Trawl Web on Alaska Beaches

Scientists at ABL have surveyed Alaska beaches since 1972 to monitor trends in the occurrence of derelict fishing gear and other plastic debris that washed ashore. Since 1988, studies have had an increased significance because of the passage of an international law (MARPOL Annex V) that prohibits dumping at sea. ABL's beach surveys have documented that MARPOL is working: the occurrence of trawl web has declined for 5 consecutive years.

Impacts of Mining

In response to increasing fisheries concerns about mining impacts, ABL has broadened its capabilities for the analysis of heavy metals and has undertaken several related studies of mining impacts.

In one cooperative study, ABL and the Juneau Branch of the U. S. Bureau of Mines are examining 75-year-old mine tailings in Gastineau Channel near Juneau to assess the long-term effects of tailings deposits. Significantly higher levels of lead, zinc, cadmium, selenium, and arsenic were found in the old tailings than were found in control sediments.

Juvenile Tanner crabs were exposed to the tailings to determine if chronic exposure would affect growth or survival. Tissues were sampled to assess whether alterations of select tissues might serve as biomarkers of metal contamination. The tailings had little or no effect on the crabs. Current studies will examine the effects of fresh tailings on behavior and growth of juvenile flatfishes and Tanner crabs.

Impacts of Fishing on Dungeness Crab Stock Structure

Staff from ABL are cooperating with the National Park Service, the University of Alaska, and the ADF&G to assess the effects of the commercial crab fishery on Dungeness crab populations in Glacier Bay. The Park Service is planning to close the fishery in part of the Bay in the near future. Studies in 1994 and 1995 mapped the distribution of crabs within the Bay and provided a census of crabs within the Bay by sex and reproductive state. Dispersion of the crabs within the Bay was correlated with the density of ovigerous crabs suggesting that ovigerous crabs are clustered with an affinity for certain sites. This behavior serves to concentrate the brood stock in a limited number of patches of optimal brooding habitat.

NATIONAL MARINE MAMMAL LABORATORY

The National Marine Mammal Laboratory (NMML) is the principal Federal laboratory responsible for long-term studies on marine mammals and their interactions with fisheries in the Bering Sea, Gulf of Alaska, Arctic, Antarctic, and California Current ecosystems.

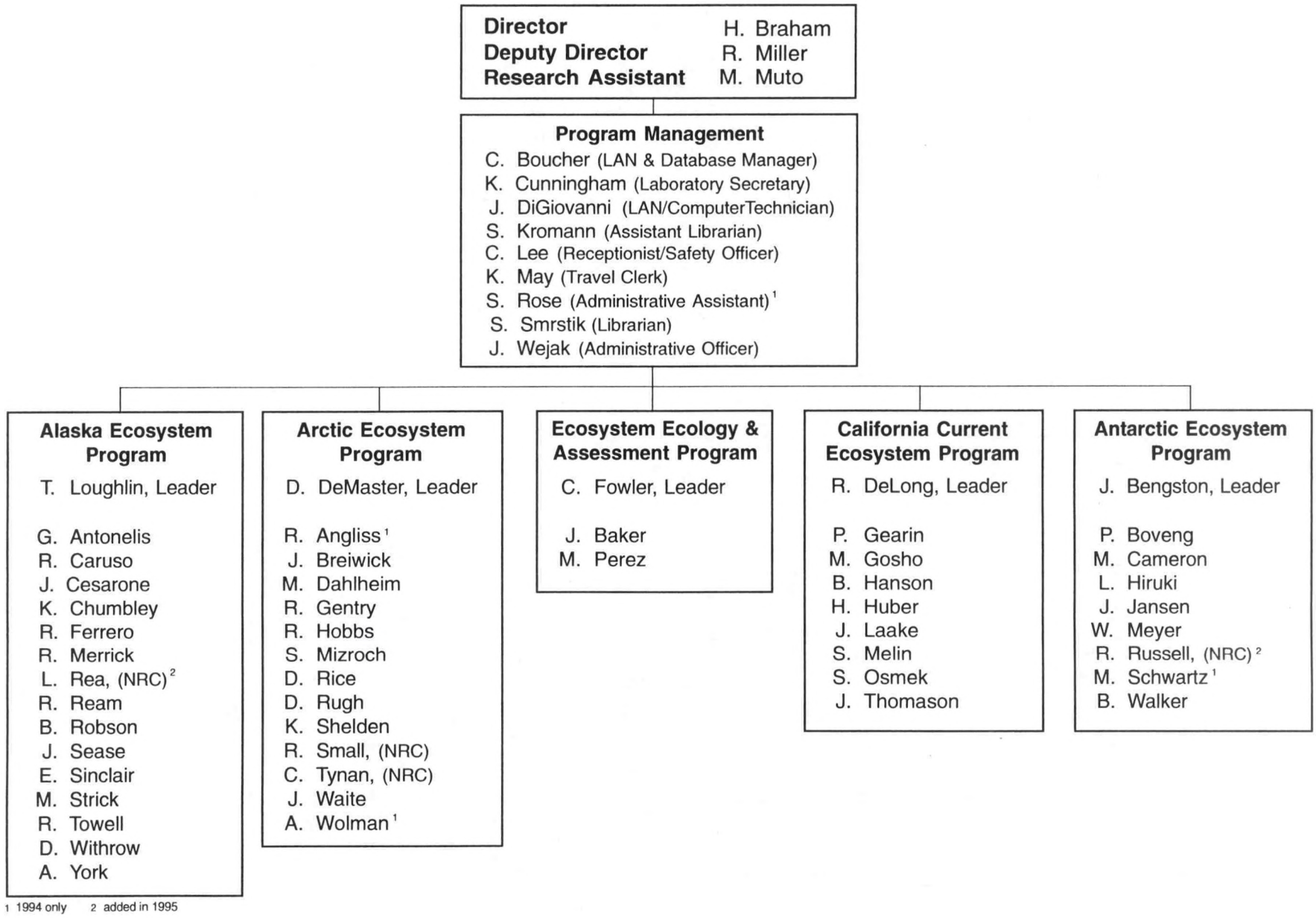
ALASKA ECOSYSTEM PROGRAM

Steller Sea Lions

Aerial and ship-based surveys of Steller sea lions (*Eumetopias jubatus*) were conducted by NMML and the Alaska Department of Fish and Game (ADF&G) during June and July 1994 from Forrester Island in Southeast Alaska to Attu Island in the western Aleutian Islands. A total of 32,930 adults and juvenile Steller sea lions were counted at 94 trend rookery and haul-out sites (trend sites are selected rookeries and haul-outs which are used to monitor population status). The 1994 count represents decreases of 5.5% from the 1992 survey (34,844 animals) and 13.7% from 1990 (38,154 animals) when Steller sea lions were listed as "threatened" under the U. S. Endangered Species Act (ESA). Annual rates of change, as estimated by linear regression, were -2.8% from 1992 to 1994 and -3.7% from 1990 to 1994 ($P = 0.008$). A total of 13,850 live pups were counted at 33 rookeries from Southeast Alaska through the central Aleutian Islands in 1994; this represents a 62% decline since the previous survey in 1989-90. Pup production has decreased in all areas of Alaska.

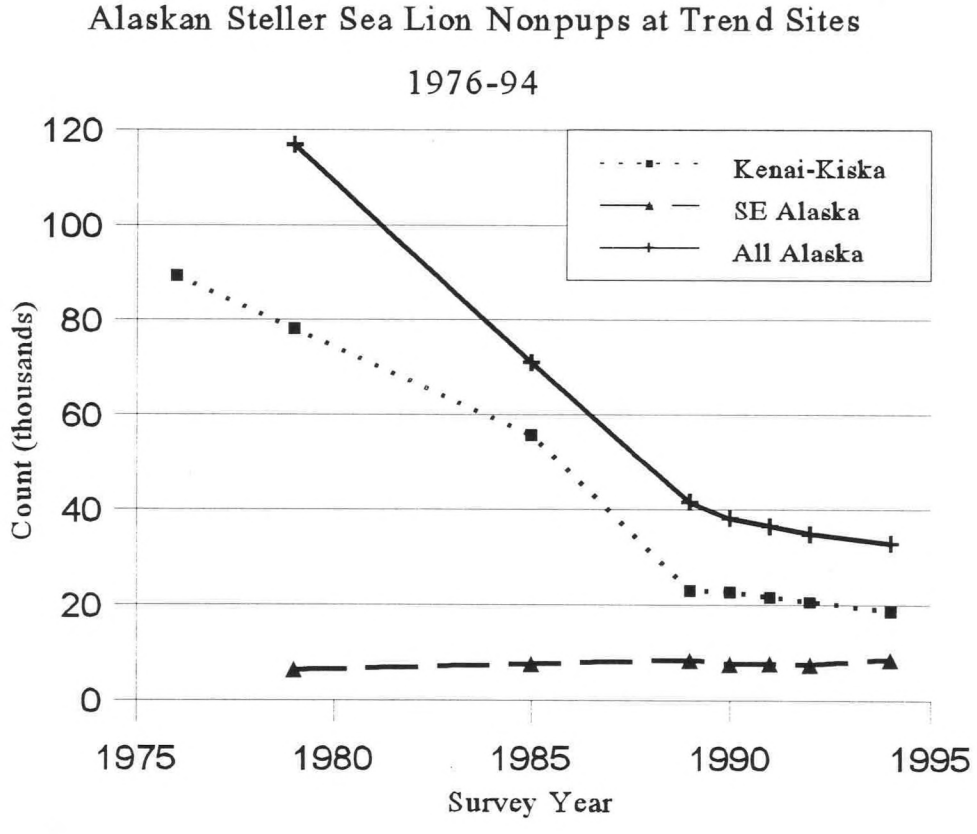
The NMML and ADF&G conducted aerial surveys during March 1993 and November-December 1994, which, in combination with the June-July 1992 and June 1994 surveys, provided the first Alaska-wide description of Steller sea lion seasonal distribution. Less than one-half as many animals were observed in the November-March period as during June-July, however the number of sea lions observed at haul-outs (rather than on rookery sites) were greater in winter than in summer. Populations on summer rookery sites were high until October-November, after which there was a rapid decline in the number of animals on the sites. During December-April, many rookery sites were empty, while many haul-out sites were occupied that were empty in the summer. The redistribution of animals appears to be the result of seasonal migrations and different regional haul-out patterns.

NATIONAL MARINE MAMMAL LABORATORY
ORGANIZATION CHART
1994-95



1 1994 only 2 added in 1995

The NMML and ADF&G have completed analyses of field studies conducted at Marmot Island, Alaska, from 1979 through 1994. Since the 1970s, numbers of non-pup Steller sea lions observed on Marmot Island during the breeding season declined dramatically -- 87.1% since 1979. Estimated annual rates of decline for non-pups were 12.5% for aerial surveys and 15.5% for cliff counts during 1979-94. The proportion of juvenile Steller sea lions on the island declined from 15-35% of all non-pups during 1979-83 to about 5% or less during 1987-94. From 1979 to 1994, pup numbers declined 88.1% (-15% per year). During 1987 and 1988, 751 pups (390 females and 361 males) were branded at Marmot Island. Through December 1994, 147 of these animals were resighted on 202 occasions at 23 different locations. Most resightings (60.0%) were from Marmot Island; the most distant resighting was at Loretta Island, British Columbia, Canada. The observed numbers of resightings were significantly below the number expected to be alive at any given age. Eight branded females were observed with pups during 1993 or 1994.



Studies of Steller sea lion foraging ecology continued during 1994-95. Conventional radio (VHF) and satellite-linked time-depth recorder tags were used to compare foraging effort in summer and winter of adult female and young-of-year (< 1-year old) Steller sea lions in

the Gulf of Alaska and eastern Aleutian Islands. Foraging effort (time spent diving) was not significantly different for postpartum adult females in summer or winter. However, compared with the summer, the adult females in winter spent more time at sea on longer trips over larger home ranges and dove to deeper depths. Steller sea lion young-of-year exerted the least foraging effort, spent the least amount of time at sea, had the shallowest and most brief dives, and had home ranges intermediate to the two groups of adult females. Consequently, young-of-year Steller sea lions appear more restricted in their foraging ability due to their shallow dive depths. Increased home ranges of both winter adult females and young-of-year animals suggest prey availability is reduced during the winter. As such, animals in winter, particularly young Steller sea lions, would be more vulnerable to changes in the distribution of their prey and could be more easily limited by food availability.

The diet of Steller sea lions was examined for the period of June-August 1990-93 from six areas in the Aleutian Islands and Gulf of Alaska, and diets were compared with the population changes that occurred during the period. Seven general prey taxa were identified, but either walleye pollock (*Theragra chalcogramma*) or Atka mackerel (*Pleurogrammus monopterygius*) dominated in every area. The diversity of prey consumed varied among sites. A strong correlation ($r = 0.951$, $P = 0.04$) was found between diet diversity and the amount of decline in an area; as diet diversity decreased, populations decreased. This suggests that Steller sea lions need a variety of prey, perhaps as a buffer to significant changes in abundance of any single prey.

Scientists from NMML, the University of Alaska, Fairbanks (UAF), and the U.S. Fish and Wildlife Service (USF&WS) aboard the USF&WS vessel *Tiglax* conducted surveys of Steller sea lion prey at rookeries in the eastern Aleutian Islands, Shumagin Islands, and Kodiak Archipelago/Barren Islands during the summers of 1994-95. Preliminary biomass estimates suggest that midwater biomass was greatest at the eastern Aleutian Islands and declined to the east. Bottom trawls made by UAF scientists at the same sites and times provided similar results.

NMML staff have been working with geneticists at Texas A&M University to identify Steller sea lions stocks. Through 1995, the group had analyzed mitochondrial DNA in over 200 Steller sea lion pups from across its range. Results of the analyses suggest that two stocks exist that can be separated near Prince William Sound, Alaska. The western stock has recently been recommended for endangered status while the eastern stock has been recommended to remain listed as a threatened stock.

Northern Fur Seals

Northern fur seals (*Callorhinus ursinus*) were studied at their breeding location on the Pribilof Islands (St. Paul and St. George Islands) and Bogoslof Island in the Bering Sea.

Research projects assessing the growth of the northern fur seal population on the Pribilof Islands involved counts of adult males in July and estimates of northern fur seal pup production in August. From 1993 to 1994, the number of territorial males observed with females decreased 10.8% on St. Paul Island and increased 4.4% on St. George Island. Similarly from 1994 to 1995, the number of territorial males with females decreased 9.9% on St. Paul Island and increased 5.5% on St. George Island. In 1994 and 1995, overall declines in total counts of adult males from the

previous year were 11.0% and 13.2%, respectively. These decreases may reflect a decline in the number of adult males; however, due to the high degree of annual variability in these counts, several more years of data are needed to assess this information for possible trends. The number of northern fur seals on Bogoslof Island has continued to increase since they were discovered on the island in 1976. A count of at least 1,200 live pups in 1995 indicated that pup production increased at least 33% since 1993.

Mark-recapture (shear-sample) studies were conducted on the Pribilof Islands in 1994 from 10 to 31 August. The estimated number of pups born on St. Paul Island was 202,995 ± 4,875, and there was no significant difference in the stability of pup production between 1981 to 1994. Estimated pup production on St. George Island was 20,775 ± 825 in 1994, and there was no significant difference in the 5.0% declining trend which began in 1973. In 1995, a special study was conducted on St. George Island to evaluate and refine the accuracy of the shear/sample method of estimating pup production.

In 1994 and 1995, ongoing monitoring studies of northern fur seals on the Pribilof Islands included collection of fecal samples for the analysis of annual prey consumption, measurements of pup weight and length for the evaluation of pup condition, collection of tooth samples for ageing, and tissue and blood samples for evaluating the health of juvenile male northern fur seals killed during the subsistence harvest. In 1995, several studies were initiated on the Pribilof Islands which emphasized the evaluation of potential factors influencing the early survival of weaned northern fur seal pups. Neonatal activity patterns and the ontogeny of swimming behavior were examined by the use of a miniaturized archival instrument measuring time with wet/dry temperatures.

To assess pup migration patterns and diving behavior, a contract was issued in FY95 for the development of a lightweight 0.25 watt satellite tag. A preliminary satellite telemetry study was conducted, in cooperation with the National Research Institute of Far Seas Fisheries Research, Japan (NRIFSF), in 1994 to identify the foraging habitat of 9 adult female northern fur seals. The foraging ecology and energetics of post-parturient female northern fur seals and the growth of pups were studied (with scientists from the University of California at Santa Cruz) on St. Paul and St. George Islands. Interdisciplinary studies were conducted with other NOAA scientists from the Center and the Pacific Marine Environmental Laboratory to assess primary productivity in the region of frontal zones

around the Pribilof Islands and its relationship to the distribution of juvenile walleye pollock and their predators.

Fishing nets and other marine debris were collected from 119 (1994) and 96 (1995) northern fur seals on St. Paul and St. George Islands. Entanglement studies conducted (with the Aleut Communities of St. Paul and St. George Islands and the NRIFSF) in 1995 indicated that entanglement rates of juvenile males in marine debris were 0.22% and 0.39% on St. Paul and St. George Islands, respectively. The potential impacts of waste discharges from commercial fish processors on northern fur seals and the causes of pup mortality were assessed on St. Paul Island in cooperation with scientists from Colorado State University (CSU), the Environmental Conservation Division of the Northwest Fisheries Science Center (NMFS/NWFSC/EC), and the U. S. Environmental Protection Agency.

Genetic studies on reproductive success and paternity were conducted (with the NRIFSF) to evaluate the importance of peripheral males in the social structure of northern fur seals. A preliminary study was initiated with scientists from the University of Washington (UW) in 1995 to evaluate the intermixture of island populations of northern fur seals through DNA analysis. Also in 1995 an evaluation of the effects of pollutants on the immune response of pups was initiated on St. George Island in cooperation with researchers from the UAF and the NMFS/NWC/EC.

Harbor Seals

In Alaska, harbor seals (*Phoca vitulina*) range throughout southern Alaska waters in the Gulf of Alaska, the Aleutian Islands, along the north side of the Alaska Peninsula, and Bristol Bay (to about 59°N). Harbor seals were once considered abundant in all parts of their Alaskan range until surveys by ADF&G researchers in the 1980s indicated declining population trends in some areas. The NMML, with funding from the Office of Protected Resources (NMFS/OPR), has conducted census surveys in Alaska intermittently since 1976 and yearly since 1991 to obtain a minimum population estimate for the state. The state of Alaska was arbitrarily subdivided into four regions for census purposes: 1) Bristol Bay, Prince William Sound, and Copper River Delta; 2) Gulf of Alaska and Prince William Sound; 3) Southeastern Alaska; and 4) the Aleutian Islands. These four regions roughly follow the estimated stock separations, but logistical considerations were the primary factors used for this geographical delineation.

Minimum population estimates were obtained for harbor seals in the Aleutian Islands region during the molt surveys in August/September 1994. The maximum count for each of the four areas occurred on different days; the sum of these maximum counts totaled 3,437 harbor seals. The mean was 2,672 seals with a coefficent of variation (CV) of 5.9%. Due to the conservative nature and extreme difficulty of censusing harbor seals

along the Aleutian Islands, it is our recommendation that the maximum count (3,437 seals) be utilized for population estimates in the Aleutian Islands region. The maximum count for harbor seals in Alaska during 1991-94 totaled 51,073 harbor seals. The sum of mean counts for these 4 years totaled 45,441 seals. The application of the 1.74 correction factor (described below), to account for seals not hauled out on land during the molt surveys, yields an "adjusted total" of 79,067 harbor seals in Alaska.

In 1995, the NMML began a re-census and evaluation of each of the four regions in order to provide current population figures and estimates of population trends, especially in areas of decline and their neighboring locations. The NMML surveyed along the north side of the Alaska Peninsula and in Bristol Bay using the same procedures as earlier surveys. Preliminary mean estimates for the north side of the Alaska Peninsula were 7,783 seals (CV = 4.4%). This represents a difference of -745 seals (-9.5%) compared with the 1991 surveys.

In 1995 the NMML also began a study to determine the proportion of animals missed during the molt census aerial surveys. These surveys missed an unknown number of animals that were at sea or that moved between haul-out sites. In addition, the number of animals hauled out was influenced by tidal state at many locations, but tide may not have influenced haul-out patterns at others. NMML has been conducting research to develop correction factors in different areas for varying haul-out substrates to estimate the proportion of seals missed. These corrections will be applied to the minimum population estimates to determine more accurate estimates of harbor seal abundance in Alaska. The first phase of this study was initiated on rocky substrate in Southeast Alaska just prior to the 1994 molt census surveys. Thirty-six harbor seals were captured and equipped with radio transmitters. Of these, 20 were males and 16 were females (which were comprised of 22 adults, 12 sub-adults, and 3 pups). Aerial surveys were flown during the molt period in early September to record the percentage of tagged seals hauled out. A data collection computer was placed on a nearby island which recorded haul-out patterns for each seal. Most seals remained in the location where they were tagged or nearby (within 2-3 nautical miles (nmi). A few seals traveled to other locations (9-15 nmi away). The optimal dates to census, when the highest counts of tagged seals occurred, was between 26 August and 15 September. More seals were observed to haul out during low or falling tides and between the hours of 12:00 and 16:00. Males, females, and pups spent an average of 27.1%, 9.7%, and 7.0%, respectively, of their time hauled out. The mean percent number of tagged seals hauled out each day was 57.5%. A correction factor of 1.74 (CV = 0.068) was computed. This correction should be applied to those areas similar in geography and phenology. A similar study was started in 1995 on sandy substrate in Prince William Sound using 25 harbor seals (i.e., 13 males and 12 females; 19 adults, 5 subadults, and 1 pup).

On 14-16 November 1995, a workshop was held at Fairbanks, Alaska, to review research on the assessment of the population status of harbor seals in Alaska. The workshop, which was sponsored by NMML, was convened and contracted by Dr. Robert Small (CSU). Overviews and input were sought from a variety of experts to address questions about detectable levels of population change by time and area and to develop research recommendations and priorities.

ANTARCTIC ECOSYSTEM PROGRAM

The Antarctic Ecosystem Program conducts pinniped and seabird research identified under the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR). These projects are carried out as part of the CCAMLR Ecosystem Monitoring Program, a multinational program designed to detect significant changes in key components of the Southern Ocean ecosystem and to distinguish between changes due to commercial fisheries and natural causes. The underlying objectives of this research are to determine what factors are primarily responsible for influencing the population dynamics of Antarctic pinnipeds and seabirds. Current studies focus on predator feeding ecology, reproductive success, growth and condition, demography,

abundance, prey availability, and environmental conditions. There are two principal projects within this program: 1) Antarctic fur seal and seabird ecology and 2) pack-ice seal ecology.

Antarctic Fur Seals and Seabirds

Pinniped and seabird research projects have been conducted at the NOAA field camp on Seal Island, South Shetland Islands, Antarctica, since the 1986-87 austral summer. In 1995, a focused effort was initiated to summarize and prepare for publication of the results of the previous 9 years' studies at Seal Island. Antarctic fur seals (*Arctocephalus gazella*) and seabirds prey on Antarctic krill (*Euphausia superba*) and various finfish species within areas of important commercial fisheries. Because Antarctic fur seals and birds breed ashore at traditional sites, they are well-suited to annual, long-term studies of their ecology and behavior. Specific research topics addressed by the Seal Island studies include: 1) assessing pup growth rates and foraging behavior of Antarctic fur seals; 2) pup production, diet, abundance, survival, and recruitment of Antarctic fur seals; 3) evaluating the breeding success, fledgling size, reproductive chronology, foraging behavior, diet, abundance, survival, and recruitment of chinstrap (*Pygoscelis antarctica*) and macaroni (*Eudyptes chrysolophus*) penguins; and 4) assessing the growth and condition of chinstrap penguin chicks and seasonal patterns in the diving behavior of adult chinstrap penguins in relation to intra- and inter-annual changes in food supply and

environmental conditions. Analyses of stomach and fecal contents of Antarctic fur seals and penguins have shown that krill is predominate in these predators' diets. Prey fed to penguin chicks by their parents contained 99% krill by weight. The principal diet of Antarctic fur seals varied from krill (62%), to fish (13%), to mixed krill and fish (25%). Traces of squid beaks were also found in 15% of the Antarctic fur seal scat samples. In each of the past two field seasons, time-depth recorders and/or radio transmitters were attached to 40 Antarctic fur seals and 80 chinstrap penguins to assess foraging behavior. Antarctic fur seals and penguins foraged at depths averaging 20-30 m and 35-50 m, respectively.

Pack-Ice Seals

Research in the pack-ice zone is conducted to complement land-based studies at Seal Island. The most numerically important Antarctic pinniped species are those inhabiting the sea-ice zone, with crabeater seals (*Lobodon carcinophagus*) being the most abundant. Crabeater seals are the focus of studies in which foraging ecology, demography, distribution, and abundance are investigated. Field work includes on-site surveys and investigations using remote-sensing technology. Satellite telemetry has been successfully used to assess the seasonal movements, habitat use, foraging behavior, and activity patterns of crabeater seals in the Weddell Sea and along the Antarctic Peninsula. Crabeater seal data and specimen material from a variety of sources over the past 25 years have been compiled into a database at the NMML. Analyses of the seals' reproductive status and age distribution have revealed patterns of increasing age at sexual maturity and fluctuating cohort strength. NMML scientists are continuing these analyses in an attempt to explain the causes of these fluctuations.

ARCTIC ECOSYSTEM PROGRAM

Gray Whales

In June 1994, the eastern Pacific stock of gray whales (*Eschrichtius robustus*) was removed from the list of Endangered and Threatened Wildlife. The ESA requires that stocks/species removed from the list be monitored for a minimum period of 5 years and its status reassessed at the end of that period of time. Therefore, as part of the delisting process, NMFS developed a 5-year monitoring and research plan for eastern gray whales and initiated this program in 1994. As part of this 5-year plan, counts of southward migrating gray whales were conducted in January 1994 and from December 1995 to February 1996 as they passed the Granite Canyon research station in central California. The project was directed by the NMML with assistance of personnel from the Southwest Fisheries Science Center (NMFS/SWC). During the 1994 study, an experiment was

conducted using 25-power binoculars and a thermal sensor to determine the onshore-offshore distribution of migrating gray whales. In the 1995-96 study, the research was directed at determining total abundance. The abundance estimate of approximately 22,600 animals was based on the number of whales observed during the daytime watch and a series of correction factors to account for whales that were not counted. This estimate of total abundance was similar in value to an estimate based on data collected during the winter of 1993-94.

Bowhead Whales

No field studies were conducted in 1994-95 on bowhead whales (*Balaena mysticetus*) by NMML due to lack of funds. However, several analyses and reports were either undertaken or completed in 1994-95 using existing data. For example, three papers were completed by NMML staff that related to the development of a regime for the International Whaling Commission's (IWC) management of aboriginal subsistence whaling. In addition, NMML staff collaborated with researchers from the UW and LGL Inc. on a report on the utility of photo-identification in estimating the annual survival rate of adult bowhead whales. These papers were submitted to the Scientific Committee of the IWC for consideration at their June 1995 and 1996 meetings.

The NMML, in cooperation with other Center staff, also continued their studies on the utility of radio-isotope ageing of bowhead whale ear bones. The initial studies have used gray whale earbones, but upon completion of the calibration phase, bowhead whale ear bones will be aged based on changes in the ratio of lead and radium isotopes in the calcium matrix of the bone. To date, researchers have not been able to develop reliable methods for determining the age of a bowhead whale. It is likely that a combination of approaches will have to be used to cover the full range of the age structure of this species, such as also using carbon-isotope ratios and eye lens protein racemerization.

Humpback Whales

In September 1995, a workshop was convened by NMFS to develop an implementation plan for North Pacific humpback whale (*Megaptera novaeangliae*) stocks. During this workshop, a recommendation was made to update the North Pacific Fluke Catalog, which at that time included 12,000 fluke photographs contributed by over 30 researchers, but which had not been updated since 1991 due to lack of funds. Since then, NMML staff have updated the catalog to include photographs taken in 1992 through 1994. Further, with funding from NMFS/OPR's Endangered Species Program, NMML has again solicited photographs of humpback whales from the North Pacific research community, after having stopped this practice in March 1994 due to a lack of funds. NMML has also initiated a pilot study using sight-resight techniques to produce within-season estimates of

abundance for the population of humpback whales that winters in the waters off the Hawaiian Islands.

Ice Seals and Alaskan Small Cetaceans

No field studies were conducted in 1994-95 on either ice seals or Alaskan small cetaceans by the NMML staff due to lack of funding. However, proposals for future aerial surveys to determine the abundance of these species were prepared by the NMML and tentatively approved for support as part of NMFS/OPR's Marine Mammal Assessment Program. The surveys have been tentatively scheduled for the summers of 1997 through 1999 for small cetaceans and 1998 through 2000 for ringed seals (*Phoca hispida*) and bearded seals (*Erignathus barbatus*). In addition, a report on the abundance of harbor porpoises (*Phocoena phocoena*) in Alaska was completed and submitted for publication. The estimate of abundance in this report is the first such estimate of total harbor porpoise abundance in the state of Alaska.

Beluga Whales

Aerial surveys and dive behavior studies of the beluga whales (*Delphinapterus leucas*) in Cook Inlet, Alaska, were conducted in June 1994 and July-August 1995 by the NMML, in cooperation with the NMFS Alaska Region Office in Anchorage, the Cook Inlet Marine Mammal Council, and the Alaska Beluga Whale Committee. In these aerial surveys, NMML staff determined the distribution of beluga whale groups in Cook Inlet, made standardized counts of these whale groups, and recorded aerial videotapes of the groups during the counts. The dive behavior studies involved the use of VHF radio tags attached to the whales by a suction cup. A second study using satellite-linked dive recorders was unsuccessful. Using the aerial counts and correction factors developed from the analyses of the dive data and the videotapes, the abundance in Cook Inlet was estimated at 750 beluga whales.

Co-Management of Marine Mammals in Alaska

NMML staff participated in several meetings during 1994-95 regarding the development of agreements between NMFS and Alaskan Native Organizations regarding the co-management of marine mammal stocks in Alaska, as allowed under the amended Marine Mammal Protection Act. These meetings included a workshop in May 1995 sponsored by the Alaska Beluga Whale Committee. At these meetings, NMML staff made presentations regarding the status of beluga whales in Alaska and the preliminary results of the 1994 and 1995 abundance surveys of Cook Inlet for beluga whales.

Status of Alaska Marine Mammal Stocks

A report on Alaska marine mammal stock assessments in 1995 was completed by NMML staff which summarizes the status of the 31 stocks of marine mammals that are the management responsibility of the NMFS. This report, mandated by the amended Marine Mammal Protection Act, listed 9 stocks which are classified as strategic (i.e., either the annual removal rate exceeds the Potential Biological Removal level or the stock is formally listed as threatened, endangered, or depleted), while 19 stocks were listed as not being strategic. Three marine mammal stocks (Gulf of Alaska harbor seal, Norton Sound beluga whale, and Cook Inlet beluga whale) were not classified pending the development and implementation of co-management agreements with Alaska Native Organizations regarding the management of these stocks.

CALIFORNIA CURRENT ECOSYSTEM PROGRAM

Northern Fur Seals

Population growth of the northern fur seal population at San Miguel Island, California, is monitored using counts of pups as an index. A pup count of 2,634 in 1994 represented a 23.4% increase from 1993, but the 2,506 pups counted in 1995 represented a 4.8% decline from 1994 to 1995. The fact that the northern fur seal population increased steadily throughout the 1992-93 El Niño, and has continued to increase in 1994-95, is an indication that the most recent El Niño did not depress northern fur seal population growth as did the 1983 El Niño. During the previous

El Niño, it took 7 years before the number of northern fur seal pups born was as high as the level in 1982, the year before the onset of the El Niño.

In 1975, long-term studies of behavior and survival of individual northern fur seals in the San Miguel Island population were initiated. In 1994 and 1995, 300 pups were tagged to continue these studies. Efforts to sight tagged individuals resulted in sightings of 306 individuals during the summers of the 2-year period. Ages of individuals ranged from 2 to 15 years. Tag recoveries along the California, Oregon, and Washington coast continue to provide useful information on movements of individuals once they leave San Miguel Island for the winter, an aspect of behavior that remains little known for this population.

California Sea Lions

Studies of the population dynamics of the California sea lion (*Zalophus californianus*) population at San Miguel Island have been conducted by the NMML since 1972. Each

year, pup counts are conducted and used as an index of the growth of the population. In 1994 and 1995, total counts were 19,738 and 20,297, respectively, representing a 19.8% increase from 1993 to 1994 and a 2.8% increase from 1994 to 1995. Pup mortality (to age 3 months) was estimated at 18.8% and 17.8%, respectively. Pup production was depressed in 1993 due to the 1992-93 El Niño conditions along the California coast. The large increase in 1994 indicates that the population recovered quickly from the 1993 decline and the El Niño had only a single-year effect upon California sea lion pup production, unlike the 1983 El Niño which depressed pup production from 1983 through 1987.

In 1987, a branding program was initiated by the NMML for California sea lions at San Miguel Island. For the first 3 years, two-hundred 4-5 month old pups were hot branded with unique numbers on their left shoulder. The results indicated that this marking method was effective, and in 1990, a long-term program was undertaken with 500 pups branded each year. The objectives of the study are to determine survival, age at first reproduction, age-specific natality rates, and longitudinal natality rates for individuals for use in population modeling, as well as to determine the distribution and movements of individuals during the non-breeding season. The first marked reproductive females were recruited into the population in 1991. No females younger than 4 years of age have been sighted with pups. In 1994 and 1995, 44% and 30.7% of marked females (ages 4-8 years) were sighted along with their pups. In 1995, 28% of females (5-8 years old) sighted with pups had been sighted with pups in a previous year. These records are the first long-term reproductive histories of California sea lion females. Sightings of marked individuals along the California, Oregon, Washington, and British Columbia coasts during the non-breeding season have been obtained with the cooperation of researchers in those areas. These sightings provide the first records of the distribution and movements of known-age animals during the non-breeding season.

A foraging ecology study of female California sea lions was conducted by the NMML in 1991, 1992, and 1993 at San Miguel Island. The results, which indicated that females were foraging far offshore and far north of the breeding rookery, were confounded by the presence of El Niño conditions along the California coast from January 1992 through December 1993. This study was continued in the breeding season of 1995 and will be continued in the non-breeding season in 1996 to adequately describe the foraging behavior and food habits of California sea lion females.

A study was conducted by the NMML beginning in 1994 to investigate the distribution and abundance, movements and migration, and fishery interactions of California sea lions in Washington State. From October 1994 through June 1995, 210 male California sea lions were captured and marked with flipper tags, brand numbers, and red neoprene patches at Shilshole Bay in Puget Sound, Washington. Three California sea lions were fitted with VHF radio transmitters and one with a satellite-linked time-depth recorder.

California sea lions were tracked during aerial, vessel, and land-based surveys and sightings of marked animals were also recorded by other researchers in British Columbia, Washington, Oregon, and California.

The results of the sighting data indicate that California sea lions move freely between Washington and British Columbia during the fall, winter, and spring. The southward migration of California sea lions from Puget Sound back to the California Channel Island rookeries begins in late March and continues through mid-July. The southward migration route is coastal, generally within 0.5-5 km of shore. Some California sea lions stop along the route to haul out at various resting sites in Washington, including Tatoosh Island, Cape Alava, and Carroll Island; in British Columbia at Race Rocks; in Oregon at the Columbia River, Cascade Head, Cape Arago, and Rogue Reef; and in California at St. George Reef, San Francisco, the Farallon and Año Nuevo Islands, and numerous small rocks from Monterey Bay southward along the Big Sur Coast. The southward migration covers a distance of approximately 2,000 km and is rapid for some individuals which averaged 122 km per day and made the trip in 16-17 days. The maximum distance traveled per day was 177 km. One hundred of the 210 marked California sea lions were recorded at rookeries in the Channel Islands by 10 August 1995.

Aerial and vessel surveys were conducted by the NMML in Washington State to record the distribution and abundance of California sea lions during 1994 and 1995. The numbers of California sea lions in Puget Sound peaked in late March 1994 when 595 were counted and in April 1995 when 1,234 were counted.

Harbor Seals

In 1994, the NMML began a preliminary study of predation by harbor seals and California sea lions on spring chinook salmon (*Oncorhynchus tshawytscha*) in the Columbia River. Effort was focused on documentation of scarring by marine mammals on spring chinook examined at the Bonneville Dam and at eight hatcheries on the Columbia River and two hatcheries on the Snake River. Snake River spring chinook are an endangered species. Overall, for spring chinook, 16% (775 of 4856) had marine mammal marks, 67% were unmarked, and 17% had marks from some other source. Most of the marine mammal marks were minor descalings, but about 4% were more serious bites which might have had an effect on pre-spawning survival. Ninety percent of the marine mammal marks were attributed to harbor seals based on intercanine distances. It is not clear if the preponderance of harbor seal-attempted predation was the result of more harbor seals feeding on spring chinook or that harbor seals are less successful in capturing and consuming spring chinook than California sea lions.

Analysis of harbor seal food habits data was completed by the NMML based on 223 scat samples collected in south Puget Sound between June 1994 and October 1995. Harbor

seals in the area feed primarily on Pacific tomcod (*Microgadus proximus*), plainfin midshipman (*Porichthys notatus*), Pacific herring (*Clupea pallasi*), and Pacific whiting (*Merluccius productus*). About 4% of the samples contained salmonid remains. In April 1995, the food habits of harbor seals in the Columbia River were assessed using scat, enema, and lavage (stomach pump) techniques. The lavage samples contained 4 prey species, the enema samples contained 13 prey species, and the scat samples contained 27 species. Primary prey were Pacific staghorn sculpin (*Leptocottus armatus*), Pacific herring, and flatfish. Salmonid remains (both adult and smolts) were found in 10% of the enema samples and 20% of the scat samples.

Analysis of a correction factor to account for harbor seals in the water during aerial surveys was completed in 1995. That correction factor (1.53 times the number of seals on land during surveys) was based on a proportion of radio-tagged harbor seals which was representative of the total population ashore during surveys. The corrected state-wide estimate for Washington in 1993 was 29,968 to 38,879 harbor seals. Since 1978, counts of harbor seals in Washington have increased 7.68% annually.

In 1994 and 1995, NMML, the Washington Department of Fish and Wildlife (WDFW), and the Oregon Department of Fish and Wildlife (ODFW) conducted cooperative aerial surveys of harbor seals for a long-term study of trends in abundance and pup production. Surveys were flown over the coastal estuaries, outer coast, Puget Sound, and Hood Canal in Washington and the outer coast and coastal estuaries of Oregon. Because of funding constraints, those data have been only partially analyzed.

The NMML, in conjunction with the WDFW, initiated studies on the population dynamics of harbor seals using permanently marked (branded) seals in south Puget Sound. These research studies include information on survival, longevity, natality, and long-term reproductive success in female harbor seals. A total of 160 animals have been branded through 1995. In addition, data on disease screening, genetics, and contaminant levels in blubber were also collected. Because of funding constraints, those data have been only partially analyzed.

Harbor Porpoise

Field tests were conducted by NMML on the effectiveness of acoustic alarms in reducing the incidental catch of harbor porpoise in gill nets in the northern Washington marine set-net fishery. Four experimental nets were used to control for net length, depth, and condition to replace tribal gillnets which would normally have been fishing in the area. The incidental catch mitigation experiment was conducted from 27 July to 28 August 1995 in the Spike Rock fishing grounds of the Pacific Ocean. Each net acted as both a control and an experimental net depending on whether they were outfitted with alarms or not. The experimental nets were 100 fathoms (183 m) in length and contained 11 alarms,

spaced along the cork line at 16.6 m intervals. The alarms produced a broad band signal centered at 20 kHz, with source levels ranging between 121.7 and 124.7 dB re 1 micropascal @ 1 m. Nineteen harbor porpoises were taken in the control nets and only one was taken in an experimental net. The differences in porpoise catches between nets with or without alarms was significant ($c^2 = 5.28$, df = 1, P = 0.02), indicating that alarms were effective in reducing catch rates in the area. There were no significant differences in catch rates of chinook salmon, the species targeted in the fishery, in control or experimental nets ($c^2 = 0.31$, df = 1, P = 0.58). Sample sizes for harbor seal catch and observations of seal predation on fish were too small to test for significant differences.

An observer program was not conducted by NMML during the 1994 northern Washington marine setnet fishery, but six harbor porpoises recovered from the fishery were turned in by fishermen. During 1995, 20 harbor porpoises were incidentally caught in the fishery and 19 were recovered for necropsy. Total fishing effort continued to decline in this fishery in 1994 and 1995 due to low numbers of chinook salmon. Total fishing effort during the 1995 season was 123 net days fished.

A live-capture method using a tangle net was developed for harbor porpoises in the Pacific Ocean for subsequent tagging studies. Floating nets, constructed of 30.5 cm (12 inch) stretched-mesh monofilament web and a 68 g/m (0.3 lb/fathom) lead line, were deployed by the NMML along coastal northern Washington State where harbor porpoises commonly occur. The first trial deployments involved anchoring the net's float-line to keep the 120-200 m (60-100 fm) net in place while allowing the lead line to move freely. Harbor porpoises often moved within meters of the floating set-net and our boats but no animals were entangled. Currents kept the immobile net from hanging vertically. When the same 18.3 m (60 ft) deep net (200 m in length) was deployed in deeper water as a drift-net, the net hung more vertically and resulted in the live-capture of one immature female harbor porpoise. Within several minutes after capture, this animal was disentangled and safely transferred to an inflatable boat for tagging. A satellite-linked (PTT) and VHF radio tag was attached to either side of the preformed thermal-plastic saddle that was fitted around the leading edge of the dorsal fin and affixed with plastic pins and detachable links. Between 28 July and 17 August 1995 (21 days), over 50 locations were received via the satellite-linked PTT. The porpoise's movements were mostly restricted to the Olympic Coast Marine Sanctuary where it was captured.

ECOSYSTEM ECOLOGY AND ASSESSMENT PROGRAM

The activities of the Ecosystem Ecology and Assessment Program during 1994-95 included cooperative activities involving other programs within NMML, such as the northern fur seal population assessment, which are reported elsewhere in the NMML

section. Other activities involved contributions to ecosystem level management and assessment of incidental take of marine mammals in commercial fisheries.

Entanglement Among Adult Female Northern Fur Seals

In both 1994 and 1995, through cooperative studies with Japanese scientists, adult female northern fur seals on St. Paul Island breeding rookeries were counted to determine the incidence of entanglement in marine debris. These data are used to monitor any changes in entanglement that may occur between years. Repeated counts were conducted on Reef Rookery to monitor seasonal change in entanglement among adult females. For the past several years, results have indicated that there is an increasing incidence of entanglement from early July to early August.

Ecosystem Management

Ecosystem management has been an objective for a variety of agencies, including the National Marine Fisheries Service. The Ecosystem Ecology and Assessment Program has undertaken the task of developing a basis for committing fisheries agencies to management that achieve these objectives. During 1994-95, a manuscript for a book on ecosystem ecology and management was prepared.

Incidental Take of Marine Mammals in Domestic Groundfish Fisheries

United States fisheries observers placed on vessels in the domestic groundfish fisheries in the U.S. Exclusive Economic Zone (EEZ) in Alaska during 1994 and 1995 recorded the number of marine mammals caught in trawl, longline, pot, and jig fishing gear. A total of 31 (1994) and 19 (1995) marine mammals of 10 species were observed to have died incidental to fishing operations in 1994-95; 12 (1994) and 3 (1995) of these observed animals were Steller sea lions. A total of 17 (1994) and 3 (1995) Steller sea lions were estimated to have died incidentally in trawl fishing operations in the domestic groundfish fisheries in Alaska during 1994-95. The estimated incidental mortality of Steller sea lions in the Alaskan trawl fisheries in 1995 was lower than the average annual mortality take of 17 animals during 1990-94. One harbor seal was incidentally caught and injured by jig gear in the groundfish fishery in the Bering Sea in 1995. This was the first reported take of a marine mammal by the use of jig gear in the Alaska groundfish fisheries. In addition, two harbor seals, one each in the Bering Sea and Gulf of Alaska, died by entrapment in pot gear in the domestic groundfish fisheries in 1995; these were the first known marine mammal takes by groundfish pot gear in Alaska since 1992.

U.S.-RUSSIA MARINE MAMMAL PROJECT

Marine Mammal Project 02.05-61 is one of eight projects in Area V of the U.S.-Russia Agreement on Cooperation in the Field of Environmental Protection. Previously titled "The U.S.-U.S.S.R. Environmental Agreement", this landmark bilateral agreement of 1972 was renegotiated in 1994 to its current, more restricted coverage with only the Russian Republic. The Project is co-chaired by NMFS/NMML (R.V. Miller) and VNIRO (V.A.Vladimirov) and is coordinated under Area V by the US F&WS. The goal of this Project is to conduct cooperative research on the biology, ecology, and population dynamics of marine mammal species shared by both countries, leading to the development of methods for the rational management and protection of these animals.

In 1994, a total of nine exchanges were carried out involving a broad spectrum of research activities that ranging from field work to laboratory studies, data analysis, and a study of archival harvest records. The last research item carried out by one U. S. scientist, who visited the museums in Moscow, St. Petersburg, and Petropavlovsk-Kamchatskiy study historical records of Russian sea otter harvests in North America between 1741 and 1867. The harvest records will be used to reconstruct estimates of North American sea otter population size and distribution in North America prior to the onset of major harvesting. A National Biological Service (NBS) scientist worked with Russian colleagues from late March to mid-May in capturing and marking polar bears, and in surveying dens on Wrangel and Herald Islands, the Russian mainland along northern Chukotka, and the Novosibirsk and Severnaya Zemlya Islands in the Russian Arctic. In April, a NMFS scientist from the National Marine Mammal Laboratory (NMML) traveled to Petropavlovsk-Kamchatskiy to take part in a meeting of the International Working Group on Northern Fur Seal and Steller Sea Lion Population Dynamics. This was the second meeting of the working group, and it involved review of recent otariid seal research, status of the various stocks, and development of long-range plans for federal and cooperative research efforts. In June and July, a Russian scientist visited Alaska to participate in NMML vessel and land censusing of Steller sea lions. Another Russian scientist worked with NMML researchers in southeastern Alaska in August on radio tagging and aerial assessment of harbor seals in a project designed to determine correction factors for aerial survey data. Other joint work included a long-term study in which a Russian scientist from Petropavlovsk-Kamchatskiy worked with ADF&G researchers from August to November on harbor and spotted seals in field and laboratory activities. A study of the effects of ecotourism on walrus haul-outs on Arakamchechen Island in August included one scientist from the USF&WS, a team of Russian specialists, and a multi-agency conference in September in Nome that brought together representatives from the USF&WS, the State of Alaska, Alaska Native groups, and Russian officials to continue technical discussions on proposed joint management of the shared populations of polar bears and walrus. Unfortunately, economic and organizational problems within Russia prevented completion of several joint activities, including a major aerial survey using U.S. aircraft of Steller sea

lion rookeries and haul-outs around Kamchatka and the Kurile Islands and a scheduled vessel survey in the Sea of Okhotsk for gray and bowhead whales.

During 1995, a total of 11 exchanges involving 27 American and 29 Russian scientists took place. Joint research activities began in April with a U.S. scientist traveling to the Laptev, Kara, and Barents Seas in the western Russian Arctic to work with colleagues on capture and satellite tracking of polar bears to obtain data on movements, migrations, and distribution patterns. The work included a workshop in Moscow with Russian and Norwegian scientists to develop a cooperative program to determine radionuclide levels in polar bears throughout their range. Polar bear studies continued in July with two Russian scientists visiting Alaska to work on analyses of survey data and to prepare manuscripts for publication.

Joint efforts continued in August with cetacean studies involving three NMFS scientists working with Russian colleagues on surveys and biological studies of bowhead and gray whales in the Sea of Okhotsk off the east coast of northern Sakhalin Island. Also in August, two Russian scientists visited the United States to work on pinnipeds in Alaska. One scientist from KamchatNIRO (the Kamchatka Research Institute for Fisheries and Oceanography) spent 3 weeks on the Pribilof Islands working with NMFS scientists from NMML on population studies of northern fur seals and to learn new radio tagging and tracking techniques. The other scientist, from the Kamchatka Fisheries Inspection Service (KamchatRybVod) worked with NMML researchers on Alaska harbor seal biological studies designed to determine appropriate correction factors for population assessments.

In September, three major conferences were held in Kamchatka. The first was the Fifth Biennial Sea Otter Workshop that included 7 American and 16 Russian specialists reviewing past work and planning future studies on sea otter biology and population dynamics. The second conference included 12 American specialists meeting to review and agree on principles for joint conservation and management of the Alaska-Chukotka polar bear population, and to carry out preliminary planning for a joint agreement on management of the Bering Sea-Chukchi Sea walrus population. The last conference was the 13th Meeting of the Marine Mammal Project that included 6 American specialists and over 20 Russian participants. Joint and cooperative research activities conducted during the previous 20 months were reviewed and the group developed a comprehensive plan for research over the next 2 years. Proposed activities include: 5 joint studies on gray, bowhead, and beluga whales; 9 studies on walrus biology, harvest monitoring, data synthesis and analysis, and continuation of work toward a joint agreement; 13 cooperative activities on sea otters, ranging from examination of past harvest records to genetic analyses for stock determination to benthic community studies; and 12 proposed studies on pinnipeds, including 7 on harbor and ice-dwelling seals involving work on aerial survey methodology, foraging ecology, analyses of satellite tag data, and reproductive ecology and behavior. Finally, there are also 6 proposed activities on Steller sea lion biology and assessment to take place across almost the entire range of

the species, from the Gulf of Alaska to the Kurile Islands and Kamchatka, and 2 studies on northern fur seals to take place on the Pribilof Islands.

Additionally, in November a Russian Academy of Sciences researcher visited the United States to work with U.S. scientists to assess the effects of accumulated radiation doses on long-lived mammals of the Russian Arctic, and in December another Russian scientist visited Alaska to work on data analyses of spotted seals and develop a multi-agency cooperative study on harbor seals in both Alaska and Kamchatka. Finally, a NBS scientist visited Magadan, Russia, to help plan and establish a Pacific walrus international database with the Institute for Study of Biological Problems of the North.

RESOURCE ASSESSMENT AND CONSERVATION ENGINEERING DIVISION

The RACE Division continued its program of resource assessment to provide scientific information for the management of marine fish and shellfish. During 1994-95, major resource assessment surveys were conducted in the Gulf of Alaska, Bering Sea, Aleutian Islands region, and waters off the U. S. West Coast. In research to reduce bycatch of prohibited or unwanted catches of fish and crab, special purpose surveys were also conducted in waters in the vicinity of Kodiak Island and in the Bering Sea to examine fish behavior in and around trawls and crab behavior in and around crab pots. Research continued on recruitment processes through the Fisheries-Oceanography Coordinated Investigations (FOCI) study in Shelikof Strait in the Gulf of Alaska and in the Bering Sea. In addition, studies on fisheries pathology, ecology, acoustics, and gear performance were also conducted. These activities were supported by RACE data management and gear maintenance groups.

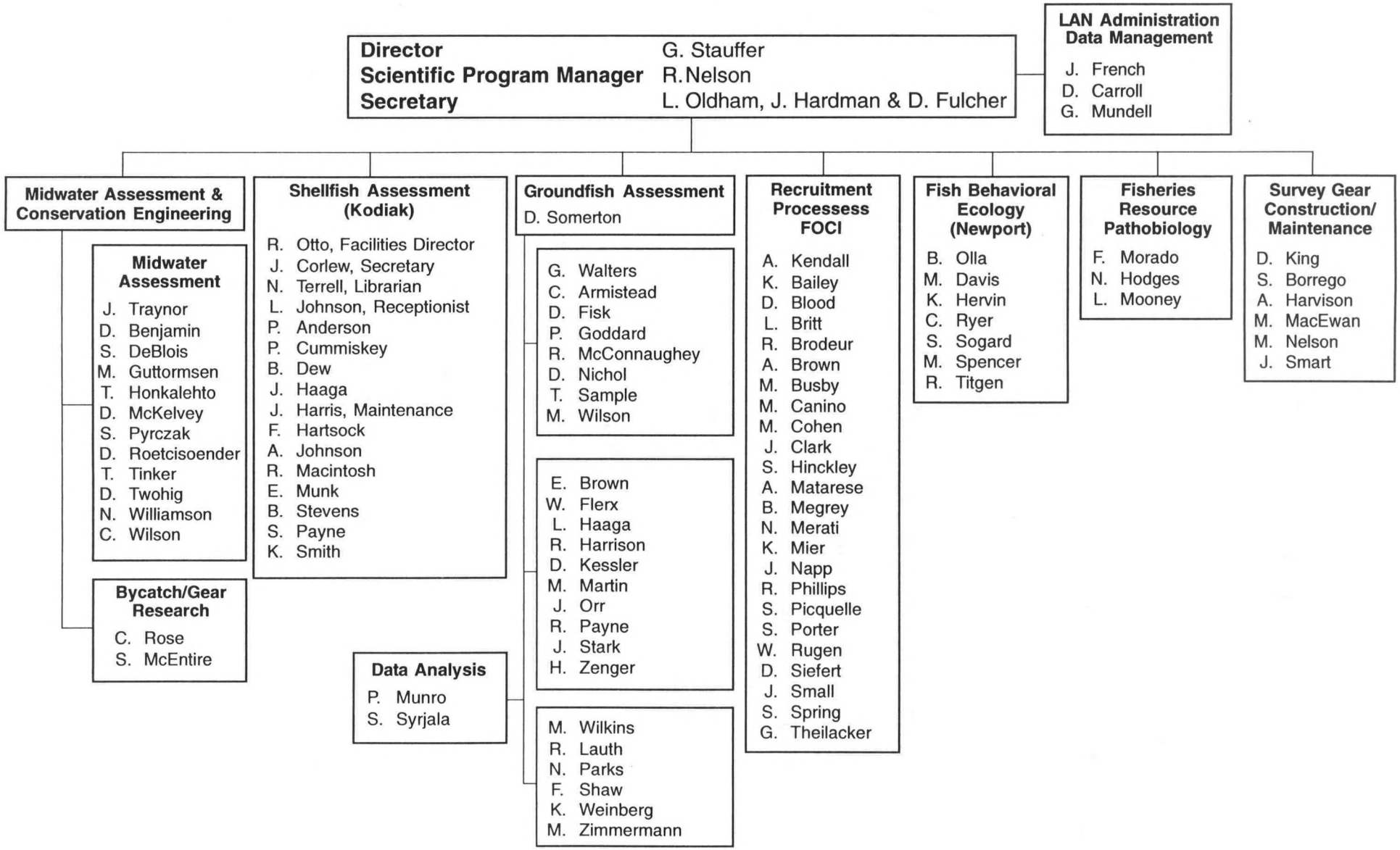
GROUNDFISH ASSESSMENT

Bering Sea Groundfish Assessment

The Bering Sea Groundfish Subtask, in association with the Shellfish Assessment Program in Kodiak, completed bottom trawl surveys of the eastern Bering Sea in 1994 and 1995. The primary purpose was to assess the biological condition of important fish and shellfish. These surveys were a continuation of a series of annual assessment surveys that began in the early 1970s. Since 1979, the survey has included a standard area encompassing approximately 465,000 km^2, including eastern Bering Sea continental shelf waters from inner Bristol Bay west to the 200-m depth contour and from the Alaska Peninsula north to St. Matthew Island. Additional sites north of the standard area were also sampled to assess the condition of snow crab (*Chionoecetes opilio*). Each survey was conducted aboard two chartered fishing trawlers from 1 June to mid-August.

Survey results indicate somewhat varying abundance levels for many important commercial groundfish species and fairly stable abundances for others. Several species had record high levels for 1994 and then returned to near 1993 levels in 1995.

RESOURCE ASSESSMENT AND CONSERVATION ENGINEERING DIVISION
ORGANIZATION CHART
1994-95



Walleye pollock (*Theragra chalcogramma*), historically the most abundant fish species in the eastern Bering Sea, had an estimated biomass of 5.0 million metic tons (t) and 5.4 million t in 1994 and 1995, respectively. Pollock biomass estimates have ranged from a low of 1.0 million t in 1980 to a high of 7.7 million t in 1990, but estimates have remained fairly stable since 1983. Pacific cod (*Gadus macrocephalus*) biomass was estimated at 1.4 million t in 1994 and 1.0 million t in 1995. The 1994 estimate was double that of 1993 and probably is an overestimate. Yellowfin sole (*Pleuronectes asper*) abundance has remained at a stable level since the mid-1980s. Biomass estimates from 1994 and 1995 were 2.6 million t and 2.0 million t, respectively. Rock sole (*Pleuronectes bilineatus*) had a record estimate of 2.9 million t in 1994 and then lowered somewhat to 2.2 million t in 1995. Rock sole abundance has markedly increased since the early 1980s, more than tripling in biomass since 1983. Arrowtooth flounder (*Atheresthes stomias*) and flathead sole (*Hippoglossoides elassodon*) both exhibited peak biomass levels during the 1994 survey before returning to near 1993 levels in 1995. Arrowtooth flounder reached a peak biomass of 571,000 t in 1994 and 481,000 t in 1995; this reflects a long, steady increase, more than tripling since 1983. Flathead sole attained a peak biomass of 725,000 t in 1994 and remained high: 593,000 t in 1995. This represents an increase of more than double since 1983. Alaska plaice (*Pleuronectes quadrituberculatus*) estimates have remained somewhat stable, with annual biomass estimates ranging between 500,000 and 800,000 t since 1981. Alaska plaice biomass estimates for 1994 and 1995 were 623,000 t and 552,000 t, respectively. Greenland turbot (*Reinhardtius hippoglossoides*) experienced a dramatic decline in biomass over the standard shelf area (due to poor recruitment) from 1979 (225,600 t) to 1986 (5,600 t). This species has shown some evidence of recovery in recent years. Estimates during this period were 49,000 t and 35,000 t in 1994 and 1995, respectively.

In both 1994 and 1995, additional experiments were performed to a) improve the accuracy of our estimates by examining catchability, b) improve our survey methodology resulting in improved estimates, and c) extend our knowledge of inshore fish distributions and biology. In 1994 an experiment was carried out to estimate the amount of herding by the trawl cables. This experiment will allow RACE to better estimate the effective trawl path of the net. Another experiment, using a trawl with two separated codends (trouser trawl), examined methods to reduce bias caused by sub-sampling large catches. In 1995, a similar experiment on this bias was conducted to examine the impact of shorter tow times (15 minutes versus the standard 30 minutes). Underwater video equipment was also used to examine the escapement of flatfish under the footrope of the trawl. Also in 1995, a small boat survey using a beam trawl was performed in the Togiak area of inner Bristol Bay. This survey will provide an estimate of yellowfin sole that are outside our normal survey area as well as providing valuable information on fecundity, maturity, and spawning activity. Results of these experiments are discussed in more detail below.

Gulf of Alaska/Aleutian Islands Groundfish Assessment

Aleutian Islands Triennial Bottom Trawl Survey

The fifth triennial bottom trawl survey of the Aleutian Islands region was completed during the summer of 1994 by the Gulf of Alaska/Aleutian Islands Subtask. Previous surveys in this series were conducted in 1980, 1983, 1986, and 1991. The triennial groundfish surveys are designed to describe and monitor the distribution, abundance, and biological condition of the important groundfish stocks in the Aleutian Islands area.

The Aleutian Archipelago consists of 47 major islands extending westward in a nearly 1,500 kilometer (km) arc from the Alaska Peninsula to Attu Island. Located among the westernmost islands are several prominent banks and reefs including Petrel Bank located north of the island chain at approximately long. 180°W, Buldir Reef and adjacent Tahoma Reef (long. 176°E), and Stalemate Bank, west of Attu Island (long. 171°E). The bathymetry of the sea floor in the Aleutian Islands region reflects the volcanic origin of the islands and is characterized by an irregular bottom, narrow continental shelf, and abrupt continental slope. The Aleutian Trench, approximately 120 km south of the chain, with 4-7 thousand meter (m) depths defines the southern limit of the continental shelf and slope. The northern continental shelf and slope varies from 30 to 75 km in width and is bounded by Bowers Basin in the west and the Aleutian Basin in the east.

Historically, the Aleutian Islands have been important fishing grounds for a variety of groundfish species including Pacific ocean perch (*Sebastes alutus)*, Atka mackerel (*Pleurogrammus monopterygius*), walleye pollock, Pacific cod, Pacific halibut (*Hippoglossus stenolepis*), sablefish (*Anoplopoma fimbria*), rockfishes (*Sebastes* spp.), and several invertebrate groups including crabs and squid.

The survey was conducted in three 23-day legs aboard two chartered commercial trawlers, the F/V *Pacific Knight* and the F/V *Vesteraalen* from 1 June to 9 September 1994. The stratified random survey design used for the 1983, 1986, and 1991 triennial surveys was employed during 1994 to make the most efficient use of limited vessel time and to provide consistency with earlier surveys. Within each stratum, stations were selected randomly from a pool of previously sampled stations and arbitrarily divided between the two survey vessels to minimize temporal and spatial separation of sampling effort.

The survey area covered a portion of the southern Bering Sea, from long. 165°W to long. 170°W and throughout the Aleutian Islands from long. 170°W to Stalemate Bank, long. 170°30'E (Fig. 1). Sampling proceeded from east to west at pre-selected stations at depths ranging from 16 to 476 m. Successful trawls were achieved at 387 of the 436 sites attempted, at depths ranging from 16 to 476 m, an increase of 14% over the 340

successful stations completed during the 1991 survey. An additional 13 non-quantitative tows were completed for additional projects.

In the Aleutian Islands region (west of long. 170° W), Atka mackerel, Pacific ocean perch, Pacific cod, walleye pollock, northern rockfish (*Sebastes polyspinis*), and sponges dominated the catches in most areas. As in 1991, the highest fish densities encountered during the survey were generally in the western Aleutian Islands region (west of long. 177°E) where catches were composed primarily of Atka mackerel, Pacific ocean perch, and northern rockfish. The most abundant species in the central Aleutian Islands region including Petral Bank (long. 177°W- 177°E) were Pacific ocean perch, Atka mackerel, Pacific cod, and walleye pollock, while catches in the eastern Aleutian Islands (long. 170°W- 177°W) were represented mainly by Atka mackerel, Pacific ocean perch, Pacific cod, and walleye pollock. Important components of catches from the southern Bering Sea portion of the survey area (long. 165°W- 170°W, north of the Aleutian chain) were Atka mackerel, walleye pollock, and Pacific cod.

Atka mackerel had, by far, the highest abundance of any species: 688 thousand t, up slightly (+4%) from the 1991 triennial survey. Pacific ocean perch with 448 thousand t was second in overall abundance, up nearly 10% from 1991. Other important species exhibiting positive biomass trends were Pacific cod, 194 thousand t (+6%), shortraker rockfish (*Sebastes aleutianus*), 29 thousand t (+7%), rougheye rockfish (*Sebastes borealis*), 14 thousand t (+9%) and shortspine thornyheads (*Sebastolobus alascanus*), 7 thousand t (+15%). Major species exhibiting apparent decreases in abundance from 1991 were northern rockfish, 82 thousand t, down 55%, and walleye pollock, 151 thousand t, down 43%.

Gulf of Alaska Domestic Longline Survey

The results of the eighth and ninth annual NMFS longline surveys of the upper continental slope and deep gullies of the Gulf of Alaska were used to evaluate the condition of sablefish stocks as well as provide data on the relative abundance and size compositions of shortspine thornyhead, and shortraker rockfish and rougheye rockfish thornyhead. Conducted in cooperation with the Auke Bay Laboratory, the results of these surveys are described above in the section on Auke Bay Laboratory research.

West Coast Groundfish Assessment

Triennial Bottom Trawl Survey

The West Coast Groundfish Subtask continued its series of triennial bottom trawl surveys of the groundfish resources off California, Oregon, Washington, and British Columbia during the summer of 1995. The survey began 8 June near Pt. Conception, California, and concluded on 6 September off Nootka Sound, British Columbia. Two chartered vessels successfully completed trawl hauls at 524 of the scheduled 610 stations between the depths of 55 and 500 m.

The 1995 trawl survey extended the depth range of past triennial surveys; previous surveys covered 55-366 m while the 1995 survey covered 55-500 m. Four strata of high station density were downgraded to the background station density because we found that the small precision improvements in sablefish abundance estimates, realized by the higher station density, did not justify the time spent sampling the extra stations. By reallocating the high-density stations to the deep stratum, we hoped for more comprehensive cover of the habitat of slope rockfish species (*Sebastes* spp.), excluding thornyheads (*Sebastolobus* spp.).

Pacific whiting, also known as Pacific hake (*Merluccius productus*), biomass estimates from the 1995 bottom trawl survey were larger than in any of the previous triennial surveys. Juvenile hake made up a large proportion of the population in all areas of the survey. Two-year-old hake were the largest year class off southern and central California, although one-year olds were also important. Atypically, 1-year-old hake were the predominant year class from northern California to the northern extent of the survey area.

Good weather allowed regular survey sampling to be completed approximately 20 days ahead of schedule. The remaining charter time provided the opportunity to examine the interaction between trawls and the fish they encounter using a video camera mounted in the mouth of the trawl. This project focused on the footrope bottom contact and the proportion of fish that escape capture by passing under the footropes of the trawls used in the Bering Sea crab/flatfish survey and the West Coast and Gulf of Alaska rockfish surveys.

Continental Slope Bottom Trawl Survey

Scientists from the West Coast Groundfish Subtask conducted assessment survey gear research off the coast of Oregon between 16 October and 13 November 1994, aboard the NOAA ship *Miller Freeman*. The cruise period was divided between two studies, each providing a distinct and independent approach to addressing concerns about gear performance. The first half of the cruise compared our standard bottom trawl (swept-

area) survey technique with a video sled line transect survey technique. The second leg of the cruise investigated bottom trawl gear performance using different net configurations and towing protocols.

One method for assessing how well the trawl survey estimates fish density is to compare it with an alternative survey technique. A video sled offers one independent method of estimating fish density. The video-camera equipped sled offers the added advantage of being able to see details of this habitat's physical and biological characteristics. The standard West Coast Slope Survey Nor'eastern trawl was used for the trawling portion of this experiment. The video sled used during the experiment was designed and built specifically for this cruise by Dr. Waldo Wakefield, the Science Director at the National Undersea Research Center and a Research Professor at the Institute of Marine and Coastal Science at Rutgers University. Thirteen video sled tows and 19 trawl tows were completed during this experiment, including 12 pairs of video sled and trawl tows at depths of 450, 750, and 1,150 m (4 tows at each depth).

Trawl gear performance was investigated by making changes to the gear or towing protocol and observing the resultant changes in net performance and catch. The objectives were to experiment with changes to the trawl system that would improve gear performance, have minimal affect on net selectivity so that we could maintain continuity with our slope survey data time series, and avoid reducing the maximum depth limit (1,300 m) of our present slope survey. Three modifications were chosen: 1) shorter scope (ratio of trawl warp length to depth); 2) a four-point bridle attachment to the V-door; and 3) lighter ground gear. All combinations of the trawl configurations were tested using a randomized block design. Within each block, treatments were done in random order. Twelve replicates of each block of treatments were completed for a total of 96 tows. All sampling was done between 460 and 480 m in the area between lat. 45°05' N and lat. 45°35' N, carefully avoiding crossing over the path of any previous tow.

Analyses of the physical behavior of the trawl show that the original configuration was unstable; the distance between the doors and the distance between the wingtips fluctuated significantly. The two treatments that appeared to stabilize the trawl the most were the lighter footrope and the 4-point bridle attachments. When we compared catch rates for different configurations, we found that the lighter footrope caught significantly fewer fish of the target species; Dover sole (*Microstomus pacificus*), sablefish, shortspine thornyheads, and longspine thornyheads (*Sebastolobus altivelis*).

In October-November 1995, the annual series of upper continental slope (100-700 fm) bottom trawl surveys of groundfish resources was resumed using the new gear configuration and towing protocols to improve gear performance based on the results of the 1994 experiment in the INPFC Eureka area using the NOAA ship *Miller Freeman*. Changes included a 4-point door bridle, shortened drop chains connecting the ground gear and the footrope, and an increased target towing speed from 2.0 knots to 2.3 knots.

Instrumentation was added to the trawl gear to improve our ability to monitor gear performance. Besides the regular SCANMAR equipment for measuring net dimensions and the bottom depth data logger, we attached a bottom contact sensor to the footrope, a tilt sensor on the trawl doors, and a new Wesmar net sonar system to the headrope. The Wesmar sonar provides a real-time image of the mouth of the trawl while it is fishing on bottom. Video footage was made of the new 4-point trawl door configuration and the ground gear while they were fishing on the bottom.

Data derived from annual slope surveys are used by fishery managers to assess stock condition and to establish annual harvest guidelines for sablefish, Dover sole, and two species of thornyhead rockfish. It presently takes 4-5 years to complete a trawl survey of the entire U.S. West Coast because of the length of the coastline, the time necessary to collect trawl samples from deep water, and the availability of only 1 month of vessel time for the survey each year. Slope groundfish resources in the INPFC Eureka area were last surveyed in 1990.

West Coast Extension of Domestic Longline Survey

The domestic longline survey of sablefish and other groundfish that the AFSC has conducted annually in the Gulf of Alaska from 1987 to 1994 was extended to the coasts of Washington and Oregon in 1994. The F/V *Alaskan Leader* sampled 14 stations between 29 September and
12 October using the standardized longline gear developed for the Gulf of Alaska survey. The main objective of the Washington-Oregon section of the survey was to estimate the relative abundance and size composition of continental slope groundfish species. We plan to relate the results of this survey to previous slope groundfish research in the area, primarily the 1979-91 pot index surveys and the 1984-93 slope trawl surveys.

Groundfish Research - Estimating the Catchability of Survey Trawls

Scientists from the Groundfish Assessment Program initiated a study designed to experimentally estimate the value of Q, the catchability or the proportion of the fish within the swept area of a trawl that are caught, for several species sampled with the 83-112 trawl used in the Bering Sea groundfish survey. Swept-area estimates of groundfish biomass are the primary product of RACE Division trawl surveys and require knowledge of the catchability, Q. Since catchability has never been estimated for any of the species sampled by the trawl surveys, it has been assumed to be equal to 1.0 in the calculation of biomass. Departures of Q from 1.0 would lead to biased estimates of biomass and possibly faulty advice for fishery management.

Two types of experiments were used: one to measure herding or movement of fish into the net path by the action of the bridles and one to estimate escapement under the footrope of the trawl. The first of three herding experiments, which was conducted in September 1993, aboard the NOAA ship *Miller Freeman* near Kodiak, Alaska, was primarily a pilot study to develop sampling methodology and to determine if the target species, arrowtooth flounder, displayed any tendency to herd. The second herding experiment, which was conducted in July 1994, aboard the F/V *Aldebaran* in the Eastern Bering Sea, applied the methodology to Pacific cod, snow crab and three species of flatfish. The third experiment, which was conducted in September 1994, aboard the R/V *Alaska* off the Washington Coast, applied the methodology to five species of flatfish.

Over the course of these experiments, it became clear that flatfish are herded by direct contact with the lower bridle and herding is minimal in the area between the wings and doors where the lower bridle is not in contact with the bottom. To help solve this problem, a cruise was conducted aboard the R/V *Alaska* in August 1995 to estimate by direct observation with a low-light video camera the length of the bridle that remains in contact with the bottom. Analysis of resulting video images demonstrated that bottom contact increased with increasing distance behind the doors and at 28 m, contact was maintained 50% of the time. For flatfish species, herding typically varied between 0.20 and 0.30 (i.e., 20-30% of the fish between the doors and the wingtips of the trawl were herded into the path of the net) but ranged from 0.10 for Pacific sanddab (*Citharichthys macrops*) to .47 for slender sole (*Eopsetta exilis*). Snow crab and Pacific cod were not effectively herded.

An experiment designed to estimate net avoidance or escapement under the footrope of the 83-112 trawl was conducted in August 1995 on four species of flatfish (flathead sole, yellowfin sole, rock sole, Alaska plaice) by directly observing fish behavior with an underwater video system. Efficiency was then estimated as the number of fish that entered the net divided by the number of fish encountering the footrope. The mean efficiency (0.78) was considerably lower than previously believed by RACE stock assessment scientists.

Values of Q were calculated for the three species of Bering Sea flatfish that were the subjects of both herding and escapement experiments. All of the Q values are greater than 1.0 (1.2 for yellowfin sole, 1.3 for rock sole, and 1.1 for flathead sole), indicating that the effects of herding exceed the effects of escapement and result in estimates of apparent fish density that are greater than the actual density.

MIDWATER ASSESSMENT AND CONSERVATION ENGINEERING

Midwater Assessment

Bering Sea Pollock Surveys

From 27 February to 9 March 1994, scientists from the Midwater Assessment and Conservation Engineering (MACE) program aboard the NOAA ship *Miller Freeman* carried out an echo integration-trawl (EIT) survey of the southeastern Aleutian Basin near Bogoslof Island to assess distribution and abundance of walleye pollock. This survey has been conducted annually since 1988 (with the exception of 1990) and is important because the area has supported an economically significant commercial pollock fishery (restricted since winter 1992), and because Bogoslof spawning pollock are presumed to be related to pollock inhabiting the international waters of the Aleutian Basin and central Bering Sea known as the "Donut Hole". The winter 1994 survey was composed of parallel north-south transects covering an area between 165° 51' W and 169° 53' W long. and trawl hauls were made frequently to identify echo sign. Pollock were most concentrated along the southern ends of each transect within about 30 nautical miles of the Aleutian Islands chain. Two types of pollock echo sign were identified and quantified from this region. The first formed large spawning aggregations over deep water and were mainly in pre-spawning maturity stages. Their estimated biomass was 0.49 million t and they numbered around 478 million fish. They ranged in length (fork length) from 39 to 67 cm with a predominant length mode at 52 cm and ranged in age from 4 to 24 years. Five-year-old pollock (the 1989 year class) accounted for 19% of this spawning population by number. The second echo-sign type was characterized by pollock inhabiting shallower water in the eastern portion of the survey area and close to the Aleutian Islands chain. The fish were mainly in developing maturity stages. Their estimated biomass was 0.05 million t and they numbered 71 million fish. Their predominant length mode was 44 cm. Fifty percent of their numbers were age-5 fish.

From 27 June to 14 September 1994, scientists conducted an EIT survey to assess walleye pollock abundance in the Bering Sea. The survey area included the eastern Bering Sea (EBS) shelf and slope from the Alaska Peninsula in the southeast to Cape Navarin in the north, the western Bering Sea (WBS) shelf and slope from Cape Navarin to the southern edge of the Gulf of Kamchatka in the southwest and a portion of Aleutian Islands waters. The survey was part of a cooperative survey effort involving research vessels and scientists from the United States, Japan, and South Korea. Researchers from Russia and the People's Republic of China participated aboard the NOAA ship *Miller Freeman.* Walleye pollock echo sign varied markedly throughout the survey area. Pollock aggregations of highest density were encountered on the EBS shelf between the Pribilof Islands and Cape Navarin. Although aggregations were generally less dense east of the

Pribilof Islands, high densities were encountered just north of Unimak Island. Very little echo sign was encountered along the Russian coast. Pollock east of the Pribilof Islands were generally larger than pollock west of the islands. The length composition of pollock caught east of the islands was trimodal, with a small mode at 3 cm, a larger mode at 31 cm, and the largest mode at 46 cm; virtually no fish between 6 and 25 cm were caught. West of the Pribilofs to Cape Navarin, pollock in the 15-25 cm range were very common. Three modes were observed at 15, 37, and 22 cm (in order of increasing dominance). On the WBS shelf, pollock typically ranged in length from 18 to 29 cm, with few larger pollock and none smaller. A preliminary pollock biomass estimate for the U.S. Exclusive Economic Zone (EEZ) portion of the EBS shelf is 2.70 million t.

MACE scientists carried out the 1995 EIT Bogoslof Island area survey using the NOAA ship *Miller Freeman*. The survey, conducted in two passes between 26 February and 9 March, covered an area between 165° 51'W and 170° 27'W long., from the Aleutian Islands chain north to between 53° 45' N and 54° 40' N lat., and was composed of parallel north-south transects. Isolated pollock aggregations were encountered off the edge of the shelf north of Akutan Island and over deep water northeast of Bogoslof Island. High-density pollock aggregations were observed along the north side of Umnak Island from 168° W to 169° 30' W long. Pollock ranged in length from 10 to 68 cm, with the majority between 40 and 60 cm. Little evidence of a non-spawning component of the pollock biomass (as had been observed in 1993 and 1994) was observed and most female pollock were in a pre-spawning reproductive state. The spawning biomass estimate, 1.10 million t, was more than twice the March 1994 estimate of 0.49 million t.

Also in April 1995, an EIT survey was conducted from the *Miller Freeman* to assess abundance of walleye pollock on the southeastern Bering Sea shelf. The survey area covered the shelf and slope from the Alaska Peninsula in the southeast to west of the Pribilof Islands. The southern extent of transects extending off the shelf was near the 1,000 m bottom depth contour. The northern extent of the survey area was limited by the winter ice pack. Greatest densities of pollock were observed near Unimak Island. Relatively little echo sign was observed west of 167° W. Pollock were observed right up to the ice edge along most transects. Pollock captured in trawls ranged in length from 26 cm to 79 cm. Male pollock caught in midwater rope trawl hauls averaged 43.1 cm long; females averaged 46.3 cm. Pollock caught in bottom trawl hauls were larger than pollock caught in midwater rope trawls; males averaged 46.8 cm and females averaged 53.2 cm.

Gulf of Alaska Pollock Surveys

During 15 March to 9 April 1994, MACE scientists conducted the annual (started in 1981) EIT survey to assess the distribution and abundance of walleye pollock within the Shelikof Strait area in the Gulf of Alaska using the NOAA ship *Miller Freeman*. The surveyed area included the Strait proper and the area of the sea valley that extended

southeast of the Strait to near Chirikof Island. Moderate pollock echo sign was observed in the southernmost area between Chirikof Island and Sitkinak Strait. Pollock within the southern region ranged between 9 and 65 cm fork length and produced size distributions with modal lengths around 12, 22, 33, and 47 cm. The smaller modal lengths were largely absent within the Strait. The densest pollock aggregations within the Strait were broadly distributed along the west side near Capes Kekurnoi and Kuliak. The size composition for fish within this area ranged between 9 and 71 cm with a dominant mode at 47 cm. An estimated number of 664 million pollock having a biomass of 467,000 metric tons (t) were in the survey area immediately prior to the time of peak spawning (i.e., Passes 1-2). These values are most comparable with previous abundance estimates for the Strait area with respect to survey timing. About 1-2 weeks later (Pass 3), estimates had declined to 559 million fish with a biomass of 354,000 t. These estimates suggest that fish had begun to emigrate from the Strait area.

The 1995 survey was conducted from 18 to 27 March aboard the *Miller Freeman*. As in previous years, most spawning pollock were distributed along the western side of the Strait with greatest densities near Capes Kekurnoi and Kuliak. The size distributions of pollock from hauls within the Strait generally exhibited dominant modes around either 10-12 cm or 48-50 cm, although weaker modes centered around 23 cm and 36 cm were sometimes present. Age-1 pollock (10-12 cm) formed a strong, well-defined acoustic layer in midwater (150-175 m depth), which was broadly distributed between Uyak Bay and the southern limits of the surveyed area near Chirikof Island. The areal extent and strength of this layer may be indicative of a relatively strong year class. Estimates for the Shelikof Strait area are 2 billion pollock weighing 725,000 t. Based on results from the earlier EIT surveys, the abundance of pollock within Shelikof Strait has shown a dramatic decline since the highest estimate of about 2.8 million t in 1981. Since 1988, estimates have remained relatively low and stable compared with earlier years, and results from the present survey, although slightly increased, generally continue this trend.

An exploratory EIT survey was conducted during 12-14 March to determine whether potentially important spawning aggregations of walleye pollock were present around the Shumagin Islands. Dense patches of pollock echo sign were distributed throughout the survey area. The aggregations were often in midwater and often over relatively shallow water depths (i.e., less than about 200 m). The most dense pollock aggregations were found immediately south of the Shumagin Islands, between Unga and Nagai Islands in West Nagai Strait, immediately west of Cape Kupreanof in Stepovak Bay, and in the Shumagin Gully. Pollock was the dominant fish species captured; all other species composed less than 1% of the catch. The pollock ranged between 22 and 63 cm and produced a bimodal distribution with a dominant mode at 45 cm and another at 33 cm. However, the younger fish that comprised the mode centered at 33 cm were only caught in the single haul made in the Shumagin Gully area. Pollock captured in the other three hauls were characterized by unimodal size distributions with modal lengths centered around 45 cm. This survey was designed to identify locations of significant pollock

densities in the vicinity of the Shumagin Islands. Inadequate vessel survey time prevented uniform transect coverage throughout the area, and thus the resulting survey trackline was considered marginal for generating accurate estimates of fish abundance. In addition, most adult females were in a post-spawning ("spent") stage of maturity development which suggested that some fish may have already left the area. With this understanding, preliminary estimates were generated which indicated that there were 191 million pollock having a biomass of 112,000 t within the survey area. These levels of post-spawning pollock suggested the presence of potentially important spawning aggregations in the Shumagin Islands area.

A comprehensive EIT survey for spawning walleye pollock was conducted around the Shumagin Islands during 14-20 February 1995 aboard the *Miller Freeman* as a follow-up of the preliminary 1994 survey. During the 1995 survey, quantities of mature, pre-spawning pollock were detected throughout the study area although most fish were concentrated immediately to the northeast of the Islands near Renshaw Point and Stepovak Bay. Significant quantities of mature fish were also detected within the Shumagin Gully. The size distributions of pollock from a total of 14 hauls throughout the area were remarkably similar; mean lengths among hauls ranged between 47 and 49 cm and distributions were strongly unimodal except on three occasions where age-1 fish also produced a significant mode. The age-1 fish, which ranged in length between 8 and 13 cm, were only captured in the Shumagin Gully. About 80% of the adult females were in a mature stage of reproductive development and would have been expected to spawn within the next few weeks. Estimates for the Shumagin Islands area are 354 million pollock weighing 290,100 t. Alhough the biomass estimate is more than double the 1994 estimate of 112,000 t, the 1994 survey was designed as an exploratory survey to identify locations of significant pollock densities in the vicinity of the Shumagin Islands. Thus the 1994 vessel survey trackline did not provide adequate coverage of the area for generating comparable estimates of fish abundance. In addition, the 1994 survey results indicated that the survey had occurred after peak spawning when some fish would have likely left the area.

West Coast Pacific Whiting Surveys

Scientists from the MACE program conducted the 7th triennial EIT survey of Pacific whiting off the west coast from central California to Dixon Entrance, Alaska, during 1 July to 1 September 1995 aboard the NOAA ship *Miller Freeman*. The survey area was expanded farther offshore and to the north compared with previous surveys. Expanded survey coverage within Canadian waters was conducted in cooperation with Canadian scientists working aboard the Canadian research vessel *W.E. Ricker*. Relatively dense Pacific whiting echo sign was observed off California near Point Arena and Cape Mendocino; off central Oregon (43-45°N); over Juan de Fuca Canyon near Cape Flattery; and off northern Vancouver Island. No echo sign was attributed to Pacific whiting north

of 51°N or south of about 38°N. Although Pacific whiting were sometimes caught south of 38°N, scattering from other species was so prevalent that it prevented identification of Pacific whiting echo sign from this area. The size composition of Pacific whiting differed over the survey area. Young-of-the-year fish (2-8 cm fork length) were only captured in the southern California area (34°55'-40°30'N). Fish comprising the 20-30 cm mode (primarily 1-year olds) were also present in the southern California area, strongly represented in the north California area (40°30'-43°00' N), moderate in Oregon (43°00'-45°46'N), and present in relatively low numbers in the northern areas (i.e., Washington (45°46'N) to north Vancouver (51°03'N)). The distribution of 1-year-old fish extended farther to the north than that reported from previous EIT surveys. Fish comprising the 30-40 cm length mode (primarily 2-year olds) were strongly represented in the California areas and nearly absent in the northern areas. Adult fish (>40 cm) were present throughout the survey area, although their contribution was minimal in the southern California area. Preliminary coast wide estimates are 584 billion fish weighing 2.5 million t.

Methodology Research

Research continues to improve midwater survey estimation procedures. Target strength measurements of walleye pollock and Pacific whiting are made opportunistically whenever field situations are observed that are conducive to such measurements. The in situ target strength measurement procedures require that the transducer be located within about 100 m distance (vertically) from the fish to minimize bias in target-strength measurements. A lowered transducer assembly was used to make measurements of walleye pollock in the Bering Sea during 1994. This technique shows promise for making measurements of pollock and whiting in conditions normally not conducive to the measurement of fish target strength (e.g., spawning fish and daytime aggregated fish). The current rigging is cumbersome and requires very calm seas and can only be lowered to about 60 m in the water column. The MACE program is in the process of developing specifications for a lowered transducer assembly that can be operated routinely at sea.

During the summer 1994 Bering Sea survey, measurements were taken of pollock reaction to the NOAA ship *Miller Freeman*. An acoustic system was installed on a launch and monitored as the *Miller Freeman* passed. In some instances, fish were observed to avoid the ship, while in other situations, little or no avoidance was observed. MACE is in the process of developing an acoustic buoy to repeat such measurements in a variety of vessel configurations (e.g., free-running versus trawling operations) for a variety of fish sizes and depths. (The research with the launch could be carried out only in very calm waters.) With time, we plan to be able to quantify the effect of fish reaction to survey vessels and the impact on both midwater and bottom trawl survey results.

Conservation Engineering and Bycatch

The Conservation Engineering group within the MACE program has continued its work to determine the effects of variability in the operating dimensions of standard RACE bottom trawls on survey results. Trawl mensuration equipment was provided for routine monitoring during all assessment surveys. Equipment and expertise for underwater video observations were also provided to a number of experiments to determine the effectiveness of our standard survey trawls. These have included studies of the herding of fish by trawl bridles, escape under the groundgear, tests of alternate groundgears and fish behavior during the transitions as survey trawls contact and separate from the sea floor. Tilt recording devices were developed to monitor trawl door attitude and footrope contact with the seafloor, important parameters that were not previously possible to measure directly.

Work also continued in 1994 and 1995 on a project begun in the spring of 1990, in cooperation with the International Pacific Halibut Commission and the fishing and fishing gear industries, to develop fishing gear technology capable of both effective fishing and reduced bycatch of Pacific halibut and other unwanted or prohibited species. An underwater video/sonar system was used to observe the behavior of Pacific halibut, Pacific cod, small flatfish, and crabs in the vicinity of a range of trawl modifications, as well as in unmodified nets. Results from this work in 1994-95 have included observations of Bering Sea crabs encountering several types of trawl ground gears and the behavior of walleye pollock in codends. Several trawl modifications to reduce crab and halibut bycatch in groundfish fisheries were tested.

In addition to this specific project, support has been provided to other bycatch reduction studies with in situ observation equipment. This cooperative work has included trawl manufacturers, regional academic institutions, and state fisheries agencies of both Oregon and Alaska.

SHELLFISH RESEARCH

Bering Sea Crab Assessment and Crab Fisheries

The Shellfish Assessment Program estimated the abundance of eastern Bering Sea crab stocks from the 1994 and 1995 crab/groundfish bottom trawl surveys. The estimates were used by the Alaska Department of Fish and Game (ADF&G) to set guideline harvest levels (GHL) for all major Bering Sea fisheries in accordance with the Fishery Management Plan (FMP) for commercial king and Tanner crab fisheries in the Bering Sea/Aleutian Islands region (Crab FMP).

The 1994 abundance index for Bristol Bay red king crab (*Paralithodes camtschatica)* showed a decrease relative to 1993. The abundance index for legal male Bristol Bay red king crab was 5.5 million crab as compared to 7.3 million in 1993. The abundance index for mature females fell from 14.2 million crab in 1993 to 7.5 million crab in 1994 which was below the threshold value of 8.4 million crab established by the Crab FMP. Because the abundance of females was below threshold, there was no fishery for Bristol Bay red king crab in 1994. The Bristol Bay stock continued to suffer from a long period of low recruitment. Abundance indices for juvenile and sub-legal crabs were among the lowest on record.

In 1993, abundance of red king crab in the Pribilof Islands area was high enough (2.5 million legal crabs) to justify opening a separate fishery for the first time. The 1994 abundance index was 1.9 million crab. Red king crab were found over a small area and the population index was uncertain. The Pribilof Islands fishery opened 15 September 1994 with a GHL of 2.0 million pounds.

Blue king crab (*P. platypus)* abundance in the Pribilof Islands area showed an index of 1.0 million legal crab in each year from 1991 to 1993 but decreased slightly to 0.8 million in 1994. The Pribilof fishery has been closed due to low stock abundance since 1988 and remained closed in 1994. The abundance estimate for legal male blue king crab in the St. Matthew Island area was 3.6 million crab in 1993 and 2.5 million in 1994. The fishery opened on 15 September 1994 with a GHL of 3.0 million pounds which was identical to the 1993 landings.

The 1994 abundance index for the Tanner crab (*Chionoecetes bairdi*) was 15.4 million legal males as opposed to 20.6 million in 1993. The 1994 GHL was set at 7.5 million pounds as compared with a 1993 catch of 16.9 million pounds. The eastern Bering Sea Tanner crab stock generally showed high levels of juvenile abundance and good recruitment from 1987 to 1991 but juvenile abundance declined in 1992 and 1993. The current abundance of legal males is below the historical average and likely to continue to decline into 1995 as a large cohort continues to pass through the stock. The 1994 GHL only reflected stock abundance in the area west of 163°. Areas to the east have been closed to fishing in order to protect female red king crab from possible adverse effects related to bycatch in the Tanner crab fishery.

Abundance indices for commercial-sized snow crab (*C. opilio*) declined from a record high of 484.1 million crab in 1991 to 256.4 million in 1992 and 135 million crab in 1993. The 1994 index showed a further decline to 71.6 million crab. The 1994 GHL was 55.7 million pounds as compared with a catch of 149.8 million pounds in 1993. Declining abundance was expected in this stock due to the continued passage of an extremely large cohort through the population which had supported record catches from 1988 to 1991.

The Bristol Bay red king crab fishery remained closed for a second year in 1995 due to low abundance of females. The 1995 trawl survey index of mature female abundance was 8.0 million and was virtually unchanged from 1994. The index for legal male crab was 6.3 million, up slightly from 5.5 million in 1994, but still well below the 9.8 million in 1993 when the fishery was last open (6,600 t or 14.6 million pounds). The index for pre-recruit males that would enter the Bristol Bay fishery over the next 1-2 years was 5.4 million crab, which is the lowest in the 27-year survey time series. The trawl survey index for the Pribilof Islands red king crab was 2.7 million legal males as opposed to 2.0 million in 1994. Although the survey showed an apparent increase, the 1995 fishery produced only 395 t (870,000 pounds) as compared to 607 t (1.3 million pounds) in 1994. Although the survey index has been roughly constant over the past 3 years, commercial catch and CPUE have been falling.

The Pribilof Islands blue king crab fishery opened in 1995 for the first time since the fall of 1987 (318 t or 701,000 pounds). The 1995 survey index of 2.0 million legal males was up considerably from 0.8 million in 1994 and above the FMP mandated threshold. The 1995 fishery landed 576 t (1.27 million pounds). The 1995 survey index for legal males was 1.9 million as opposed to 2.5 million in 1994. The St. Matthew Island blue king crab fishery landed 1,440 t (3.2 million pounds) as opposed to 1,720 t (3.8 million pounds) in 1994.

Survey abundance of legal male Tanner crab in 1995 was 10.0 million as compared to 15.4 million in 1994 and 20.4 million in 1993. In addition to declining abundance, the Tanner crab fishery has been hampered by regulations that prohibit all crab fishing east of 163° W long. in years when the Bristol bay red king crab fishery is closed. This regulation is intended to protect red king crab, particularly females, but it has decreased the availability of legal male Tanner crab by about 50% over the past 2 years.

Survey abundance of large male (> 102 mm or 4.0 in. carapace width) snow crab in 1995 was 69.0 million as compared with 72.0 million in 1994 and 135.0 million in 1993. Abundance has been declining since 1991 but is expected to increase in 1996 as legal but unmarketable male (78-102 mm) abundance increased by 88%. The 1996 eastern Bering Sea snow crab fishery had a guideline harvest level of 23,000 t (50.7 million pounds), as compared with 25,265 t (55.7 million pounds) in 1995.

In 1995, the AFSC on the part of the National Marine Fisheries Service entered into a Memorandum of Understanding with the Bering Sea Crab Survey Fund (a non-profit organization) to conduct an experimental survey of red king crab in the eastern Bering Sea. The Bering Sea Crab Survey Fund chartered the commercial fishing vessel F/V *Columbia* for the survey and the RACE Division provided scientific personnel, standard survey trawls, and trawl mensuration equipment during the survey. The survey began on 5 June and ended on 26 June. The purpose of the experimental survey was to increase the precision of abundance estimates of adult female red king crab.

FISHERIES RESOURCE PATHOBIOLOGY

Efforts to monitor the distribution and prevalence of Bitter Crab Syndrome (BCS) in the snow crab (*Chinoecetes opilio*) and Tanner crab (*C. bairdi*) populations of the Eastern Bering Sea were reinitiated in 1994. Approximately 125 stations throughout the survey area were randomly pre-selected for BCS sampling. In both 1994 and 1995, bloodsmears from approximately 1,750 crabs were prepared. The incomplete data from these 2 years collections support past trends on the prevalence and distribution of BCS. In *C. bairdi*, the disease continues to be sporadic and confined to deep stations just north of Unalaska Island. In contrast, the disease in *C. opilio* is more widespread being relatively sparse and at low prevalence south of 60°N. North of 60°N, the disease is more widespread and present at higher prevalences.

In 1994, the Task entered a cooperative agreement with the U.S. Environmental Protection Agency, Environmental Research Laboratory, Gulf Breeze, Florida designed to examine and compare the condition of grass shrimp (*Palaemonetes pugio*) and two penaeid shrimp species (*Peneaus aztecus* and *Peneaus duorarum*) from three and two collections sites around Pensacola, Florida, respectively. The objective of the study was to perform a broad histopathological study that could potentially identify a useful bioindicator of pollution. During the 1-year study, a total of 227 penaeid and 650 grass shrimp were collected. In grass shrimp, few lesions and parasites were present, and none was present at a significant level to suggest that it could potentially serve as a useful indicator of pollution. In *P. aztecus,* however, non-viral cytoplasmic inclusions in the epithelia of both the hepatopancreas and midgut were more prevalent in shrimp collected from the affected site than from the reference site. The nature of the cytoplasmic inclusions is uncertain but is believed to be related to a metabolic dysfunction; those shrimp from the affected area being more affected than shrimp from the reference site. In contrast, larval trematodes were more prevalent in penaeid shrimp collected from the reference site than from the affected site. There are contradicting theories on how to interpret parasite prevalence data from control and affected areas, both possess reasonable as well as unreasonable hypotheses. Because most studies, including this study, are spatially and temporally limited, it is doubtful the issue will be resolved. However, this study does emphasize the need to consider the overall condition of the study organism and not to only focus on a particular cell or biological feature.

RECRUITMENT PROCESSES

Fisheries-Oceanography Coordinated Investigations (FOCI) is a cooperative research program with the Pacific Marine Environmental Laboratory (PMEL), Oceanic and Atmospheric Research (OAR), designed to investigate causes of annual recruitment variations in fish stocks of economic importance in the Gulf of Alaska and Bering Sea ecosystems. The research is directed at understanding the causes of large natural fluctuations of walleye pollock (*Theragra chalcogramma*) stocks that spawn in Shelikof Strait, Gulf of Alaska, and in the eastern Bering Sea (with support from NOAA's Coastal Ocean Program). This research based on the paradigm that recruitment of pollock to the mature population is largely set during the egg and larval stages as the result of a host of physical and biological processes determining their survival to the juvenile stage. The objective of this research is to improve the accuracy and extend the time horizon of estimates of recruitment for forecasting future population trends on which to base management decisions on optimal harvest levels.

Field Studies

FOCI field studies in 1994 began with a joint cruise with the MACE Task of RACE aboard the NOAA ship *Miller Freeman* from 11 March to 9 April 1994, in the Shumagin Islands area and the Shelikof Strait. The primary objectives of the FOCI study were to: 1) conduct an ichthyoplankton survey in Shelikof Strait to determine the horizontal patterns of distribution and abundance of walleye pollock eggs in relation to spawning adults; 2) spawn mature pollock and rear the eggs for larval studies; 3) investigate vertebrate and invertebrate predation on pollock eggs; 4) deploy surface moorings containing physical and biological sensors at four locations in the study area; 5) calibrate chlorophyll absorbance meters on the four surface moorings and a single subsurface mooring; 6) obtain female copepod/egg ratio samples in parallel with walleye pollock egg samples to examine match/mismatch of food production with first-feeding-larvae; 7) obtain discrete sea surface chlorophyll samples in the Shelikof Strait area for mapping spatial patterns; and 8) conduct vertical casts with a video camera/light system to observe small-scale distribution patterns of spawning walleye pollock.

The first FOCI cruise to the Bering Sea in 1994 was from 11 to 30 April aboard the NOAA ship *Miller Freeman*. During this cruise, a large-scale survey of pollock larvae on the southeast Bering Sea shelf was conducted and biophysical calibration samples were collected in the vicinity of moored platforms. Studies of pollock larvae, their food, and predators were conducted in several domains of the Southeast Bering Sea. A major emphasis was a comparison of the slope and shelf environments as suitable habitats for larval pollock. Samples for collaborative studies with Dr. Lew Haldorson, University of Alaska, were also collected. The abundance and distribution of larvae was found to be

very different than it had been in 1993. The timing of the spring bloom and production of major prey for larval pollock also appeared to be delayed relative to 1993.

From 1 to 15 May 1994, FOCI conducted a cruise that included a study of the effects of a storm on pollock larvae in Shelikof Strait. During this cruise, a large-scale survey first mapped the distribution of larvae and located the center of abundance. This survey was followed by an intense study of the larvae, their condition, and their food. Sampling lasted for 72 hours and was centered around a drogue placed in a patch of larvae. As this study was being conducted, a storm developed and sampling during the storm provided information on the effects of the storm on the larvae and their food.

A second pollock larval cruise in Shelikof Strait in 1994 occurred from 23 May to 2 June. During this cruise, oceanographic moorings were recovered, hydrographic time series measurements were taken, and a larval survey was conducted. The larval survey sampled southwesterly through the strait along the Alaska Peninsula on a zig-zag course to the Shumagin Islands. Relatively high rough counts of pollock larvae (> 350 larvae 10 m^{-2}) were found at inshore stations along the peninsula, prompting the addition of several bongo net stations at embayments from Sutwik Island to Mitrofania Island. The larval survey then proceeded in a northeasterly direction to Chirikof Island and then farther to the northeast to complete the survey of the strait. Preliminary estimates of larval pollock abundance and satellite drifter tracks indicated that the main "patch" identified during the previous cruise had moved southwest and now occupied a position along the central axis of the sampling grid and that some inshore stations had high larval abundance. Also during the cruise, a series of live tows were conducted to provide a time series of larval gut contents to be used for estimation of gut-filling trajectories and the stage of digestion of prey items in the gut, and to obtain Pacific cod larvae for immunoassay procedures used by FOCI biologists to determine predation upon fish larvae.

During mid-September 1994, FOCI conducted site-intensive studies of the distribution of juvenile walleye pollock in the Bering Sea in relation to oceanographic features using two NOAA ships: the *Miller Freeman* and the *Surveyor*. The area in the vicinity of the Pribilof Islands was chosen as a study site because the unusual oceanographic fronts occurring there tend to concentrate both juvenile pollock and their prey and predators. The mid-shelf front north of the Pribilof Islands was also examined. The frontal areas were first located and areas of high and low juvenile pollock abundance were identified by a large-scale hydrographic/acoustic survey conducted by the *Surveyor* in the 2 weeks prior to joint-ship operations. Both ships employed continuous acoustic monitoring, using 38 kHz, 120 kHz, and 200 kHz transducers with a Simrad EK-500 to examine vertical distribution of juvenile pollock, their predators, and prey. Detailed concurrent physical sampling (conductivity-temperature-depth; CTD), Acoustic Doppler Current Profiler (ADCP) current measurements, ADCP moorings, and satellite-tracked drifter deployments) was also done to characterize the physical habitat around the fronts. Several types of trawls (e.g., anchovy, Methot, and Isaacs-Kidd midwater) with fine-mesh liners

were used to sample acoustic sign suspected to be juvenile pollock during this survey. Both sides of several fronts were sampled intensively and continuously during this period alternating between small midwater trawls for juvenile pollock, MOCNESS sampling for prey items, and larger midwater or bottom trawls for potential predators. An area at the

head of Pribilof Canyon, which also appeared to be an important area where age-0 pollock and predators aggregate, was also sampled.

Bering Sea FOCI staged two major cruises to the southeast Bering Sea in spring 1995 (16 April to 1 May and 3 May to 18 May) aboard the *Miller Freeman.* The first cruise surveyed the continental slope and southeast shelf regions and the second cruise concentrated on the shelf region. The multi-disciplinary cruises collected samples to determine the abundance, distribution, and condition of pollock eggs and larvae, the abundance and incidence of predation on eggs and larvae, the feeding selectivity of larvae, the availability of prey for larvae, age structure of the populations, stock structure using molecular probes, and to contrast the suitability of different habitats on larval survival. During both cruises, FOCI's biophysical moored platforms were serviced. Of special interest this year was the influence of sea ice, which remained in the southeast much longer than usual. One consequence was a very long egg developmental period. Many of the eggs sampled on the first cruise had not hatched before the midpoint of the second cruise.

The pollock late larval survey conducted aboard the NOAA ship *Miller Freeman* during late May 1995 in Shelikof Strait indicated high abundance of pollock larvae over a large area. Larvae had a broad size range, from 6.5 to 20 mm. Areas of high larval densities extended farther northeast than is typical, but the main patch was a little southwest of the usual location.

FOCI scientists participated in a cooperative cruise with the Japanese aboard their ship the *Kaiyo Maru* in the Bering Sea in May-June 1995. The research followed up on FOCI field studies in spring 1995 to document the occurrence of walleye pollock eggs and larvae on the continental shelf of the southeastern Bering Sea, and to study the associated physical and biological environment.

FOCI scientists made trawl collections during a 2-week cruise in July 1995 aboard the Hokkaido University research vessel *Oshoro Maru.* The trawl collections were part of a series of cruises begun in April 1995 to describe the distribution and growth of early life stages of walleye pollock in the Bering Sea. A small-mesh beam trawl was fished on a grid of 30 stations on the eastern Bering Sea shelf. Catches were the highest in the central shelf region and near the Pribilof Islands and were low in the northwest part of the grid. The size of juvenile pollock caught generally increased with increasing latitude. Several species of jellyfish were the only other taxa collected with age-0 pollock in these trawls and there was some indication of feeding by these large medusae on small juveniles.

During September 1995, FOCI scientists continued process studies initiated in 1994 on habitat characteristics of juvenile pollock in the Bering Sea. The first leg of the cruise of the NOAA ship *Miller Freeman* consisted of joint operations with the NOAA ship *Surveyor,* which examined the distribution of juvenile pollock in relation to oceanographic fronts around the Pribilof Islands and in the middle shelf region. Acoustical surveys were run by both ships using different frequencies, and the *Surveyor* conducted CTD transects and plankton sampling. The *Miller Freeman* did multiple-net plankton sampling (MOCNESS), midwater and bottom trawling, and deployed a remotely operated vehicle (ROV) with video cameras to identify acoustic sign and observe fish habitats and behaviors. Many juvenile pollock were seen in midwater deployments, often in association with large medusae.

During the second leg, after the departure of the *Surveyor* on 20 September 1995, the *Miller Freeman* revisited several areas of high juvenile abundance. Several cooperative predation studies were undertaken at this time with scientists from the REFM Trophic Interactions Program (fish predation studies), NMML (fur seal studies), and University of California at Irvine (seabird studies). Special sampling was done in areas where satellite-tagged fur seals were located and where seabirds were foraging. A series of ROV deployments in the Pribilof Canyon were made to examine rockfish aggregations observed in the acoustic signals. An abbreviated third leg was added to sample juvenile pollock in the Gulf of Alaska in order to get an indication of the abundance of the 1994 and 1995 year classes of pollock.

Laboratory Studies

In 1994, FOCI laboratory experiments were conducted to examine the relationships among nucleic acid contents, RNA/DNA ratios, and protein growth rates of first-feeding walleye pollock larvae in response to food densities. Pollock eggs were stripped from ripe females during cruises in Shelikof Strait and the Southeast Bering Sea and fertilized and maintained on board ship until the end of the cruise when they were transported in insulated containers to the experimental laboratory in Seattle. After hatching, the larvae were used in a series of controlled experiments, in which they were exposed to varying food densities. Experimental results indicated a positive relationship between biochemical indicators and food densities and that pollock larvae can achieve positive protein growth rates at food densities typical of subarctic environments.

The development of swimming and feeding behaviors in walleye pollock larvae was examined through laboratory experiments by FOCI scientists during 1995. Using larvae obtained as in 1994, a preliminary ontogenetic series of 3-D video recordings of larvae feeding on natural prey assemblages was obtained. The video images will be analyzed to determine changes in the perceptual field, attack and capture successes, and ingestion rates

of larvae as they mature. In addition, preliminary experiments examining temperature effects upon ingestion rates of pollock larvae were conducted.

FISHERIES BEHAVIORAL ECOLOGY

Two major groups of studies were conducted at the RACE Division's experimental facilities at the Mark O. Hatfield Marine Science Center in Newport, Oregon. Laboratory bycatch studies focused on the potential for recovery of juvenile and adult walleye pollock and sablefish that initially survive capture or are otherwise impacted by fishing gear. Behavioral studies with early juvenile stages of walleye pollock focused on the ability of fish to modify their behavior according to the environmental conditions they encounter.

The goal of the bycatch studies is to establish behavioral baselines and bioassays to measure lethal and sublethal effects to develop post-capture survival indices for important north Pacific bycatch species exposed to fish capturing processes that simulate commercial fishing conditions. Studies were aimed at evaluating: 1) the potential for long-term survival following capture; 2) whether fish that survive capture suffer deficits in behavioral capabilities that may compromise their ability to feed successfully and avoid predation; 3) whether the capability of surviving and recovering from capture differs with age and species and; 4) how environmental factors interact with the stresses imposed by capture to influence survival and recovery of behavioral mechanisms. Preliminary results indicated significant differences in potential for recovery among walleye pollock and sablefish. When walleye pollock juveniles were entrained in a net, in a procedure which simulated trawling, adverse effects were manifested in behavior, delayed mortality and elevated cortisol concentrations, with no potential for recovery apparent. In contrast, juvenile sablefish were more resistant to the stress induced by net entrainment and showed a high potential for recovery.

Laboratory studies on juvenile walleye pollock behavior examined social interactions including schooling and responses to varying temperature and food conditions. Experiments testing the response of juvenile walleye pollock to varying temperature and food conditions revealed flexibility in their behavior. When held at low temperatures ($<3^{\circ}C$), juveniles are able to endure long periods (2-3 months) without food. If provided with a temperature gradient, pollock selected different temperature layers depending on their prior success in obtaining food. Fish that have been deprived of food for extended time periods selected colder temperatures. In addition, they reduce their level of motor activity. These responses presumably result in reduced energetic costs, providing a mechanism by which fish can forestall starvation.

Observations in experimental systems have revealed that the compactness or cohesiveness of walleye pollock schools varies with food distribution and density and with different levels of predator threat. When prey are dispersed, schools are less cohesive, with fish foraging more independently. When prey are aggregated (mimicking the encounter of discrete patches of zooplankton in the sea), walleye pollock are more closely aggregated with individual fish quickly exploiting food patches discovered by others in the school. Overall low prey abundance results in less cohesive schools, but the threat of potential predation results in greater cohesiveness.

RESOURCE ECOLOGY AND FISHERIES MANAGEMENT DIVISION

The Resource Ecology and Fisheries Management (REFM) Division conducts research on the ecology, status, bio-economics and management of fisheries resources off Alaska and the U. S. West Coast. Scientists from the Division also provide technical liaison between research and the fisheries management process.

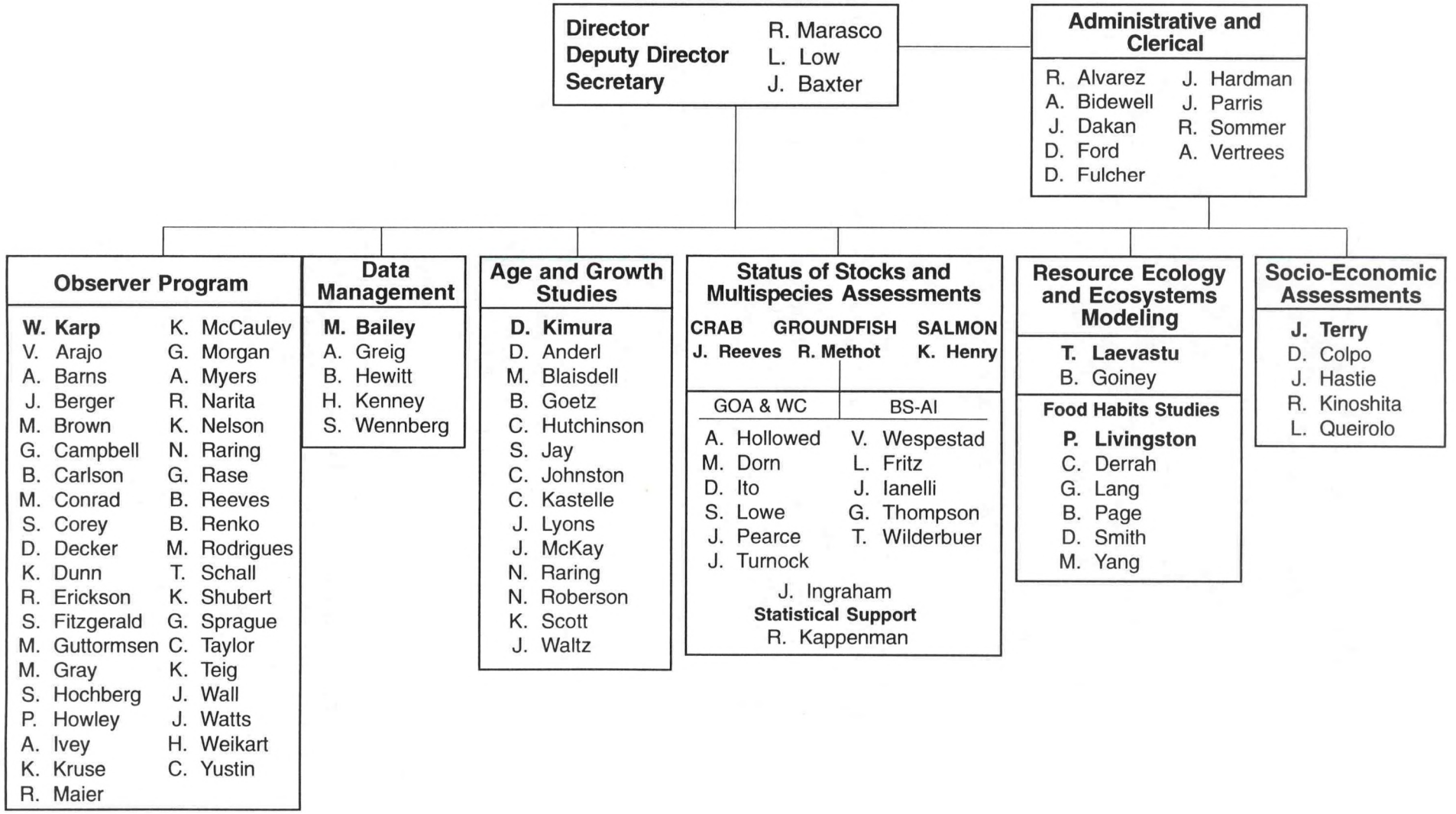
FISHERIES OBSERVER PROGRAM

The Task is responsible for implementing an observer sampling program to monitor groundfish fisheries off Alaska and the Pacific Northwest. The program places observers to monitor catches aboard domestic vessels and at shore-side processing facilities. They collect data for in-season management of the fisheries and for evaluating and developing long-term fisheries management strategies. Their data are useful for monitoring compliance to fishing regulations.

During 1994 and 1995, the program deployed 1,089 observers on 394 vessels and at 31 shoreside plants. Most of the observers were deployed to monitor the domestic groundfish fisheries off Alaska where such coverage is mandatory. Only a few observers were deployed to monitor the fisheries off Washington, Oregon, and California where coverage is not mandatory. For Alaska, observers coverage was nearly 100% on vessels greater than 125 ft in length and about 30% on vessels between 60 and 124 ft in length. Coverage was nearly 100% at shoreside plants that process more than 1,000 metric tons (t) of groundfish per month and about 30% at shoreside plants that process between 500 and 1,000 t of groundfish monthly.

The Groundfish Observer Program operates as a shared responsibility among NMFS, the fishing industry, and independent observer contractors. The NMFS has operational responsibility for the overall administration of the program as well as defining sampling duties and data collection methods. NMFS trains the observers prior to deployment and debriefs them upon their return. NMFS is also responsible for editing and managing the resulting data. The fishing industry is responsible for making arrangements with observer contractors to provide NMFS-certified observers and for paying the direct costs to the contractors for observer services. The contractors are responsible for recruiting and deploying observers to their sampling stations, insurance, employee benefits, and delivery of observer data to NMFS.

RESOURCE ECOLOGY AND FISHERIES MANAGEMENT DIVISION
ORGANIZATION CHART
1994-95*



* as of July 1994

Throughout 1994 and 1995, the Task was involved with development of a "North Pacific Fisheries Research Plan" which would change the present observer contractual arrangement. Under the new plan, groundfish, Pacific halibut, and crab vessels would be assessed a fee of up to 2% of the ex-vessel value of their harvest; and NMFS would then contract directly with private companies to provide observer coverage. This system would serve three primary purposes. First of all, it would greatly reduce conflicts of interest between observer contractors and vessel owners. Secondly, it would assure that observers receive fair and equitable treatment with regard to compensation packages and insurance coverage. Finally, it would equitably spread the cost of observer coverage among all participants in research plan fisheries.

However, in December 1995, the North Pacific Fishery Management Council (NPFMC) voted to repeal the new research plan and its associated fee-based funding mechanism. The Council also requested that NMFS pursue another alternative that would retain the direct payment for observer services of the current system while incorporating desired changes. The desired changes would address the needs for establishing an arms-length relationship between fishing companies and observer contractors, while assure that observers receive fair and equitable compensation packages and insurance coverage. The Council also requested that NMFS develop options for helping defray costs to vessel owners who would pay an unreasonably high proportion of their gross catch value for direct observer coverage.

AGE AND GROWTH STUDIES

The primary responsibility of the Age and Growth Task is to determine fish ages for analyzing their populations. This is achieved by counting the annual growth rings on otoliths, scales, and fin-rays. The Task also develop ageing criteria for new species, examine problem areas where the generated ages appear unsatisfactory, and validate the ages being read. Currently the Task is active in ageing the following species: Greenland turbot (*Reinhardtius hippoglossoides*), Alaska plaice (*Pleuronectes quadrituberculatus*), rock sole (*P. bilineatus*), flathead sole (*Hippoglossoides elassodon*), rex sole (*Errex zachirus*), yellowfin sole (*P. asper*), English sole (*Parophrys vetulus*), starry flounder (*Platichthys stellatus*), arrowtooth flounder (*Atheresthes stomias*), walleye pollock (*Theragra chalcogramma*), Pacific cod (*Gadus macrocephalus*), sablefish (*Anoplopoma fimbria*), Atka mackerel (*Pleurogrammus monopterygius*), Pacific whiting (*Merluccius productus*), Pacific ocean perch (*Sebastes alutus*), northern rockfish (*S. polyspinis*), and dusky rockfish (*S. ciliatus*). Total ages read for 1994 and 1995 were as follows:

Year	Age Category Raw	Test	Re-aged	Unageable	Special	Totals
1994	23,885	7,963	3,772	178	958	36,756
1995	27,867	7,280	4,140	158	176	39,621

The Task has investigated various otolith preparation techniques to improve reading flatfish structures. Various dyes and baking techniques were experimented with, but baking and the use of video-imaging equipment seems to be more effective than using dyes.

The Task applied radiometric techniques to validate age readings to several species of rockfishes: Pacific ocean perch; northern, dusky, rougheye (*S. aleutianus*), shortraker rockfish (*S. borealis*), and shortspine thornyhead (*Sebastolobus alascanus*). An attempt is also being made to radiometrically age gray whales (*Eschrichtius robustus*) using the bullae (i.e., ear bone).

STATUS OF STOCKS AND MULTISPECIES ASSESSMENTS

The primary role the Status of Stocks and Multispecies Assessments Task is to assess the condition of groundfish resources in the northeast Pacific Ocean, evaluate ecological factors influencing the production of groundfish resources, and analyze strategies for groundfish management in the North Pacific Ocean and Bering Sea ecosystems. In addition, the Task supplies technical support for fishery management and evaluates methods to improve the quality of stock assessments.

Stock Assessment

For the Alaska region, Task members continued annual assessments of walleye pollock, Pacific cod, yellowfin sole, Greenland turbot, sablefish, Pacific ocean perch, other commercially important rockfish and flatfish, thornyheads (*Sebastolobus* spp.), and Atka mackerel. For the West (Pacific) Coast, Task members provided stock assessments for Pacific whiting, Dover sole, Pacific ocean perch, sablefish, and thornyheads. Expanded topics of investigation include use of new size-structured assessment models; estimating risks associated with uncertainty in stock assessment forecasts, particularly for Pacific cod in the Gulf of Alaska and thornyhead off the West Coast; explicit incorporation of walleye pollock predators in the Gulf of Alaska stock assessment; and analysis of the impact of spatial patterns in the fishery.

Research

Members of the Task participated in a variety of research activities in 1994 and 1995. They developed comprehensive working plans to improve assessments and management recommendations. They directed feasibility studies to determine the utility of using alternative trawl gear for assessing stocks of slope rockfish (*Sebastes* spp.). During the 1995 NMFS Pacific whiting triennial survey, task members conducted exploratory research on the response of whiting to their prey and evaluated the utility of echo-integration trawl methods for measuring the distribution and abundance of juvenile whiting.

Some Task members served on nationwide NMFS committees to improve the quality of national stock assessment advisory process. Working groups on risk assessment and age-structured methods comparisons met during 1992-93. One task member served on an agency panel of fishery scientists established to evaluate definitions of overfishing currently used in U.S. fishery management plans. The panel's report was submitted to the Assistant Administrator for Fisheries in 1994 and contained recommendations for modification of most current overfishing definitions.

Members of the staff also participated in national and international research activities. One Task member convened a workshop to develop plans for studies of multinational research effort to understand the influence of climate change on the carrying capacity of the North Pacific ecosystem. In 1995, a Task member traveled to Russia to assist in obtaining access to data required for the development of a Bering Sea-wide pollock assessment models.

The advent of PICES (North Pacific Marine Science Organization) has provided a new international scientific forum for researching ecosystem and climate effects on the potential yield of fish stocks in the North Pacific Ocean. Particularly relevant are the Task's internal and collaborative studies of variations in ocean conditions relative to the recruitment success of northeast Pacific Ocean groundfish and participation in a workshop on the ecology of juvenile pollock. Task members are serving on three of the PICES Working Groups.

The fraction of the Pacific whiting stock that migrates northward into Canada each summer has been an issue of negotiations on allocation of available yields between the United States and Canada. Relationships among the fraction of the Pacific whiting in Canadian waters during summer as affected by sea surface temperatures, and monthly long-shore surface currents have been demonstrated by Task members.

Task members have utilized new methods to improve our description of uncertainty in stock assessments. In general, current stock assessment methods require a number of assumptions about what is observed (the data) and how underlying processes work.

Often, these assumptions result in an underestimate of the amount of uncertainty in the results. Newly developed software that provides an extremely efficient method of nonlinear parameter optimization using automatic analytical derivatives is used to examine alternative error structures in a stock assessment framework. These routines are beginning to be used and appear to be a very effective tool for model development and analyses.

Several Task members are using Bayesian methods in stock assessment applications. Investigations involving Bayesian methods can be divided into two categories: those involving applications of Bayesian *statistics* as a means of objectively incorporating prior knowledge into the parameter estimation process, and those involving applications of Bayesian *decision theory* as a means of objectively choosing between alternative parameter estimates or management strategies. An example of the first approach is use of Bayesian methods to estimate the highly dimensional posterior probability distribution of key elements of the stock assessment (e.g., ending biomass). Stock assessment models typically involve estimation of a large number of uncertain parameters. Many of the parameters involved are not of direct interest for decision analyses and hence require integration to obtain appropriate marginal distributions. Monte Carlo methods of integration are being applied to stock assessment models for comparison. One Task member developed a model that spans both categories of Bayesian analysis using the Kalman filter to perform Bayesian updating of stock size estimates and a risk-averse loss function to define an optimal harvest strategy.

Task members worked with Pentec Environmental (Edmonds, Washington) personnel to develop a tracking system for fish in enclosed or small areas (approximately 2 km^2). The system consists of an array of moored hydrophones that receive acoustic signals from tags on fish. These signals are in turn stored and processed (frequency and repetition of tag pings) by computers hard wired to the hydrophones in buoys and radio-transmitted to a base station that integrates the information from all the buoys for data storage and real-time display of fish location. The tracking system has been used on several occasions by the U. S. Fish and Wildlife Service in their study of salmon response to various flow regimes at the fish ladder next to the Chittenden Locks in Seattle, Washington.

The OSCURS (Ocean Surface Current Simulations) numerical model was used to investigate oceanographic and atmospheric indices associated with changes in fish stocks. The model has been used to simulate trajectories, landfall, and timing of sockeye salmon (*Oncorhynchus nerka*) during the ocean migration phase of their return to the Fraser River and similar studies of Pacific whiting migration are in progress. Good agreement between OSCURS model tracks and satellite-tracked drifting buoys, drift bottles, and other flotsam have been demonstrated. An index of interannual changes in ocean currents associated with large-scale shifts in atmospheric forcing was developed based on the output of the OSCURS model.

Increasingly sophisticated computer technologies, including a geographic information system, are now available at the Center. With these tools, Task members can more efficiently and comprehensively analyze spatial data--patterns of bycatch in the fishery, distribution of fish around sea lion rookeries, and improvement of survey design by spatially and temporally contrasting survey and fishery data.

CRAB RESEARCH

Forecasts of crab catches were developed from analyses of Bering Sea crab survey data for king, Tanner (*Chionoecetes bairdi)*, and snow crab (*C. opilio*) stocks. Analyses were carried out on the status of Bering Sea/Aleutian Islands crab stocks for inclusion in regional and national status of stocks reports. This work included estimation of fishing mortality (F), both target and bycatch F values due to trawl and pot fisheries.

Research continued on the re-estimation of historic crab abundances using the Kappenman estimator. An analysis of survey catch per unit effort (CPUE) distributions of all red king crab (*Paralithodes camtschaticus*) stock components was conducted, including comparisons of the Kappenman mean with the currently employed arithmetic mean.

Liaisons with crab fisheries management activities were carried out through interaction with the NPFMC, the Bering Sea/Aleutian Islands crab fishery management plan team, the Pacific Northwest Crab Industry Advisory Committee, and other industry groups.

Fishery Management Support

Task members served on groundfish management teams for the NPFMC, Pacific Fishery Management Council (PFMC) and have participated in bilateral negotiations regarding resource allocation. They have been involved as scientific and technical experts in analyses and reviews of council and NMFS Regional Office fisheries management issues. They assess risks and bio-economic implications of fishery management options. Bycatch analyses have also been important issues that are continually worked on. They have worked closely with scientists from the Center's National Marine Mammal Laboratory and other institutions in exploring potential impacts of groundfish fisheries in the decline of Stellar sea lions and provided management recommendations for the fisheries given the present status of declining pinniped populations.

An in depth review of assessment methods was initiated in response to industry and NPFMC concerns, regarding stock assessment methodologies and the adequacy of survey

and fishery data for conducting assessments. Several members of the Task participated in this assessment review.

RESOURCE ECOLOGY AND ECOSYSTEMS MODELING

This activity centers on the collection and analysis of data relating to trophic interactions in the North Pacific and incorporation of these data into single-species and multi-species assessments and models. Systematic collection of groundfish food habits data is utilized in conjunction with auxiliary information on marine mammal and bird diets, bioenergetics models of food intake, and predator population size to derive consumption rates of marine prey groups by predators. Data are incorporated into various models including integrated catch-at-age models (synthesis), equilibrium biomass models (ECOPATH), and multispecies virtual population analysis models (MSVPA). Indicators of ecosystem change are also developed using diversity indices, exploitation rates, environmental data, and size-at-age data. These assessments and models are used to provide advice on the relative contributions of various ecosystem components to predation removals of important species, the fate and importance of fishery discards on the ecosystem, the effect of predation in influencing recruitment into a fishery, changes in species composition and abundance, and other related questions.

Quantifying food web linkages in the marine ecosystem is important in order to properly assess groundfish population trends and abundance, particularly for groundfish species that are both a target for fisheries and a major food source for other predators. Understanding the effects of fishing on the ecosystem requires a multispecies perspective because of the food web linkages between exploited and non-exploited species. Advice on the effects of multispecies interactions, particularly those involving walleye pollock, is important because the pollock fishery is the largest in terms of volume in the United States.

Regular monthly observer training for collection of food habits information on key groundfish in the North Pacific was a continuing activity. In addition, Program personnel collected fish stomach samples during resource assessment surveys in the eastern Bering Sea/Aleutian Islands, Gulf of Alaska, and off the Washington-Oregon-California coast. The following numbers of fish stomachs were collected, scanned at sea, and analyzed in the laboratory in 1994 and 1995.

Year	Collected	Scanned	Analyzed
1994	15,992	664	17,952
1995	15,089	171	12,800

Research conducted in 1994-95 included:

Continuing research on groundfish food habits and trophic interactions: diet comparison of arrowtooth flounder and Pacific halibut in the Gulf of Alaska; Pacific whiting food habits and cannibalism; development of an identification guide to the polychaetes of the eastern Bering Sea; Atka mackerel diet description; and a canonical correspondence analysis of rock sole, yellowfin sole, and Alaska plaice diet and environmental factors in the eastern Bering Sea.

A comparative approach to learning about groundfish food webs was undertaken by the group. Groundfish food webs of the eastern Bering Sea, Gulf of Alaska, and Aleutian Islands regions were constructed and various aspects of the food webs were compared, particularly with respect to the role of pollock in each food web.

An analysis of the implications of the current groundfish fishery bycatch, utilization, and discard practices on the ecosystem was completed. Results highlighted the magnitude of offal (processed fish waste) relative to fishery discards.

Eastern Bering Sea ecosystem trends were examined by developing indicators of eastern Bering Sea ecosystem change using existing time series of data on pinnipeds, seabirds, groundfish, crabs, and other benthic infauna. This research was prompted by concerns over declines in marine mammal, bird, and red king crab populations. Change indicators were compared with fluctuations in fishing removals and the environment to determine the possible role each of the influences on the observed changes.

Modeling work continued on incorporating predators into single species population assessment models. Pacific halibut, arrowtooth flounder, and Steller sea lions were added as predators in a model of walleye pollock in the Gulf of Alaska. Other modeling efforts included: parameterizing an equilibrium energy flow model and a multispecies virtual population model (MSVPA) of the eastern Bering Sea, and parts of equilibrium energy flow models of the Alaskan gyre and West Vancouver Island continental shelf regions.

Group members participated in various workshops and served on committees to provide advice on research direction and planning, particularly for the eastern Bering Sea.

SOCIOECONOMIC ASSESSMENTS

The Socioeconomic Task provided economic information and assistance to the PFMC and NPFMC, industry, NMFS, and other agencies. This included preparing reports and publications, participating on council plan teams in preparing regulatory impact reviews of Bering Sea/Aleutian Islands, Gulf of Alaska, and Pacific Coast groundfish fishery management plan amendments, and preparing and reviewing research proposals and programs.

The regulatory issues that were analyzed included the following: 1) bycatch in the Alaska groundfish fisheries, 2) the allocation of West Coast and Alaska groundfish between at-sea and on-shore processors, 3) limited entry in the West Coast halibut and groundfish fisheries and the Alaska groundfish and crab fisheries, 4) community development quotas (CDQs) for the Bering/Aleutian Islands area groundfish and crab fisheries, 5) individual transferable quotas (ITQs) for the fixed gear halibut and sablefish fisheries off Alaska, 6) stackable vessel licenses and trip limits for the Pacific Coast fixed gear sablefish fishery, 7) user fees to pay for observers in the Alaska groundfish and crab fisheries, 8) increased retention and utilization in the Alaska groundfish fisheries, and 9) methods for improving NMFS estimates of total catch and bycatch by species for a fishery as a whole and for individual vessels.

Task members contributed to studies of: 1) the economics of bycatch, 2) the management of high seas fisheries, 3) the economic status of the Alaska groundfish fisheries, 4) the exports of edible fishery products from the Pacific Northwest and Alaska, 5) the CDQ and open access Bering Sea Aleutian Islands pollock fisheries, 6) the use of marketable permits for pollution, 7) ecological and economic valuation assessment techniques for resource management, 8) the economic aspects of the management of living marine resources, 9) methods to estimate harvesting and processing costs, 10) the demand for and control of access to fishery resources within exclusive economic zones (EEZs) worldwide, 11) international seafood markets, and 12) catch, bycatch, utilization, and discards in the Alaska groundfish fisheries.

TECHNICAL LIAISON

The staff of the REFM Division serve as scientific liaison and key technical advisors to the Pacific Salmon Commission, the North Pacific Anadromous Fish Commission, the International Pacific Halibut Commission, the North Pacific Fishery Management Council,

the Pacific Fishery Management Council, the U.S.-Russia Fishery Advisory Body, and the U.S.-China Protocol on Science and Technology.

AWARDS AND HONORS

Malin Babcock (ABL) was selected by the Alaska Chapter of American Women in Science to participate in the "Taking the Initiative: A Leadership Conference for Women" held in Washington, D.C.

Michael Dahlberg (ABL), Steve Ignell (ABL), Shannon Fitzgerald (REFM), Linda Jones (NMML), and James Coe (CD) were awarded Department of Commerce Silver Medals for their work on driftnet issues.

Michael Dahlberg (ABL) was elected to the Registry of Distinguished Graduates of Oregon State University's Department of Fisheries and Wildlife in recognition for his "long record of excellence in the natural resources field."

John Eiler (ABL) was elected to serve on the Executive Board of the International Society of Biotelemetry.

Jeffrey Fujioka (ABL) received a Certificate of Appreciation from the North Pacific Fisheries Management Council for his outstanding service as part of the Gulf of Alaska Groundfish Team.

Roger Gentry (NMML) received a Special Act Award from NMFS' Office of Protected Resources for "significant contributions to NOAA's marine biodiversity activities, particularly regarding the Convention of Biological Diversity", while he was on detail to that office.

Paula Johnson (ABL) was awarded a Department of Commerce Bronze Medal for her outstanding efforts in managing the ABL library and for public service, including organizing and managing ABL's annual Sea Week activities for the local schools and for her service as a community volunteer fire fighter.

Robert V. Miller (NMML) received a NOAA's Administrator's Award for his role in the development and administration of the Marine Mammal Project of the U.S.-Russia Environmental Protection Agreement, Area V.

Sherry Smrstik (NMML) received a Department of Commerce Bronze Medal for her extraordinary services to NOAA and the marine mammal community in guiding the development of the NMML Library.

Alex Wertheimer (ABL) received a Meritorious Service Award from the Alaska Chapter of the American Fisheries Society for "Recent Outstanding Contributions to Fisheries in Alaska."

Robert DeLong (NMML), Merrill Gosho (NMML), Harriet Huber (NMML), Sharon Melin (NMML), Patrick Gearin (NMML), Brad Hanson (NMML), Steven Osmek (NMML), and James Thomason (NMML) received group "Celebration of Public Service" recognition awards from the Seattle Federal Executive Board for their work over the past several years on the problem of California sea lion predation on reduced stocks of steelhead trout and Pacific salmon at the Hiram M. Chittenden Locks in Seattle.

Kathryn Chumbley (NMML), Richard Ferrero (NMML), Richard Merrick (NMML), Rolf Ream (NMML), John Sease (NMML), Michael Strick (NMML), Rod Towell (NMML), and Anne York (NMML) received group "Celebration of Public Service" recognition awards from the Seattle Federal Executive Board for their work on studying the population decline of Steller sea lions.

ADVANCED DEGREES

Jeffrey Breiwick (NMML) received a Ph.D. in Fisheries from the University of Washington. His dissertation was titled "Population Dynamics and Analyses of the Fisheries for Fin Whales (*Balaenoptera physalus*) in the Northwest Atlantic Ocean".

Peter Boveng (NMML) received a Ph.D. in Biological Science from Montana State University. His dissertation was titled "Variability in a Crabeater Seal Population and the Marine Ecosystem near the Antarctic Peninsula".

Harriet Huber (NMML) received a Masters Degree in Fisheries from the University of Washington. Her thesis was titled "The Abundance of Harbor Seals (*Phoca vitulina richardsi*) in Washington, 1991-1993".

Michael Martin (RACE) received a Masters Degree in Zoology from the University of Rhode Island. His thesis was titled "Validation of Daily Growth Increments and Factors Affecting the Freshwater Entry of the American Eel (*Anguilla rostrata lesueur*) in a Coastal Rhode Island Stream ."

Sharon Melin (NMML) received a Masters Degree in Wildlife and Forestry from the University of Washington. Her thesis was titled "Winter and Spring Attendance Patterns of California sea lion (*Zalophus californianus*) Females and Pups at San Miguel Island, California, 1991-1994".

Richard Merrick (NMML) received a Ph.D. in Fisheries from the University of Washington. His dissertation was titled "The Relationship of the Foraging Ecology of Steller sea lions (*Eumetopias jubatus*) to Their Population Decline in Alaska".

James Murphy (ABL) received a Masters Degree in Fisheries from the University of Alaska Fairbanks. His thesis was titled "Spatial Patterns of Salmon Bycatch in the Driftnet Fishery for Neon Flying Squid, *Ommastrephes bartrami*."

James Orr (RACE) received a Ph.D. in Fisheries from the University of Washington. His dissertation was titled "Phylogenetic Relationships of Gasterosteiform Fishes (Teleostei: Acanthomorpha)."

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