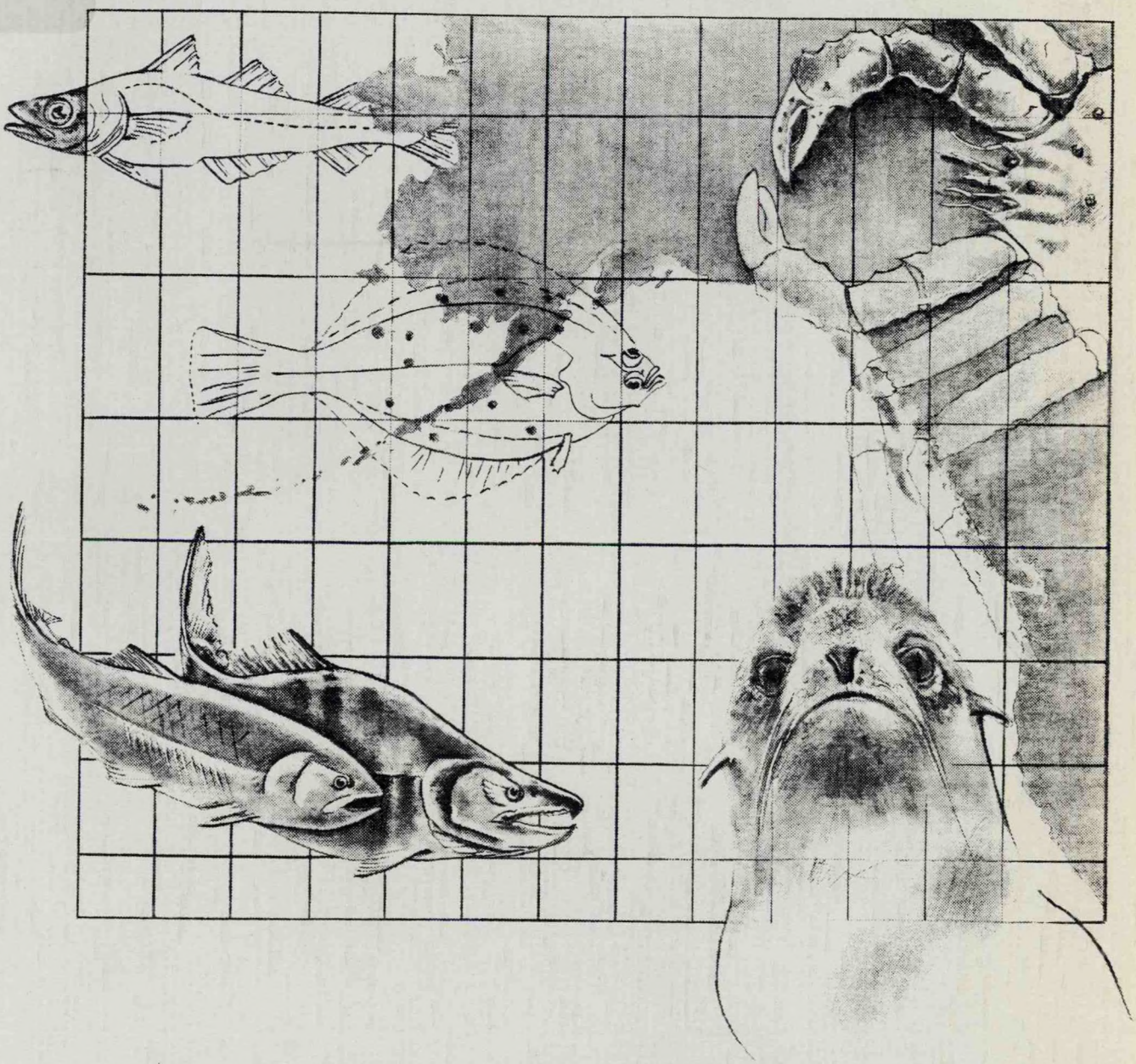
Northwest and
Alaska Fisheries
Center

National Marine
Fisheries Service

U.S. DEPARTMENT OF COMMERCE

Annual Report for Calendar Year 1989



Northwest and Alaska Fisheries Science Centers

Seattle, Washington

ANNUAL REPORT

CALENDAR YEAR 1989

Compiled by

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CONTENTS

INTRODUCTION

The Northwest and Alaska Fisheries Science Centers are the research branches of NOAA's National Marine Fisheries Service in the Pacific Northwest and Alaska. The Centers provide scientific information required for decisions relating to conservation, management, and development of fishery resources, protection of habitats, marine mammals, and endangered species.

The scope of research responsibilities of the two Centers extends from rivers and coastal waters of California, Oregon, Washington, and Alaska to the western Pacific Ocean, an expanse of more than 2,900,000 square miles. Passage of the Magnuson Fishery Conservation and Management Act and establishment of the 200-mile fishery conservation zone in 1976 (changed to Exclusive Economic Zone (EEZ) by Presidential Proclamation in 1983) gave new impetus to the Centers to conduct research in support of conservation and management of fishery resources of this region. Scientists at the Centers study the life history of this region's aquatic species and examine ways to enhance their production and utilization. They estimate the size and value of commercial fishery resources, monitor foreign fishing operations, provide information on protected species, and study the physical properties of freshwater, estuarine, and marine environments and the effects of physical alteration and chemical contaminants on aquatic biology. Scientists also interact with their counterparts in Canada, Japan, the U.S.S.R., Republic of Korea, Taiwan, and other nations to jointly preserve and conserve the area's resources. This annual report describes some of the major research activities of the Northwest and Alaska Fisheries Science Centers.

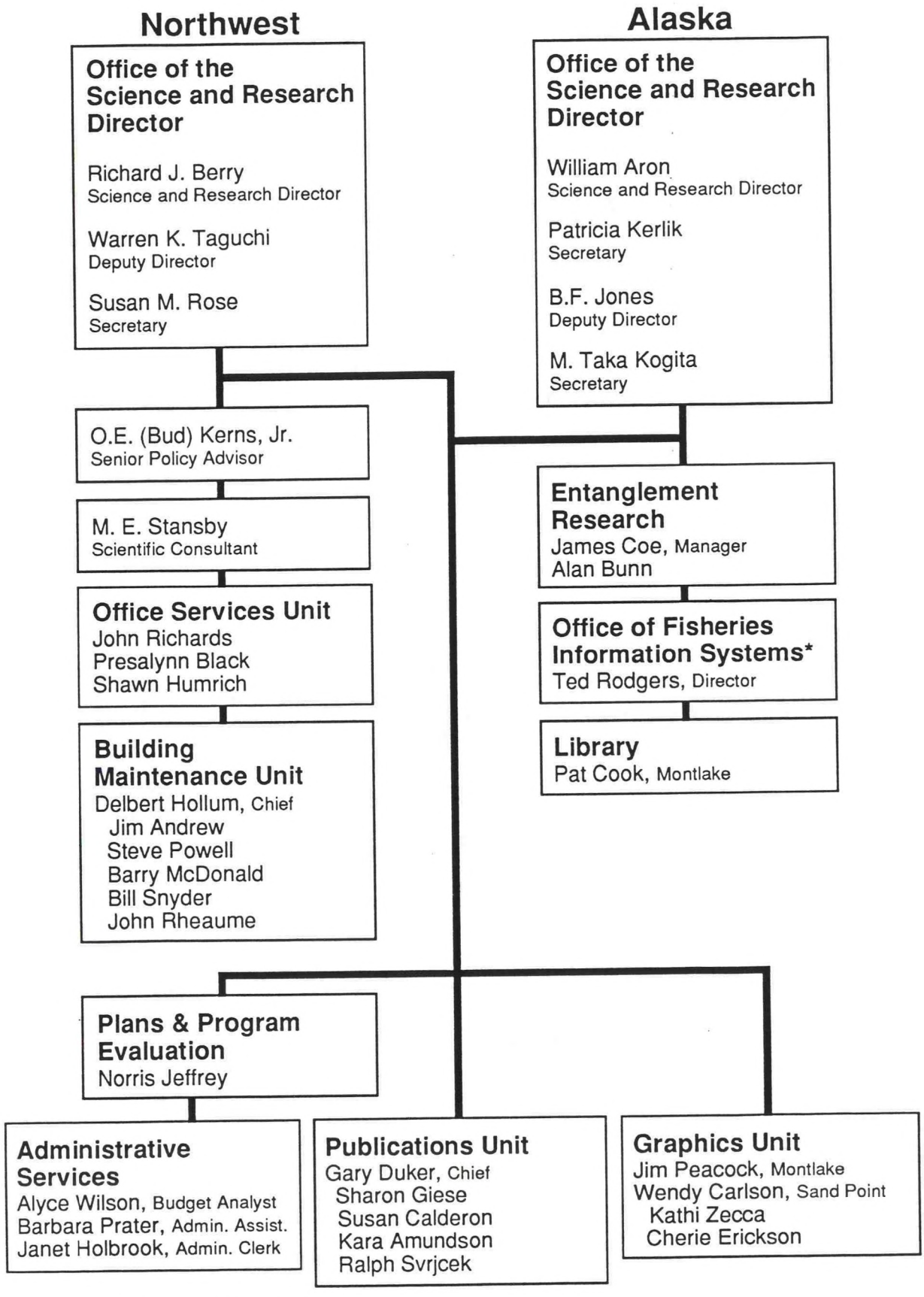
Table 1 gives names of permanent employees of the Centers who left during 1989 as a result of retirement.

Table 1.--Full-time permanent individuals who retired from the Northwest and Alaska Fisheries Science Centers during calendar year 1989.

Name	Division/ Laboratory	Termination date	Length of service Years	Months
Miles S. Alton	RACE	03/24	31	04
Michael S. Bohle	RACE	12/15	16	04
W. Jean DeGooyer	OFIS	09/30	13	08
Leola K. Hietala	NMML	05/31	12	08
Richard L. Major	REFM	01/03	34	03
Robert J. McConnell	CZES	12/29	32	06
Lael L. Ronholt	RACE	09/30	32	04
Herbert H. Shippen	RACE	03/31	37	00
Emil Slatick	CZES	05/02	32	00
Fuad M. Teeny	UR	06/02	23	07

CZES = Coastal Zone and Estuarine Studies Division.
NMML = National Marine Mammal Laboratory.
OFIS = Office of Fisheries Information Systems.
RACE = Resource Assessment and Conservation Engineering Division.
REFM = Resource Ecology and Fisheries Management Division.
UR = Utilization Research Division.

Offices of the Science and Research Directors
1989



*See separate chart for OFIS, page 40.

NORTHWEST FISHERIES SCIENCE CENTER

The Northwest Fisheries Science Center's programs are carried out at the Montlake Laboratory in Seattle and at biological field stations in Cook, Manchester, Mukilteo, and Pasco, Washington; Point Adams and Bonneville, Oregon; and Kodiak, Alaska. Various NOAA research vessels are used for coastwide sea sampling, while more localized studies employ the Center's *Harold W. Streeter, Sea Otter,* or smaller boats.

The Montlake Laboratory, located on the shore of Lake Union and adjacent to the University of Washington campus, has been a focal point for fisheries research for over 55 years. It features modern chemistry, physiology, microbiology, and genetics laboratories as well as extensive equipment for testing innovative fish processing technology. The Laboratory also has new hatchery facilities capable of holding 300,000 salmonid smolts and supports small on-site runs of salmon and steelhead.

The Center's Manchester Marine Experimental Station on Puget Sound has seawater laboratories and an extensive net-pen system for rearing salmonids from smolts to adults. The Mukilteo field station, also on Puget Sound, features holding tanks and bioassay facilities for assessing the effects of contaminants on marine organisms. Studies conducted from the Cook, Pasco, and Bonneville stations are directed toward enhancing the survival of salmon migrating past dams in the Columbia River system and improving the quality of smolts released from hatcheries. The Point Adams site houses the research base for environmental studies in the Columbia River estuary. And, in Alaska, the Kodiak station supports research to assist the fishing industry in more fully and economically utilizing their harvests.

Unexpected events placed many Northwest Center researchers in the spotlight during 1989 and added significantly to workloads and pressures. In chronological order, these were 1) the zero tolerance for *Listeria* in fishery products announced by the Food and Drug Administration; 2) the *Exxon Valdez* oil spill; and 3) a number of investigative efforts related to the continent of origin of salmon harvested illegally on the high seas. Rapid and credible responses to these events contributed to recognition of the newly formed Center and to the longstanding record of unique expertise of its scientists. Steady progress was made in numerous long-term efforts to understand and mitigate the effects of major federal projects on the Columbia River and its tributaries, to survey and evaluate the influence of marine pollution on species of importance, and to enhance the value of fishery products. Some of the Center's more notable achievements are described in the pages to follow.

COASTAL ZONE AND ESTUARINE STUDIES (CZES) DIVISION

The CZES Division has field facilities at Bonneville, Cook, Manchester, and Pasco, Washington, and at Hammond, Oregon. Research activities are divided into three Tasks: Fisheries Enhancement, Ecological Effects of Dams, and Habitat Investigations.

Fisheries Enhancement

The goals of the Fisheries Enhancement Task are to develop and test methods for restoring and enhancing depressed Pacific salmon (*Oncorhynchus* spp.) and steelhead (*O. mykiss*) runs. The research programs are aimed at developing new information to enhance anadromous salmonid runs by 1) improving the operational efficiency and contribution of federally funded hatcheries; 2) developing biochemical genetic methods for identifying salmon stocks in the international mixed-stock fisheries off Oregon, Washington, Canada, and Alaska; and 3) developing marine husbandry techniques for maintaining captive brood stocks of severely depleted wild runs.

Chinook Salmon Brood-stock Program

Under the Endangered Species Act, it is the National Marine Fisheries Service's (NMFS) responsibility to develop and implement recovery programs for threatened or endangered stocks of anadromous salmonids. CZES has an ongoing program that serves as a model for maintaining seriously depleted or threatened stocks of salmonids in captivity.

During 1989, about 1,200 spring chinook salmon from the White River (Washington) were maintained at the Manchester Marine Experimental Station as part of a cooperative program with the Washington Department of Fisheries (WDF). These fish are the last remaining group of spring chinook salmon native to Puget Sound; since the early 1980s, the NMFS program has provided 30 to 50% of the eggs available for the enhancement of this stock.

In 1989, husbandry studies of depleted stocks continued to focus on diagnosis, treatment, and prevention of infectious and nutritional diseases in marine cultured salmon. During the brood-stock program, allozyme data are collected to monitor the genetic integrity and variability of the stock.

Smolt Quality Assessment

Returns of adult spring-run chinook salmon (*O. tshawytscha*) to the Columbia River Basin have remained low despite efforts to increase the survival of outmigrating smolts (guidance around dams, transportation, specific allocations of river flow, and disease prophylaxis). In the search for solutions to the problem of low survival, scientists from CZES have teamed with scientists from other state and federal agencies to assess the quality of spring chinook salmon smolts being released from several hatcheries in the basin. Objectives of the study are to determine the distribution of a number of measured physiological indices in juvenile salmonids at the selected hatcheries and also to determine if any or all of these indices are correlated to survival of the fish to adulthood. Sampling of production fish at the hatcheries began in the spring of 1989 and will continue in 1990. Analysis of the 1989 data show that the smolt indices vary at different hatcheries. These data will be tested for correlation to total contribution when fishery and adult return data become available for the years 1990 to 1992.

PIT-Tagging System

Efforts during 1989 focused on the development and evaluation of an automated system to collect and divert passive integrated transponder (PIT)-tagged fish at Lower Granite Dam. The PIT-tag diversion system designed in 1988 proved to be functional, but refinements to the system were needed for increased efficiency. Refinements to the system will be made in 1990 and the system reevaluated.

Additional effort was spent developing adult salmon PIT-tag monitoring systems. Portable pass-through and V-lead adult PIT-tag monitor systems were successfully developed and evaluated at the WDF's Skagit River Fish Hatchery near Marblemount, Washington. The pass-through monitor can be used during hatchery spawning operations to confirm the presence or absence of PIT-tagged fish. The V-lead monitor can be used wherever a weir is used in a hatchery or stream system. Developmental work on extending the reading range of PIT-tag monitors continued with very promising results. This effort will continue in 1990.

Studies to determine the effects of the PIT-tag monitoring system on volitional movement of juvenile and adult fish through PIT-tag monitors were conducted in 1989. Results indicated the electronic field had no negative effect on fish behavior. For best fish passage, the monitor's orifice must have light, and orifice geometry and size were important in the passage of fish through the system. Additional behavioral studies with both juvenile and adult fish are planned in 1990.

Yakima River Basin Sockeye Salmon Restoration Program

CZES is a partner with Bonneville Power Administration (BPA) in a study of the potential for restoring sockeye salmon (*O. nerka*) to Cle Elum Lake in the Yakima River Basin of eastern Washington. The program involves the use of Lake Wenatchee (Washington) stock adult sockeye salmon held in net-pens as egg donors to provide juveniles for transplanting into the Yakima River Basin. The project reached a significant milestone in 1989 with the first introduction of anadromous sockeye salmon to the Yakima River Basin in over 60 years. A total of about 105,000 juvenile sockeye salmon from the 1987 spawnings were released into Cle Elum Lake and the Yakima River to assess lake survival and downstream passage. Our initial results show that fish will exit the lake and survive downstream passage to the Columbia River. However, the spillway structure at Cle Elum Dam does not appear to be very efficient at attracting and passing outmigrating juveniles and may require modification. The immediate goal of the project is to determine if sockeye salmon can successfully migrate from Cle Elum Lake under the irrigation discharge conditions that now exist.

Almost 100,000 juveniles from the 1988 spawnings are being reared at the Montlake Laboratory. In 1990, these juveniles will be used in investigations of juvenile passage at Cle Elum Dam. We also have over 125,000 IHN-free fry from the 1989 spawnings in culture at the Montlake Laboratory.

Seawater Holding and Disease Analysis of Mid-Columbia River Spring Chinook Salmon

During summer 1989, CZES continued a cooperative study with Grant and Douglas County Public Utility Districts to determine growth and survival of subyearling (zero-age) spring chinook salmon smolts following seawater entry. Three groups of accelerated subyearling and one group of yearling spring chinook salmon smolts from the Leavenworth National Fish Hatchery near Leavenworth, Washington, were transferred to seawater net-pens at the Manchester Marine Experimental Station. Growth and survival were documented for approximately 120 days of seawater culture. Growth was acceptable in all treatments, and there was no immediate mortality that could be attributed to osmoregulatory dysfunction. Approximately half of the mortalities that occurred in all groups during the study were infected with *Renibacterium salmoninarum* the causative agent of Bacterial Kidney Disease (BKD) in salmonids. However, after 95 days of seawater culture, mortality due to a bloating condition was observed in one-third of the subyearling fish. This condition did not occur in the yearling smolts and was noninfectious in nature. Mortality associated with bloating has been observed in other seawater cultured chinook salmon at the Manchester facility in past years and is

believed to be a delayed osmoregulatory phenomenon (i.e., fish were not in the optimum physiological condition when transferred to seawater).

Grays Harbor Coho Salmon Survival Study

Returns of adult coho salmon (*O. kisutch)* to the Chehalis River in southwest Washington are historically much poorer than returns to the nearby Humptulips River. This difference in survival prompted CZES and other federal and state biologists to investigate the status of health and smoltification of wild and hatchery coho salmon produced in each river system. In 1989, coho salmon smolts from the Humptulips Hatchery were placed in live boxes located throughout the lower Chehalis River and estuarine areas of Grays Harbor and then transferred to net-pens in seawater at the NMFS Manchester Marine Experimental Station. Mortality after introduction to seawater was found to correlate with the degree of infestation with metacercaria of the digenetic trematode, *Nanophyetus salmincola,* in the coho salmon smolts. Further studies will attempt to determine the relationship between duration of transit through the estuary and parasite burden in coho salmon smolts.

Genetic Stock Identification of Pacific Salmon (U.S.-Canada Salmon Treaty)

Much of the genetic research in CZES is based on the technique of protein gel electrophoresis to detect genetically-based protein variation. Stocks of salmon differ in the frequencies of protein variants. The primary goal is to describe the amount and pattern of protein differentiation among stocks in a baseline dataset and apply the information to problems of stock mixtures in fisheries. This technique is being used on a coastwide basis to monitor specific chinook salmon stocks in fisheries of interest to U.S.-Canada Treaty managers.

In 1989, several activities took place in this area of study. The genetic baseline for chinook salmon was expanded in British Columbia. A mixed-stock fishery analysis was completed for a southwestern Alaska chinook salmon fishery. Work was initiated to develop a genetic stock identification (GSI) baseline for southern coho salmon stocks with emphasis on separation of U.S. Puget Sound stocks from Canadian stocks in the Straits of Georgia that are caught in a controversial boundary fishery.

Genetic Monitoring of Chinook Salmon and Steelhead in the Columbia River Basin

In September 1989, the Task began a BPA-funded program to monitor the genetic consequences of supplementing naturally-spawning populations of chinook salmon and steelhead with hatchery-reared fish. The study encompasses eight hatchery supplementation programs (four for each species) in the Snake River drainage and is being

coordinated with state agencies in Washington, Idaho, and Oregon. Yearly samples are being collected from the hatchery stocks used for outplanting, from naturally-spawning populations that are being supplemented, and from wild populations in the same drainage that are not intended to be affected by hatchery releases. Changes in genetic and meristic traits in the populations will be monitored over time, and results will help to evaluate the success of efforts to produce sustainable increases in productivity in supplemented populations.

Identification of Continent of Origin of Salmonids Captured in High Seas Drift Net Fisheries

The growing awareness that large numbers of Pacific salmon are illegally taken in high-seas fisheries has raised concerns that North American stocks are being adversely affected. The ability to identify the continent-of-origin of salmon captured on the high seas is necessary for effective enforcement and prosecution. CZES developed a research project in the Genetics Program in 1989 to address this problem. Project goals are to expand the allozyme data set for chum (*O. keta*) and chinook salmon across the Pacific Rim by collecting Asian stocks and develop and evaluate new DNA-based genetic markers for salmon for forensic use on a case by case basis. A cooperative research program was established with the Japan Fisheries Agency. Ten stocks of chum salmon in Japan are to be sampled and sent to NWFC for allozyme analysis; and a Japanese scientist is scheduled to study allozyme research at the Center for a 6-month period. A research molecular population geneticist was hired, and the process of adapting a laboratory for mitochondrial DNA work to nuclear DNA research was begun.

Ecological Effects Of Dams

The Ecological Effects of Dams Task conducts applied research relating to migrations of anadromous salmonids in the Columbia River Basin. Studies are conducted on the effects of dams on river environment and passage and survival of fish. Emphasis is placed on development and evaluation of systems to enhance safe juvenile and adult passage.

Research is conducted at hydroelectric projects on the Snake and Columbia Rivers. Nearly all studies are cooperative efforts involving the U.S. Army Corps of Engineers (COE), BPA, or public utilities of the Columbia River Basin.

Fish Guidance Efficiency Studies at Bonneville Dam

To protect juvenile salmonids migrating downstream past hydroelectric dams, the fish are diverted from turbine intakes and into specially constructed bypass channels. Overall fish survival relates directly to the number of juveniles guided around turbines. Fish guidance efficiency (FGE) tests were continued during spring and summer 1989 in cooperation with the COE. Spring and summer studies at the second powerhouse tested modified bar screens and various light illumination patterns to enhance guidance of downstream-migrating yearling chinook salmon. Summer studies at the first powerhouse determined the baseline guidance level prior to construction of the new Bonneville Navigation Lock.

At the second powerhouse, results indicated that modified bar screens and different lighting arrangements did not significantly improve fish guidance compared with conventional submerged traveling screens (STS). Based upon previous work, recommendations were made for the permanent installation of lowered traveling screens, streamlined trashracks, and turbine intake extensions to improve fish guidance at the second powerhouse.

At the first powerhouse, less than 5% of the subyearling chinook salmon were guided by submerged traveling screens during the summer months. Additional research is needed to develop means to improve this low guidance.

Fish Guidance Efficiency Studies at Lower Granite Dam

Standard length STSs at Lower Granite Dam guide approximately 55% of the yearling chinook salmon smolts passing the project. Extended length screens that are twice as long as STSs now installed were tested to determine their ability to improve fish guidance at the project.

The extended screens improved guidance between 10 and 15%; however, there was also increased impingement of migrants on the lower area of the screens. Additional work is necessary to determine causes for the increased impingement and a means to alleviate it.

Fingerling Bypass System Efficiency at Hydroelectric Dams: The Influence of Smolt Physiological Development

At Lower Granite Dam, intraseasonal changes in the percentage of fish guided were observed for yearling chinook salmon. The changes could not be attributed to physical or environmental conditions at the dam. We hypothesized that the changes in

guidance efficiency may be associated with the changing physiological status of the migrant population over the course of the outmigration. As juvenile salmonids metamorphose from parr to smolts, they undergo changes in behavioral and morphological characteristics which are associated with their physiological development. The purpose of our investigation was to determine if the developmental status of the yearling chinook salmon population changed during the course of the outmigration and whether guidance was related to such changes.

Using the enzyme Na^+-K^+ ATPase as an index of smolt development, we examined the relationship between guidance and the physiological status of the migrant population. As parr transform into smolts, levels of this enzyme increase. In 1987 and 1989, assays of gill Na^+-K^+ ATPase were performed on yearling chinook salmon collected during guidance efficiency tests at Lower Granite Dam. Results demonstrated that the physiological status (smoltification) of the population changed through time, generally becoming more advanced over the course of the outmigration.

Guidance was higher when yearling chinook salmon passing the dam were more smolted. This relationship was statistically significant (ANOVA, $F_{1,14} = 20.38$, $P = 0.0005$). We concluded that as yearling chinook salmon transform from parr to smolts, they are more readily guided by the screens. Furthermore, intraseasonal changes in screen guidance efficiency can be strongly influenced by the physiological status of the migrant population.

Advanced Photoperiod Treatment for Increasing Smoltification

At hatcheries, juvenile salmon that smolt earlier can take advantage of spring freshets to speed their travel time to downstream collection points at dams and to the ocean. During winter 1989, experimental groups of yearling spring chinook salmon were exposed to different photoperiod cycles and rearing temperatures at Dworshak National Fish Hatchery. Smolt development was evaluated using gill Na^+ -K^+ ATPase. Members from each group were tagged with PIT tags to provide detailed information regarding migratory behavior. Results demonstrated that the treatment groups exhibiting the highest Na^+-K^+ ATPase levels at the time of release migrated faster and were recovered in higher proportions at sampling sites downstream. The least smolted groups were the slowest and were recovered in the lowest proportions. These results indicated that hatchery release strategies should consider the physiological development of the population. This research will continue in 1990 and include an additional hatchery site as well as an evaluation based on adult contributions.

Collection Efficiency Studies at McNary Dam

Collection efficiency at a dam is measured by the number of smolts in the collection system versus those passing the dam through all alternate routes. This observation is vital if fishery managers are to determine populations of smolts arriving at specific dams, such as McNary.

Efforts continued to evaluate collection efficiency for populations of spring chinook and sockeye salmon and steelhead at McNary Dam. Preliminary data indicate McNary Dam collection rates varied considerably due to handling techniques at the dam. The data are being analysed to determine if variability in collection rates can be decreased sufficiently to use mark-recapture techniques at the dam to measure differences in survival.

Yakima River Radio Telemetry Studies

A 4-year telemetry study, initiated in 1989, will help decide the number of unique stocks that exist in the Yakima River system, establish spawning dates and locations, and determine the relative proportion of each stock. Equipment was purchased and steelhead were radio tagged in 1989 to develop research procedures and data handling techniques. Beginning in 1991, spring chinook salmon will be added to the study.

Smolt Transportation Studies at Lower Granite and McNary Dams

Transportation by truck and barge around dams currently protects juvenile salmonids migrating down the Columbia and Snake Rivers. Recent modifications of fish collection systems at Lower Granite and McNary Dams require ongoing evaluation to determine their effects. At Lower Granite Dam, smolts were marked with coded wire tags and released into the river (control) or transported by barge (test) to safe release sites below Bonneville Dam. Marking for the study at McNary Dam was completed the previous year. Recovery of marked adults is ongoing, and results to date indicate more returns from transported juveniles than returns from the nontransported counterparts for all species tested.

In the second year of a study, juvenile spring and summer chinook salmon in wild and natural production areas of Idaho and Oregon were marked with PIT tags. Recoveries of these fish the following spring at Lower Granite Dam will determine if transportation of wild fish can be evaluated using the tag. Additionally, a new system designed to automatically divert PIT tags back to the river at Lower Granite Dam was evaluated. The system showed great promise and may be used to provide in-river marked fish for a new transportation study as well as other future studies.

Habitat Investigations Task

The Habitat Investigations Task conducts research and develops environmental information to support the conservation and enhancement of fishery resources and their habitats in the lower Columbia River and its estuary and the nearshore coastal zones of Washington and Oregon. The research program in 1989 included several studies focusing on the impacts of dredging and dredge-material disposal on the fish and invertebrate communities in selected estuarine and nearshore areas and on impacts of lower Columbia River hydroelectric development on physical, chemical, and biological processes in the estuary. Also ongoing were studies on abundance, distribution, and early life histories of selected estuarine or estuarine-dependent species of commercial, recreational, or ecological importance.

Dredging and Dredged-Material Disposal

Disposal of large volumes of sediments generated annually by maintenance dredging of the navigation channel in the Columbia River estuary has filled most existing upland disposal sites. New disposal sites and strategies are critically needed. Accordingly, staff of this Task are working with the Portland District, COE under their Long-Term Management Strategy (LTMS) Program to assess the suitability of several new areas in the Columbia River estuary as potential repositories for dredged material. Areas studied in 1989 included intertidal and subtidal areas adjacent to man-made islands, some of which were created over 50 years ago with dredged materials. Preliminary results of our surveys indicate island-associated, shallow-water areas are important habitats for several fish species, including juvenile salmonids. Several of these areas also support high densities of benthic invertebrates, including several species important in the diets of commercially and recreationally important fishes. These results suggest there can be benefits associated with island construction as a strategy for dredged-material disposal.

Other dredge-related studies undertaken in 1989 included biological assessments in Coos Bay and the initiation of environmental monitoring at Ocean Disposal Site F located off the mouth of the Columbia River. The preliminary survey conducted in Coos Bay revealed a diverse and abundant benthic fauna at several locations in the navigation channel. Based on these findings, a recommendation for more comprehensive sampling and analysis was made before the proposed deepening of the channel is further considered. At Area F, staff from the Point Adams Biological Field Station are monitoring the impacts of disposal of sediments dredged from the area between the piers at the deactivated Navy Base at Tongue Point on the Columbia River estuary. The monitoring includes collections of sediments for the analysis of benthic community structure, determinations of selected physical properties, and analysis for a broad

spectrum of organic chemical contaminants. Trawl surveys are being conducted to characterize the demersal fish assemblages of the area. We anticipate this monitoring will continue for 3 to 5 years.

Surveys to develop a long-term data set on the abundance, size-class structure, and distribution of Dungeness crab (*Cancer magister)* at and adjacent to frequently dredged areas in the Columbia River estuary continued in 1989. The Columbia River estuary is an important nursery area for this species, and these data are critical in developing NMFS's recommendations to the COE for scheduling dredging and other in-water work to minimize adverse impacts to crab populations.

National Estuarine Inventory

The National Estuarine Inventory Project is a NOAA program designed to bring together, in altas form, comprehensive data on living aquatic resources in selected U.S. estuaries. Task scientists at the Pt. Adams Station are working with personnel from the National Ocean Service's Ocean Assessments Division to compile high quality data on the abundances, distributions, and life histories of over 47 species in 32 west coast estuaries. During 1989, a preliminary data report was published and work started on a comprehensive report summarizing data on life histories of over 40 key species.

Columbia River White Sturgeon

Recent restrictions on salmon fishing due to declining runs in the Pacific Northwest have catalyzed considerable new interest in sport fishing for white sturgeon *(Acipenser transmontanus)*. In 1988 alone, over 43,000 sturgeon were caught by recreational anglers in the Columbia River below Bonneville Dam. Concomittant with this increased fishing pressure is a need for better data on population biology and early life history of this species. NMFS scientists are responding to this need as participants in a BPA-funded, multiagency research project focusing on abundance, spawning, early life history, and habitat requirements of white sturgeon.

During 1989, over 2,000 eggs and 2,500 juvenile sturgeon were collected by NMFS as part of the lower Columbia River-phase of this study. New information was generated on riverine physical parameters required for successful spawning and early rearing of this species, and stomach contents analysis yielded new information on the importance of selected invertebrate species as prey. Studies were also initiated on the distributions of benthic invertebrates in the lower Columbia River and estuary that are important components of white sturgeon diet. These data are contributing significantly to a better understanding of the biology of this species in the Columbia River and will, in turn, contribute to more informed management strategies.

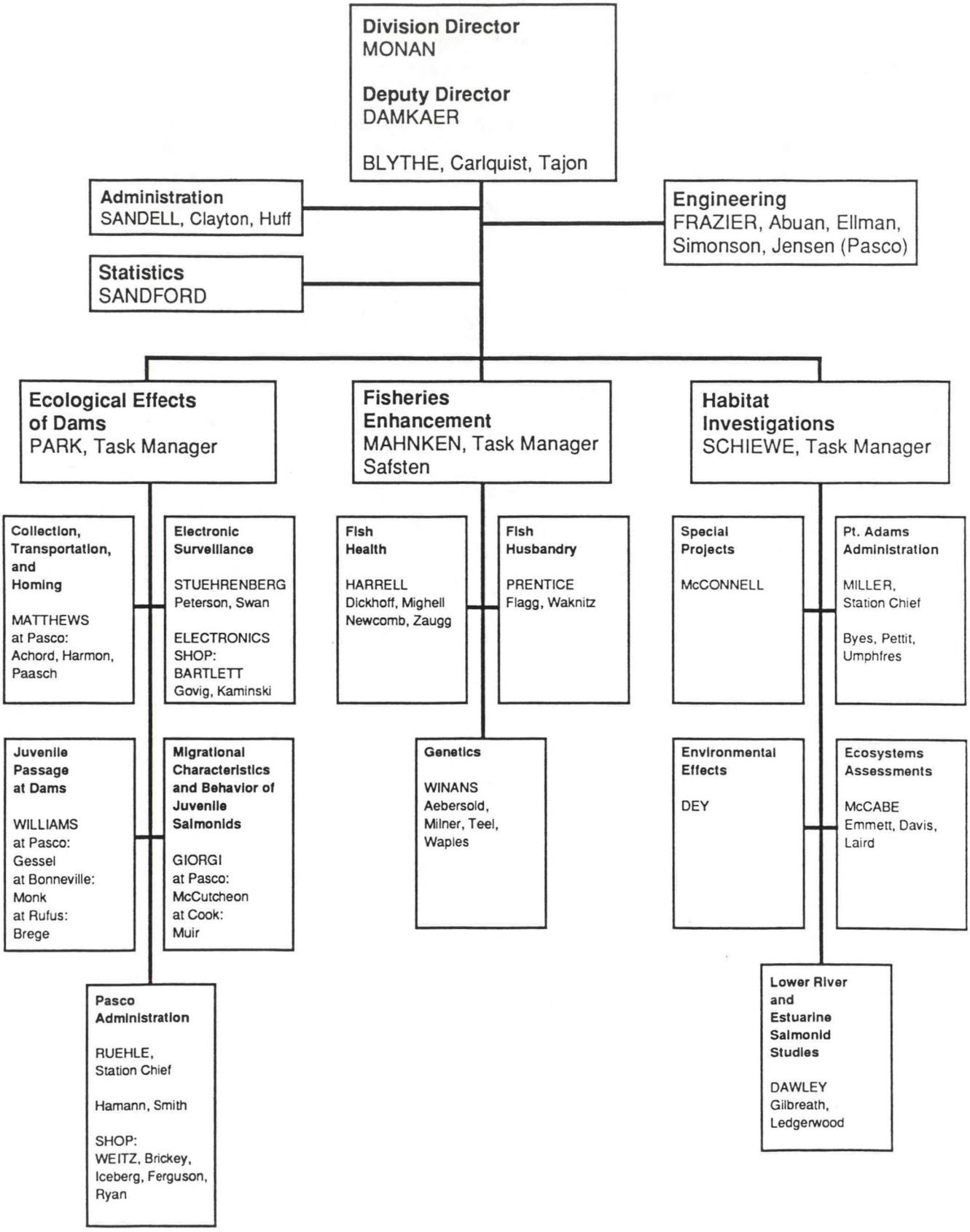
Juvenile Salmon Survival Studies

The third year of a 7-year study to evaluate relative survival of subyearling fall chinook salmon after passage through the Second Powerhouse turbines, bypass system, or spillway of Bonneville Dam was completed in 1989. Over 2.2 million juvenile chinook salmon were marked with coded-wire tags and cold brands and released at selected locations above and below Bonneville Dam. As an initial means of assessing relative survival, fish were recovered by purse and beach seine 157 km downstream at the head of the Columbia River estuary. However, the ultimate measure of survival will be based on long-term survival as determined by adult returns.

The 1989 field season marked the completion of the juvenile-release phase of this study, and data from all 3 years of estuarine recoveries have been analyzed. Not surprisingly, the highest relative survival was observed among fish passing the dam via the spillway; however, the lowest relative survival was observed among fish using the bypass system. The latter finding was completely unexpected, as bypass systems were designed and installed at dams as a safe alternative to turbine passage. Other studies have shown turbines cause about 10 to 15% mortality. As a result, additional studies are being planned for 1990 to further define and resolve this apparent bypass-related problem.

Coastal Zone and Estuarine Studies Division

1989



ENVIRONMENTAL CONSERVATION (EC) DIVISION

During 1989, the EC Division maintained a strong research commitment to enhance its ability to assess the nature, fates, and effects of environmental contaminants. Several types of field investigations were conducted to evaluate various types of pollution and their effects on marine species and their habitats. Highlights of this research included studies conducted in response to the *Exxon Valdez* oil spill in Alaska; continued field surveys on the west, northeast, southeast, and gulf coasts to assess the extent of chemical contamination of sediments and marine fish and associated effects on these fish; and multidisciplinary studies to evaluate reproductive impairment of winter flounder *(Pseudopleuronectes americanus)* and English sole (*Parophrys vetulus*) exposed to pollution in Boston Harbor and in Puget Sound. Other major research projects included the validation of recently developed sediment bioassays which measure sublethal effects, the improvement of analytical methods to reduce assay costs and improve accuracy, the development of new analytical methods for measuring chemical compounds, such as coprostanol and chlorinated chemicals found in pulp mill effluents, and the testing of biomarkers of contaminant exposure and early effects for use in NOAA's Status and Trends Program (NSTP) monitoring studies.

Prince William Sound Oil Spill Response

Because of their expertise in marine pollution, EC Division scientists were requested to oversee and participate in several *Exxon Valdez* oil spill-related cooperative projects with other state and federal agencies, as well as with other NOAA components. The Division completed a number of studies to determine impacts of the oil spill on important marine resources in Alaska.

Halibut Fishery

In cooperation with the International Pacific Halibut Commission and the Utilization Research Division (URD) of the NWFC, the Division conducted a survey of portions of Prince William Sound, lower Cook Inlet, and the central Gulf of Alaska to determine if Pacific halibut (*Hippoglossus stenolepis*) were appreciably exposed to oil. Samples were collected from approximately 400 halibut and the presence of hydrocarbons in edible tissues was assessed by sensory tests and by other sensitive analytical methods. Exposure to oil was assessed by analyses for metabolites of aromatic hydrocarbons in bile. Earlier laboratory research conducted by Division scientists had demonstrated by the use of radiolabeled hydrocarbons that fish metabolize aromatic compounds in the liver and concentrate them in the gall bladder. This process in fish results in minimal accumulation of hydrocarbons in edible flesh. A report indicating

that no measurable exposure had occurred was promptly completed, reviewed, and distributed to: the International Pacific Halibut Commission, the U.S. Food and Drug Administration (FDA), the Alaska Department of Environmental Conservation (ADEC), and others.

Commercial Salmon and Crabs

In response to a request from the ADEC, the Division also analyzed samples from several species of Pacific salmon (e.g., pink, *Oncorhynchus gorbuscha*, and sockeye, *O. nerka*) commercially landed near Kodiak Island, Cook Inlet, Cordova, Valdez, and Bristol Bay (reference area), to test for oil contamination. Several Dungeness crabs from the Kodiak Island area were also analyzed in the same manner. Little evidence of oil contamination of edible flesh was found. Results of these chemical analyses of salmon were provided to ADEC, FDA, and NMFS to aid in making timely management decisions regarding the continuance of commercial harvesting.

Subsistence Fisheries

Because of urgent concerns among native Alaskans that their subsistence seafood could be contaminated by petroleum hydrocarbons, NOAA entered into an agreement with Exxon to analyze subsistence marine resources collected from sites near native Alaskan villages in Prince William Sound, Lower Cook Inlet, and around Kodiak Island. The results of analyses conducted by the Division showed few indications that the edible flesh of fish was contaminated by aromatic hydrocarbons; however, clear evidence of oil exposure was obtained for the edible flesh of molluscs from several sites. Molluscs lack the ability to convert or metabolize hydrocarbons; hence they tend to accumulate hydrocarbons. Analyses of fish bile samples, using a method developed by Division scientists, indicated that some fish from sites near the villages were exposed to oil, but because of the active metabolism of aromatic-compounds by fish, little or no hydrocarbons accumulated in edible flesh. Thus, testing of several hundred samples from oil-spill impacted areas showing no flesh contamination in fish and high levels in molluscs validated earlier laboratory findings. A report of the 1989 results was completed and delivered to ADEC, Alaska State Department of Health, FDA, and to the Expert Toxicology Committee which concluded that the low levels of hydrocarbons found in fish flesh should pose negligible hazards to human health, but that consumption of oil-exposed molluscs could constitute a significant risk.

Damage Assessment Studies

Division scientists actively participated in the Natural Resources Damage Assessment (NRDA) program in Alaska. Thousands of samples of tissue and bile from several fish

species were sampled during two cruises of the NOAA ship *Fairweather* during May-June and August-September at sites in Prince William Sound, Cook Inlet, and other locations in the northern Gulf of Alaska. Damage to fishery resources caused by the oil spill was assessed by analyzing tissue samples from juvenile and adult salmon, Dolly Varden (*Salvelinus malma*), and selected flatfish for concentrations of petroleum hydrocarbons and associated effects. Exposure was assessed by analyses of hydrocarbon metabolites in bile and of aryl hydrocarbon hydroxylase activity in liver tissue. Initial efforts were made to evaluate effects by examining selected fish species for pathological conditions and indications of DNA damage and reproductive impairment. Analyses were completed, and the exposure and impacts of petroleum hydrocarbons on a wide range of fish species important to commercial and subsistence fisheries over several geographical areas are currently being assessed. A progress report for the first year of the study and a proposal of a second year of studies were submitted to the NRDA Trustee Council.

Related Activities

EC Division scientists also participated in several other oil-spill related cooperative projects with other state and federal agencies. For example, Division personnel performed chemical analyses of samples from marine mammals collected by NOAA and ADF&G scientists. Overall, the Division served as a focal point for a variety of oil spill assessment studies and provided timely and important data for critical management decisions.

National Status And Trends Program

The National Benthic Surveillance Project (NBSP) is part of NOAA's National Status and Trends Program (NSTP) and is intended to assess the long-term changes in the environmental quality of the Nation's coastal and estuarine waters. In 1989, Division scientists took on an expanded role in NBSP-related research and field surveys by assuming nationwide responsibility for all analyses of organic contaminants and fish histopathology in the NBSP. This expanded role entailed measuring hundreds of samples collected in NBSP's fifth year (1988). Also, during the fifth year of the NBSP, a new biochemical measure of early physiological change resulting from exposure of fish to contaminants (activity of hepatic aryl hydrocarbon hydroxylase (AHH)) was added to the suite of measures used in the NBSP and the analyses were completed in 1989. Results of these analyses of AHH activity in fish liver samples were presented at OCEANS '89. Division scientists also completed chemical analyses of fish tissues and sediment samples, and histopathological examinations of fish liver for specimens collected during 1988. In addition, data collected from different regions of the United

States during previous years of the NBSP were reported in a variety of reports and publications; examples of some of these findings are given below.

West Coast

The Division completed Part II of a summary report on the status of chemical contamination and fish diseases at selected sites on the west coast. This report covers the first 3 years (1984-86) of the NBSP. In addition, the results of the fourth year (1987) of the west coast portion of NBSP were presented at OCEANS '89.

During this fourth year of the NBSP, San Diego Bay and San Francisco Bay were selected for more intensive sampling to evaluate the magnitude of pollution problems in these bays, and to better define the spatial distribution of chemical contamination and biological effects. The results of the intensive studies in San Francisco Bay not only supported previous findings that the sites in the southern portion of the bay (e.g., Hunters Point) generally had sediments and fish with the highest levels of many contaminants, but also identified the site in the Oakland Estuary as one of the most contaminated on the Pacific coast. For San Diego Bay, the high concentrations of chemical contaminants and high prevalences of fin erosion previously found at a site in the southern part of San Diego Bay were also found at a nearby site next to National City. In addition, a high prevalence of liver neoplasms was detected in black croaker *(Cheilotrema saturnum)* from a site in the northern part of the bay. Concentrations of many contaminants in sediments and fish were generally higher at the sites in the inner portions of San Diego Bay compared to sites in nearby nonurban areas.

Northeast Coast

The results of analyses of samples collected from eight sites on northeast coast during 1987 indicated that concentrations of aromatic hydrocarbons (AHs), PCBs, and DDTs in sediments from most of the sites were generally similar to those reported for previous cycles (Cycles 1 and 2) of the NBSP. The mean concentration of AHs in sediments from the site in Boston Harbor was among the highest of all the sites. The mean concentrations of DDTs in sediment and in the liver of winter flounder from Raritan Bay were also significantly higher than for any of the other sites. Of particular interest was the finding that there were no significant differences in PCB concentrations in sediments from the various sites, due in part to high intrasite variability. However, concentrations of PCBs in liver tissue were significantly higher in winter flounder from the sites in Boston Harbor and Raritan Bay. Similarly, levels of certain fluorescent aromatic compounds in bile were significantly higher in flounder from these two sites. In addition, coprostanol concentrations (used as an indicator of sewage contamination) in sediments were also highest at the Boston Harbor and Raritan Bay sites.

In addition to this involvement in the NBSP, Division scientists also participated in NOAA's Coastal Ocean Program. As part of intensive studies conducted in Boston Harbor, sediment samples obtained from 16 stations inside and outside Boston Harbor were subjected to the Microtox bioassay. The Microtox bioassay, which measures the toxic effects of saline and organic solvent extracts of sediment on bioluminescent marine bacteria, has proven to be a useful method to evaluate the relative toxicity of contaminated sediments. Generally, the toxic effects of the organic extracts followed the probable chemical contaminant gradient in Boston Harbor, that is, the most toxic areas were in the inner harbor, whereas the least toxic areas were in the outer harbor.

Research and Development

Biochemical Effects of Contaminants

Biochemical indices of contaminant exposure and sublethal effects in fish have received considerable attention because of the need for sensitive and reliable tools for assessing the quality of aquatic environments. Currently, the EC Division is evaluating a spectrum of biochemical indices in fish as indicators of contaminant exposure and early physiological effects. These indices, known as bioindicators, include induction of xenobiotic metabolizing enzymes in liver (hepatic aryl hydrocarbon hydroxylase (AHH) and ethoxyresorufin-O-deethylase (EROD) activities), alterations in glutathione levels in liver (an indication of oxidative damage), and interaction of xenobiotics and their metabolites with the genetic material (DNA) (DNA adducts, as analyzed by the ^{32}P-postlabeling assay). To assess the ability of this suite of bioindicators to detect contaminant exposure in benthic fish, a major study was conducted in which three species of benthic flatfish (English sole; starry flounder, *Platichthys stellatus*; and rock sole, *Lepidopsetta bilineata)* were sampled from up to seven sites in Puget Sound, Washington, chosen to represent a gradient of chemical contamination in the sediment. The sites were sampled six times during the year to assess seasonal variability of the bioindicators. The preliminary results show that all the bioindicators examined can discriminate among sites having different degrees of chemical contamination and indicated that the use of several bioindicators in concert enhanced the ability to identify sites where benthic fish are being impacted by chemical contamination. These studies will aid in establishing the role of bioindicators of contaminant exposure and early biological effects as important tools in monitoring programs assessing the environmental quality of marine waters.

To further enhance the usefulness of induced cytochrome P-450-dependent monooxygenase activity as an indicator of exposure to xenobiotics, EC Division scientists evaluated the EROD assay as a measure of the activity of this specific cytochrome

enzyme which is induced in liver of fish exposed to chemical contaminants. Preliminary results show that EROD correlates with AHH activity in the liver of both English sole and coho salmon. The use of EROD will complement AHH and provide additional information on the level of enzyme induction in fish after exposure to chemical contaminants.

An enzyme-linked immunosorbent assay (ELISA) for the quantitation of the major form of the family of cytochrome enzymes induced by chemical contaminants was incorporated into the Division's suite of bioindicators with the aid of Dr. Anders Goksøyr of the University of Bergen, Norway. The ELISA utilizes the specificity of antibodies to recognize a specific compound of interest, and is capable of quantitating the level of chemically-induced cytochrome P-450 enzyme in fish liver samples in which enzymatic activity has degraded. Selected samples from the NBSP, the *Exxon Valdez* Damage Assessment Program and other studies are currently being analyzed by the ELISA technique. The results of these studies will aid in identifying the relative merits of the three assays for measuring the induction of cytochrome, an important bioindicator of chemical exposure and early physiological effects in marine species.

Effects of Pulp Mill Effluents

In cooperation with the U.S. Environmental Protection Agency (EPA) and the Washington State Department of Fisheries, EC Division scientists participated in a study to assess the impact of pulp mill effluents on outmigrant juvenile coho salmon in Grays Harbor, Washington. In these studies, coho salmon smolts were exposed to effluents from two different pulp mills either in an aquarium, where the concentration of the effluents was held constant (bioassay study), or in net pens anchored in different areas of Grays Harbor, where there was a gradient in the concentration of effluents (cage study). Because of the relatively short exposure time during outmigration of juvenile salmon through an estuary, sensitive measures are needed to detect physiological changes from exposure to chemical contaminants. In the present study, the AHH and EROD assays were used to assess contaminant exposure and biochemical changes in coho salmon smolts in the two studies. Both AHH and EROD were used because they are extremely sensitive assays capable of measuring the induction of cytochrome P-450. The preliminary results indicate different degrees of induction of AHH and EROD activities resulting from exposure to the two pulp mill effluents, and thus, suggest that individual effluents elicit different levels of physiological response. Furthermore, the study results are in agreement with previous studies showing that induction of cytochrome P-450-dependent activity in fish is a sensitive indicator of exposure of fish to several classes of toxic chemicals.

Juvenile Salmon Studies

The EC Division conducted studies in cooperation with the U.S. EPA to determine if salmon migrating through polluted estuaries in Puget Sound take up toxic chemicals, and if exposure to such chemicals may affect their survival. Urban estuaries are vital habitats for several species of juvenile salmon during their migration from rivers into Puget Sound. In 1989, chinook salmon were collected from the Duwamish Waterway (Seattle), Nisqually River (a nonurban, reference estuary in south Puget Sound), the Puyallup River (Tacoma), the Snohomish River (Everett), and hatcheries for each of these waterways. The results of chemical analyses demonstrated that salmon from the Duwamish Waterway and the Puyallup River estuary consistently had concentrations of contaminants that were higher than those in salmon from the hatcheries and the reference estuary, although concentrations of these contaminants in salmon from near the mouth of the Puyallup River were usually somewhat lower compared to those from the Duwamish Waterway. Salmon from the Snohomish River had concentrations of contaminants that were consistently lower compared to salmon from the other two urban estuaries. In terms of possible effects of these contaminant exposures, the livers of salmon from the Duwamish Waterway had higher levels of DNA damage than did salmon from the reference estuary and hatcheries, and the livers of salmon from the Duwamish Waterway and the Puyallup River estuary had activities of xenobiotic metabolizing enzymes that were higher than those in fish from the Snohomish River and the reference estuary.

Effects of Contaminants on Reproductive Success

The Division concluded sampling in a 2-year study evaluating the effects of exposure to xenobiotic compounds on reproductive success in winter flounder. Winter flounder were collected from several sites within Boston Harbor and along the New England coast from Massachusetts to Long Island Sound. In 1989, samples were also taken in Raritan Bay. The data are currently being analyzed.

Reproductive success studies continued on fish species in Puget Sound. Work with English sole was expanded to include investigation of contaminant effects on fecundity and a new assay which measures *in vitro* estradiol production by ovarian tissue fragments in fish from contaminated and reference sites. The findings, though preliminary, suggest that these methods will yield useful information. In addition, studies examining contaminant effects on ovarian maturation and spawning were initiated with Puget Sound rock sole. Preliminary results suggest that effects on ovarian maturation and estradiol production are not as severe in rock sole as in English sole, but rock sole may show other signs of spawning impairment.

Analytical Chemical Methods

A rapid method to rank the sediments for levels of AH contaminants was provisionally established. In order to rapidly analyze great numbers of sediment samples from the NSTP and the *Exxon Valdez* oil spill studies, a method to screen the samples according to heavy, moderate, and low levels of contamination was necessary so that priority could be given to analyzing the most important samples in detail by the more costly standard method which employs gas chromatography and mass spectroscopy.

In addition, because of the discharge of municipal sewage effluents and sludges into the coastal oceans, the need has arisen to monitor the dispersion of sewage-related contaminants throughout the marine environment. Coprostanol originates in the intestines of higher animals, and is not a natural constituent of marine fauna, which makes it suitable as a sewage tracer. EC Division scientists developed an analytical method for measuring coprostanol in sediment which separates coprostanol from closely related interferent(s) and reduces the amount of manual labor used in standard methods.

Studies were also completed to select an endogenous component of bile upon which to base results of analysis of fluorescent aromatic compounds (FACs) in bile of fish. In the NBSP, the measurement of bile FACs is used as an indicator of contaminant exposure in fish. The use of a specific protein as a marker of bile composition was found to enhance the usefulness of this method as a tool in rapidly screening fish for exposure to aromatic hydrocarbons. This analytical procedure has been particularly useful and cost effective in measuring oil exposure in fish and marine mammals, and accordingly has been widely used in *Exxon Valdez* oil spill studies.

In response to the need to assess the impacts of oil spills, the EC Division, in collaboration with the Food and Drug Administration, initiated laboratory studies designed to assess the metabolism and disposition of Prudhoe Bay crude oil (PBCO) in commercially important marine species (e.g., coho salmon and Dungeness crab). Because certain metabolites of AHs can be more toxic than their corresponding parent AHs, the major objective was to measure the extent to which both petroleum-derived AHs and their metabolites are deposited in edible tissues of fish and crab and to study whether exposure to oil influences the disposition of individual AHs. Radiolabeled AHs were used in these studies because currently there are no standard analytical techniques for measuring the levels of metabolites of AHs in tissues. The results showed that the concentrations of selected AHs and their metabolites in edible flesh are much lower than in other tissues, and that the numerous compounds present in PBCO did not markedly influence the disposition of selected AHs and their metabolites in edible flesh of the fish or the crab species. These results will be very useful in evaluating exposures of fish

and shellfish in the NRDA program and the subsistence seafood project described above.

In conjunction with the studies of coho salmon and Dungeness crab, using radiolabeled AHs, the Division initiated development of a rapid screening method for analyzing both parent AHs and their metabolites in edible flesh of animals exposed to AHs. This new procedure builds on a method developed in the EC Division for analysis of metabolites of AHs in bile of fish; it will further enhance our capability to rapidly respond to the need to evaluate environmental damage and possible impacts on human health caused by aromatic hydrocarbon pollution, including that from oil spills.

Sediment Bioassays

Toxicity bioassays of marine sediments using larval or juvenile stages of four different marine organisms were evaluated for dose-responsiveness and the sensitivity of selected measures of lethal and sublethal effects. Sediment bioassays are used extensively in tests of dredged sediments to evaluate disposal options, but most available bioassays assess only acute lethal effects. Assays for assessing long-term or chronic effects are badly needed. Bioassays were conducted on sediment samples from several west coast sites sampled as part of the NBSP in 1989. Some of the results of the sediment bioassay research were presented at OCEANS '89.

Cooperative Activities

Division scientists regularly interacted with other Federal and state agencies, including the U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, the U.S. Food and Drug Administration, the Alaska Departments of Fish and Game and Environmental Conservation, the Washington State Departments of Ecology and Fisheries, and the Puget Sound Water Quality Authority, regarding research priorities and planning in Puget Sound and other estuaries.

ENVIRONMENTAL CONSERVATION DIVISION

1989

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UTILIZATION RESEARCH (UR) DIVISION

The UR research activities are directed toward the study of concepts that will generate information useful for obtaining maximum use and value from fishery resources. In addition to conducting research on preservation, product quality and safety, waste utilization, fish oil fractionation and purification, and fish proteins, the UR staff serves as a source of information on fishery technology to a wide variety of government, academia, and industry clients, as well as the general public.

Resource Utilization

Research in the area of resource utilization is an important phase of the Division's effort. The results of resource utilization research contribute to the prudent use of marine resources and to creating methods of producing nutritional and valuable products from lesser known species as well as those that have special problems.

Fish Proteins and Derivatives

Research on the use of Pacific whiting (*Merluccius productus)* for surimi preparation continued in 1989. Final action on the patent application covering the enzyme inhibitor developed here was received. The patent should be issued in 1990.

Storage studies on Pacific whiting with and without inhibitor at either the stage with cryoprotectants or at the kamaboko stage are equally effective for surimi stored for 1 year at -20°F.

During the year, work was completed on establishing a protocol for isolating the enzyme from Pacific whiting to purity. This is being confirmed with subsequent preparation which will allow sufficient material for characterization of the enzyme.

Two preparations of surimi from arrowtooth flounder were tested with our inhibitor. The control samples had absolutely no gel-forming characteristics, while the treated samples had greatly improved gel-forming properties. The test results indicate some potential for preparing surimi from arrowtooth flounder if the fish is processed soon after capture. Holding the fish chilled several days prior to processing results in irreparable damage to the gel-forming properties of the flesh.

Product Quality and Safety - Microbiology

The safety and wholesomeness of seafoods are always important to the industry and consumer as well as to regulatory agencies. There has been increasing concern over the incidence of foodborne pathogens, many of which are capable of growth in refrigerated foods. The UR Division has been engaged in microbiological research on two of these pathogens, *Clostridium botulinum* and *Listeria monocytogenes*, the organisms that cause the diseases botulism and listeriosis, respectively. Human botulism outbreaks have caused losses of over $150 million to the fishing industry during the past two decades. Ready-to-eat fishery products are being recalled because of contamination with *Listeria.*

UR has gained worldwide recognition for research on *C. botulinum* and prevention of its toxin production in seafoods. During 1989, summaries of our extensive baseline data on parameters for control of the organism in hot- and cold-smoked fish was shared with state agencies to support new regulations and guidelines and also with FDA for use in drawing up new Good Manufacturing Process guidelines for the industry. A patent application was filed for a heat-pasteurization process that was developed for vacuum-packaged hot-smoked fish. The process will be useful for increasing the refrigerated storage life of hot-smoked fish and at the same time reducing the amount of NaCl or other inhibitors required for safety and preservation. Since the heat applied in this process is sufficient to inactivate vegetative cells of other bacteria, viruses, and parasites of public health significance as well as nonproteolytic *C. botulinum* spores, there should be a broad market for this process.

Rapid detection of *L. monocytogenes* is a key factor in solving the foodborne Listeria problem. Existing protocols for meat and dairy products take from 1 to 4 weeks for a positive identification. This time-frame is not practical for food processors who wish to do Listeria testing for quality control or regulatory purposes.

The first phase of our work on *L. monocytogenes* was to develop suitable culturing techniques for fishery products. We have succeeded in developing a new medium that permits positive identification of *L. monocytogenes* within 2 days. This procedure not only is more rapid than the existing methodology, but is more sensitive, allowing detection of fewer numbers of *L. monocytogenes* in the presence of high numbers of competing organisms.

In order to determine critical control points for smoked fish products, the relative effectiveness of individual processing variables on survival and growth of *L. monocytogenes* are being studied. Variables included: time and temperature of processing, application of smoke, concentrations of salt and sodium nitrite, packaging

method, and storage times and temperatures. Experiments completed thus far show that *L. monocytogenes* can grow very well in products containing up to 5% water-phase NaCl during prolonged refrigerated storage. Although some inhibition can be achieved by increasing the NaCl concentration to 6%, levels much above the 3 to 5% range are not practical for cold-smoked fish from the standpoint of palatability and consumer acceptability. Some advantage can be gained by adding nitrite to cold-smoked salmon to inhibit *L. monocytogenes*, the results are not dramatic and additional inhibitor mechanisms are needed to increase the effect.

The Division has have been sharing its laboratory information and furnishing technical support and advice wherever possible to seafood processors regarding their immediate problems with *Listeria*. One company, shown by FDA to have problems with *Listeria* in their cold-smoked products, has been free of *Listeria* for the 7 months since the Division started to work with them. General meetings are planned with the industry to explain procedures for preventing contamination and inhibiting *Listeria* growth in their products.

Product Quality and Safety - Quality Improvement

The prediction and prevention of quality problems in seafoods is important from the standpoint of controlling economic loss as well as keeping products with quality problems out of the marketplace. This year, the Division's attention was called to the continual problem of 'greening' discoloration in canned tuna that is particularly noticeable in albacore *(Thunnus alalunga)*.

The cause of greening appears to be reasonably understood: it is a reaction between trimethylamine oxide, tuna hemoglobin, and possibly cysteine. During the precook or in the canning process, the combination of these three compounds produces a noticeable green color, thereby causing a severe visual defect in the product. We found a good model system for producing the color in the laboratory using slices of tuna muscle tissue, but the best indicator appears to be trimethylamine oxide content of the tuna muscle. We developed a safer reagent for the analytical procedure for trimethylamine oxide, replacing titanium trichloride with ferrous sulfate and ethylenediaminetetraacetic acid (EDTA). The titanium trichloride reagent is quite hazardous for both handling and in its disposal. In addition, the method we developed could be easily adapted to a high volume flow injection analysis scheme.

Aquaculture (Nutrition)

In the past year, research projects have been conducted in several areas, including fish waste utilization, fish meal quality evaluation, trace mineral requirements, and

carotenoid pigmentation of fish. Fish waste utilization continues to be an important issue in the United States, particularly in the North Pacific region. In the past, the Division evaluated processes for making fish hydrolysates, such as fish silage and liquefied fish, and compared their nutritional value to that of fish meal in aquaculture diets. These evaluations consistently found that fish silages and their products have a lower nutritional value than fish meal made from the same starting material. The research suggested that the reduced nutritional value of fish silages was due to several factors, but the most important factor was the degree to which the fish silage was allowed to hydrolyze before it was used in fish diets. Further research showed that reduced growth was caused by imbalances in plasma amino acids in the fish in the hours after a meal. Certain amino acids were found in the plasma at much higher concentrations in fish fed a diet containing fish silage compared to control fish fed a diet containing fish meal (an intact protein). The magnitude of the differences between silage-fed fish and control fish was sufficient to account for the differences in growth observed between the groups of fish.

Recently completed research has taken this work one step further to elucidate the role of the urea cycle in protein and energy utilization in salmonid fishes. The urea cycle was studied because earlier research had shown differences between silage-fed and control fish in the plasma levels of several metabolic intermediates of the urea cycle. New work was undertaken in which fish were fed a single feeding of a diet containing fish silage, or fish silage supplemented with individual amino acids or urea cycle intermediates. Plasma from the fish was sampled at intervals up to 72 hours after feeding. The results suggest that feeding hydrolyzed protein causes the urea cycle to function differently, resulting in a higher conversion of free amino acids of energy-yielding compounds. The overall result of this change in metabolism is that a higher proportion of dietary protein from fish hydrolysates is used to provide energy for the fish rather than to support synthesis and thereby weight gain, as compared to dietary protein from intact protein products, such as fish meal. The practical consequences for those wishing to use fish waste hydrolysates in aquaculture feeds is that the degree of hydrolysis must be closely monitored and stopped to ensure the highest possible nutritional value of the product as an ingredient in fish and animal feeds.

In the area of fish meal quality evaluation, research was conducted to rank several fish meals on the basis of palatability, digestibility, and nutritional value. Several feeding trials were conducted with juvenile Pacific salmon, which were fed diets in which the standard fish meal, herring meal, was replaced with fish meals from Japan, Norway, and Denmark. The fish meal from Norway was a special-quality fish meal which sells for a substantial premium over a regular fish meal and is used exclusively in aquaculture feeds in Norway. Research showed that the way in which the feeds were fed to the fish greatly influenced the ranking of the fish meals. Feeding to apparent satiation at each

feeding resulted in a Japanese whitefish meal supporting the highest weight gain. Analysis of the results showed that the fish consumed more feed when it contained the whitefish meal. Based on the results of chemical analysis, we predicted that this meal would be among the lowest quality meals. In a second study in which the amount fed to the groups of fish was fed on a percentage of body weight, the Japanese whitefish meal ranked low, while the Norwegian special-quality fish meal ranked highest. The nutritional value of the Norwegian meal was highest of the tested meals, although the fish preferred feed containing the Japanese whitefish meal. The results of this study show that there is no "perfect" fish meal for all situations. Rather, various fish meals are appropriate for use in specific fish culture situations.

The availability of magnesium from several magnesium sources was determined using rainbow trout as the experimental fish. Magnesium is an essential dietary nutrient for fish, although a portion of the requirement for magnesium can be obtained from rearing water. Semipurified diets fed to fish in laboratory studies must be supplemented with magnesium to prevent deficiency signs in the fish. The availability of magnesium to fish from common dietary magnesium sources is an essential piece of information needed to formulate balanced diets for nutritional studies. Comparison of the bioavailability of dietary magnesium from magnesium oxide, magnesium chloride, magnesium carbonate, magnesium hydroxide, and magnesium phosphate, as determined by percentage retention by the fish, were equivalent at approximately 76%. Magnesium retention from fish bones was less than that of the inorganic sources at 54%.

Several research projects on carotenoid pigmentation of salmonid fishes were conducted during the year. Two projects concerning carotenoid stability during frozen storage of fish were conducted and will be completed next year. Another study was conducted to determine the effectiveness of synthetic astaxanthin as a pigmenting agent for coho salmon. Retention of astaxanthin by the coho salmon was significantly higher than reported retention of astaxanthin by Atlantic salmon and rainbow trout. This work will lead to recommendations for appropriate dietary astaxanthin concentrations and duration of feeding to pigment coho salmon for market.

Fish Oil Research

The full utilization of fish oils includes capitalizing on their unique structures and properties. The press regularly reports on new medical studies suggesting that fish oils are useful for treating a number of autoimmune/inflammatory diseases such as heart disease and arthritis. There is also increasing evidence that one of the components of fish oils is necessary for normal human development and ought to be included in all infant formulas. Unfortunately, confusion over the exact biochemistry of fish oils hinders

full acceptance of their vital contributions to the human diet. The complex mixture of components that comprises fish oils hampers biochemical studies. Therefore, a long-range goal of the Fish Oil Program has been to develop methods for isolating individual pure compounds for use in defining the physiological properties beneficial to human health.

Research on supercritical fluid carbon dioxide ($SFCO_2$) extraction has continued with a study on the influence of structure on the relative solubilities of fatty acid esters. This work supplements earlier efforts in order to provide a firmer base for evaluating countercurrent continuous processing for the production of large quantities of concentrates of individual components. Related data also were collected during several small-scale countercurrent extractions of mixture of omega-3 concentrates to prepare 90% EPA.

Synthesis of triglycerides of omega-3 fatty acids has been another focus of research. Initial efforts starting with esters of mixtures of omega-3 fatty acids indicated that triglycerides could be synthesized from esters, an advantage over the free fatty acids needed in earlier methods. Esters are the form most readily available. They are much more stable than the acids, which undergo even more rapid degradation than their derivatives. Recent work has involved synthesis of a single triglyceride, tri-EPA triglyceride. Preparation of the starting material required repeated runs of the supercritical carbon dioxide extraction facility to amass more than 200 g of the ethyl ester EPA (eicosapentaenoic acid, 20:5ω3) in 90% purity. On the commercial market, the cost of this material would exceed $100,000, if available in such large amounts.

A series of experiments on the conversion of EPA ester to tri-EPA under controlled conditions were begun to explore the effects of variations in the mole ratio of the component esters to glycerol. Syntheses are to be performed at ratios from approximately 10:1 to 1:0. The products of each synthesis will be fractionated with $SFCO_2$ to determine the amount of unreacted esters and to separate the intermediate mono- and diglycerides and other byproducts form the desired triglycerides. Primary to the $SFCO_2$ work with the tri-EPA reaction mixtures, the Division has nearly completed a study of a simplified model system, mono-, di, and triolien, that provides an understanding of the interactions of the glyceride components in $SFCO_2$.

The second study on the applicability of pressurized cans to the storage of fish oils was completed. Since fish oils readily decompose in the presence of air, some means of excluding the air was necessary to maintain the stability of the omega-3 components that are the presumed active ingredients. Two year-long studies used oils of slightly different initial purity as indicated by the peroxide value. Both sets of data confirm that storage in a can pressurized with nitrogen is an effective method for stabilizing fish oil

and providing a means for dispensing it as a liquid in exact amounts. Pressurized cans have the added advantage over gelatin capsules that the dispensed liquid oils is readily swallowed.

Part of the effort has involved development of analytical techniques for separating and quantifying omega-3 compounds. Mono-, di-, and triolein mixtures were studied as models for analysis of mixed fatty acid triglycerides, containing both oleic and omega-3 chains.

Analytical Support Unit

The Analytical Support Unit has continued to provide analytical results that require use of sophisticated equipment or special techniques for other programs in this Division and, on occasion, for other Divisions in the Northwest Fisheries Science Center and the Alaska Fisheries Science Center. These have included macro- and trace-element analyses by inductively coupled argon plasma spectroscopy, lipid-class analysis by thin-layer chromatography, and fatty acid profile by gas chromatography. During this year, the Analytical Support Unit also assumed the responsibility for high performance liquid chromatography analysis in two areas: the analysis of complex liquid mixtures for the Fish Oil Research and Processing Program and the analysis of sorbate and benzoate in smoked fish for the Product Quality and Safety Program. Some method development and evaluation was necessary for both of these areas.

The Analytical Support Unit has also continued to provide analytical assistance and consultation on unusual problems whenever they have occurred.

Kodiak Field Station

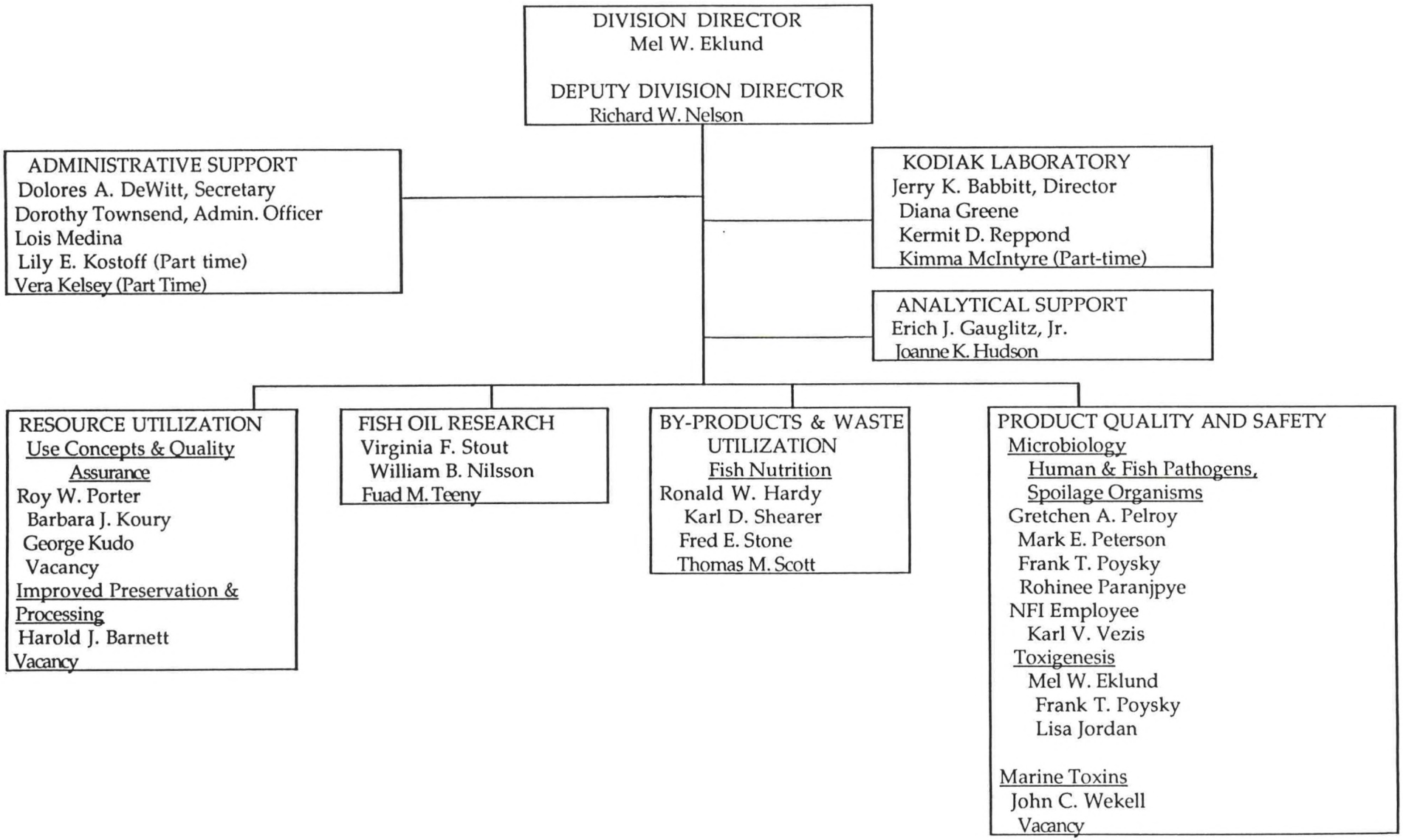
The research efforts at the Kodiak Field Station continued to focus on the quality changes of Alaska pollock, cod, and various flatfish species and ways to increase the utilization of fishery by-products. The work at Kodiak is providing data on keeping quality, chemical properties, and sensory characteristics of these species. Major emphasis included studies to understand the softening problem in arrowtooth flounder *(Atheresthes stomias)* and ways to prevent its occurrence in commercial fishery products.

In addition to the laboratory research projects at Kodiak, the staff continues to be active in the role of advisor to the Alaskan fishing industry. Cooperative research projects with industry resulted in the production of minced fish blocks from pollock and cod fillet trimmings, a better understanding of surimi processing technology, and the incorporation of a screening system in fish meal plants to improve the quality of the meal.

The research in Kodiak is being done cooperatively with the Fishery Industrial Technology Center, the Alaska Fisheries Development Foundation, the Alaska Seafood Marketing Institute, and the fishing industry.

UTILIZATION RESEARCH DIVISION

1989



ALASKA FISHERIES SCIENCE CENTER

The Alaska Fisheries Science Center is the research branch of the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) responsible for fisheries research in the coastal oceans off Alaska and the west coast of the United States. These waters, including the North Pacific Ocean and the eastern Bering Sea, support some of the most important commercial fisheries in the world--Pacific salmon, Pacific cod, walleye pollock--with a total biomass of more than 26 million metric tons. These waters are also home to the largest populations of marine mammals in the Nation.

Passage of the Magnuson Act in 1976 and establishment of the Nation's 200-mile Exclusive Economic Zone (EEZ) gave new impetus to the Alaska Fisheries Science Center to provide information for the sound conservation and management of the region's marine resources. Once dominated by foreign fishing fleets, these resources now provide 50% of the volume and about 40% of the value of the total U.S. catch in the EEZ. The mission of the Alaska Fisheries Science Center is to plan, develop, and manage scientific research programs which generate the best scientific data available for understanding, managing, and conserving the region's wealth of living marine resources and the environmental quality essential for their existence.

A primary responsibility of the Center is to provide scientific data and technical advice to two U.S. Fishery Management Councils, the NMFS Alaska Regional Office, U.S. representatives participating in international fishery negotiations, and the fishing industry and its constituents.

The Center also coordinates fisheries research with other Federal and state agencies, academic institutions, and foreign nations.

MARINE ENTANGLEMENT RESEARCH PROGRAM

During 1989, the National Marine Fisheries Service met its responsibilities to control marine debris as required by the Marine Plastic Pollution Research and Control Act of 1987 and the Driftnet Impact Monitoring, Assessment, and Control Act of 1987. The Marine Entanglement Research Program (MERP) in consultation with the Environmental Protection Agency (EPA), Department of Transportation, and other agencies has developed public awareness programs to meet the requirements of the first Act.

In 1989, the MERP initiated, supported, and participated in the Second International Conference on Marine Debris. This conference provided an international forum for the exchange of information about the impact of marine debris. The MERP is also a co-supporter with EPA and private organizations of the national voluntary beach cleanup held during Coastweeks in October each year. The 1989 cleanup involved 65,000 volunteers. The MERP sponsored the formation of a national marine debris data base designed to store marine debris information gathered during the national voluntary beach cleanups.

During 1989, MERP staff undertook a variety of actions to educate the general public about recent implementation of MARPOL Annex V in the United States. Major accomplishments in this area included the continuing operation of NOAA's Marine Debris Information Offices in San Francisco and Washington, D.C., and the development of an educational program for the commercial shipping and cruise lines industry. This work included the development of two information papers for the International Maritime Organization on waste control and plastics minimization plans for ships. Further, the MERP manager acted as Federal Program Officer for three Saltonstall-Kennedy (S-K) grants and two Program initiated grants aimed at developing information to assist ports to comply with MARPOL Annex V.

The Program managed the NMFS research program under the Driftnet Impact Monitoring, Assessment, and Control Act through 1989 and assisted in the formation and funding of an independent North Pacific driftnet research program beginning in Fiscal Year 1990.

OFFICE OF FISHERIES INFORMATION SYSTEMS (OFIS)

The OFIS Systems staff completed and implemented an Electronic Card Catalog System for the Montlake Library which includes a database of over 21,000 titles that may be easily retrieved by any UNISYS user. The system provides search capabilities by author, subject, author and key phrase, or other combinations.

Computer usage of the UNISYS B7800 increased 17% during Fiscal Year 1989, and an additional 1.4 billion characters of disk storage were added, resulting in a major disk configuration. At the end of the year over 11 billion characters of disk storage were on line to the system.

OFIS increasingly assisted personal computer users. Personal computer training was begun which continues into 1990. Several software purchases were consolidated saving users $1,200 over single copy prices.

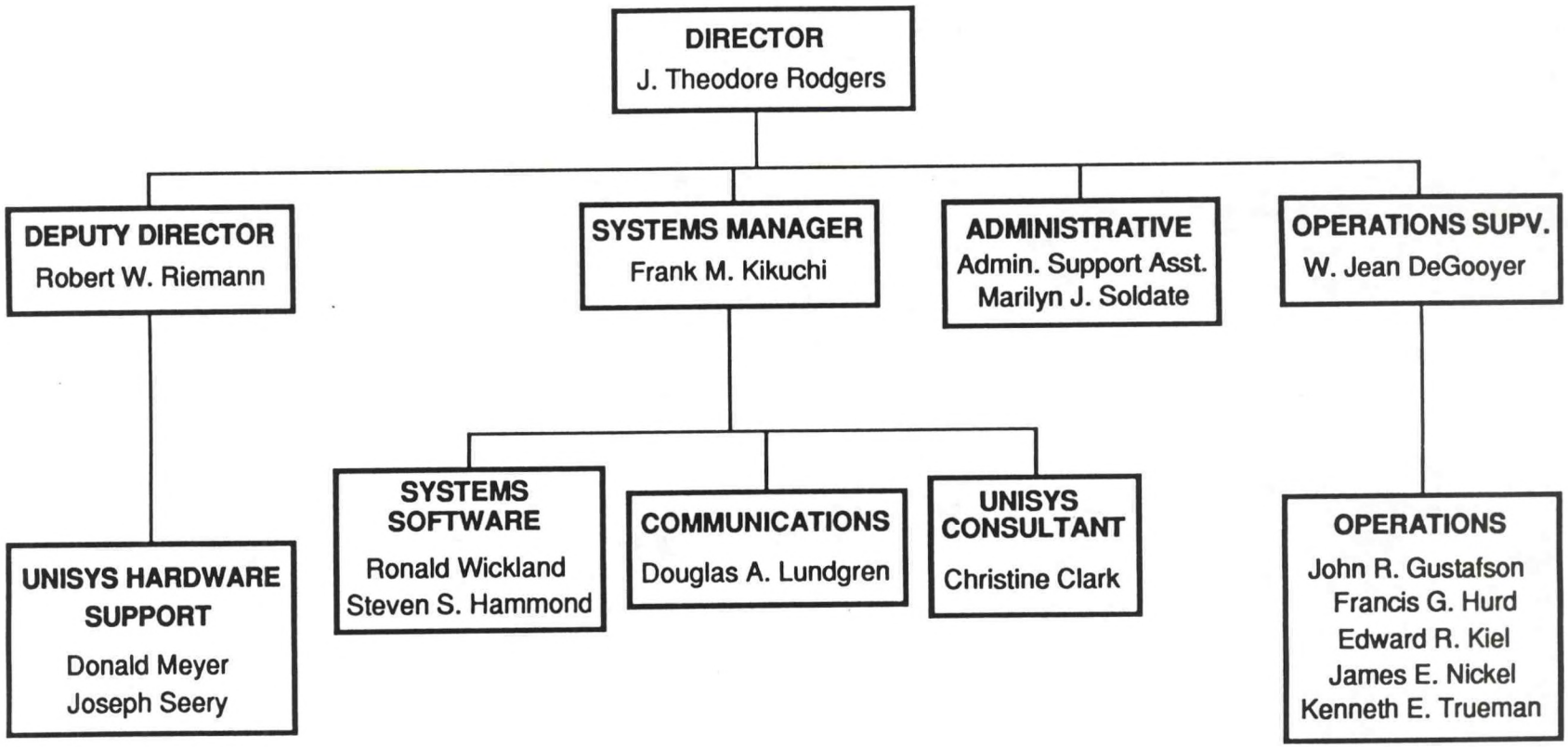
OFIS assisted the REFM Division in preparing time sequence animations of ocean surface current model runs. The series of model runs were executed on the B7800 and plotted/captured to disk files on a 386sx personal computer. The captured disk files were later animated on the PC using the 'GRASP' system and video taped. The resulting video tape was presented at several oceanographic meetings. These simulations of drifter trajectories in the Gulf of Alaska provide a new viewpoint of interannual variability in the ocean that could be obtained in no other way.

The IT-95 computer acquisition project which will ultimately replace the UNISYS B7800 was strongly supported by OFIS on several levels. Bob Riemann, Deputy Director, acted as national benchmark team leader and completed the benchmark tasks.

During 1989, OFIS and the Bureau of Mines, in Denver, Colorado acted as mutual backup sites in case of computer center disaster. OFIS provided the Bureau of Mines with support and time sharing service in completing and testing their plan.

OFFICE OF FISHERIES INFORMATION SYSTEMS

1989



AUKE BAY LABORATORY (ABL)

Habitat Assessment

Response to Exxon Valdez Oil Spill

Grounding of the tanker *Exxon Valdez* in Prince William Sound (PWS) on 24 March 1989 caused the largest oil spill in U.S. history. ABL responded to the disaster immediately by sending researchers to PWS within 2 days. Staying ahead of the spill's trajectory, they were able to resample sites established by the Laboratory in the 1970s for just such an eventuality. Within 4 days of the spill, ABL staff met in Cordova with the Alaska Department of Fish and Game (ADF&G) to devise fisheries damage assessment plans. ABL quickly planned, equipped, and implemented eight damage assessment tasks in PWS, prepared for certified hydrocarbon analyses, and established an extensive system for sample custodial archiving and related data base management at the Laboratory.

Staffing of three of the four laboratory programs (Salmon Enhancement, Habitat, Marine Assessment) was heavily altered to accommodate the damage assessment work load. A total of 2,400 staff days were spent on spill-related activity during the fiscal year, including 1,034 staff days in the field. Over 50 ABL staff members participated in damage assessment activities. Members of ABL's support staff also greatly increased their work load to meet purchasing, budgeting, personnel, travel, and library needs associated with oil spill-related activities.

Habitat Activities

The advance of Hubbard Glacier is expected to close Russell Fiord near Yakutat, Alaska, within the next few years resulting in flooding of the Situk River watershed. In 1989 Freshwater Habitat personnel conducted cooperative research with the U.S. Forest Service and ADF&G on the Situk River to determine the potential effects of such flooding on juvenile and adult salmonids. The total number of juvenile salmonids wintering in Old Situk Creek, a major tributary of the Situk River that will flood when the Hubbard Glacier closes Russell Fiord, were determined. The seasonal distribution and abundance of juvenile salmonids in the main stem of the Situk River were also determined during the spring to fall period. Ten thousand age-0 chinook salmon smolts (rare in Alaska) were coded-wire tagged in the lower Situk River to determine marine survival, exploitation rates, and ocean distribution.

In 1989, 14 Alaskan beaches were surveyed by Habitat personnel to determine deposition, trends in abundance, and fate of entanglement debris and other plastics washed ashore. In particular, the number of pieces of trawl web deposited ashore declined 30% at Yakutat from 1988 to 1989, the first such decline observed since studies began in this area in 1985.

Physiology and Pathology

To study the prevalence of the brain parasite *Myxobolus* (a potential stock identification marker), 1,500 sockeye salmon from Bristol Bay and 2,000 sockeye salmon from Prince William Sound were collected and analyzed in 1989. Research on bitter crab disease in Tanner crab, which will have management implications for the commercial fishery, was also carried out. Effects of *Hematodinium* (causative agent of bitter crab disease) on the blood chemistry of Tanner crab were determined, and a study of the seasonality of the occurrence of this agent in Auke Bay Tanner crab was initiated.

U.S.-Canada Salmon Treaty

Pacific Salmon Commission (PSC) Support

Information on long-standing salmon management issues involving interception of Pacific salmon in the fisheries of the United States and Canada is provided annually to the PSC. This information is used to balance each nation's salmon catch rates in northern British Columbia and Southeastern Alaska fisheries. ABL program staff planned and coordinated research with Canadian and State of Alaska counterparts. Research by NMFS staff included stock identification, stock assessment, and interception analysis for fisheries occurring in boundary areas, transboundary rivers, and coastwide areas. Cooperative research plans for 1990 were also developed with ADF&G and the Canada Department of Fisheries and Oceans. Stock assessment and stock identification project plans were agreed to in the Northern Boundary Area and in transboundary rivers based on priorities identified by the PSC. A cooperative agreement with the ADF&G for Pacific Salmon Treaty studies was again established and monitored in 1989.

The ABL provided technical support to U.S. negotiators working with Canadian counterparts under the Pacific Salmon Treaty. Six ABL scientists served as members on PSC Technical Committees. Reports and analyses provided to the PSC covered a variety of topics including: 1) Genetic characterization and differentiation of chum and pink salmon stocks in southern Southeast Alaska and northern British Columbia (Northern Boundary Area); 2) U.S.-Canada salmon interceptions and stock identification of sockeye, pink, and chum salmon in contentious Northern Boundary Area

fisheries; and 3) Chinook salmon escapement and distribution estimates by radio telemetry.

Radio Tagging of Chinook Salmon

Nearly 400 chinook salmon tagged with radio transmitters were tracked to spawning areas in the transboundary Taku River system. In the first year of a 2-year study, information was obtained to assess the precision of escapement estimates and to determine progress in rebuilding these stocks. By using newly developed radio telemetry technology, data on migration timing, stock distribution, spawning behavior, and escapement were obtained for the glacially turbid Taku River. This work established ABL's capability to successfully tag, track, and monitor large numbers of radio-tagged salmon in remote watersheds and large turbid rivers. It is anticipated that this radio-tagging technology will open many new avenues of research into the migratory behavior of salmon and other species.

Marine Assessment Program

Reducing High-Seas Salmon Interceptions

Salmon of U.S. origin are intercepted in Japanese high-seas driftnet fisheries for salmon. Salmon are also taken as bycatch (along with several other species of birds, mammals, and fish) in high-seas driftnet fisheries for squid pursued by fleets from Japan, Taiwan, and the Republic of Korea. The marine resource staff estimates the numbers of U.S. salmon intercepted by the Japanese salmon driftnet fishery and evaluates the impacts of foreign squid fisheries in order to provide continuous advice to U.S. negotiators on high-seas salmon issues and bycatches of other species. In 1989, reports were submitted to the International North Pacific Fisheries Commission (INPFC) at the annual meeting, and the U.S. section of the INPFC was briefed on the Japanese high-seas driftnet fisheries and their impact on North American salmonid stocks. Staff members advised the U.S. Department of State during negotiations to complete squid driftnet monitoring and assessment agreements with Taiwan, the Republic of Korea, and Japan. These agreements provide for extensive observer coverage of the fisheries in 1990 and full coverage of vessel location via real-time satellite transmitters.

Alaska Groundfish Assessments

The ecology staff in the Marine Assessment Program collects data and information on abundance, distribution, and biology of sablefish, rockfish, and other selected species in the Gulf of Alaska. Using these data, the analyses staff evaluates the status of groundfish stocks including estimates of yield and potential exploitation. This infor-

mation is provided to the North Pacific Fishery Management Council (NPFMC) and INPFC. In 1989, ABL staff provided Allowable Biological Catch (ABC) recommendations for sablefish, continental slope rockfish, and pelagic shelf rockfish to the Gulf of Alaska Plan Team for inclusion in the status-of-stocks document. The staff also identified range extensions of fish and squid. Cruise results were distributed on 1) longline catchability coefficients for the Chatham Strait sablefish population (a cooperative study with ADF&G); 2) the 1989 domestic longline survey of the Gulf of Alaska (a cooperative study with the RACE division); and 3) the Japan-U.S. cooperative longline survey of the Gulf of Alaska. ABL scientists also were placed on domestic and foreign commercial longline vessels to survey sablefish resources of the eastern Gulf of Alaska during summer 1989. Juvenile sablefish were again found in concentrations in St. John Baptist Bay and tagged for age, growth, and migration studies.

Salmon Research

Enhancement

Chinook salmon enhancement research continued at Little Port Walter (LPW) in 1989. This research is part of an annually updated multiagency chinook salmon enhancement plan and is in accordance with an annex to the U.S.-Canada Salmon Treaty for enhancing depressed chinook salmon fisheries. Three chinook stocks are now being cultured, released, and maintained at LPW. Two of these stocks from the Chickamin and Unik Rivers have been under study since the 1970s. Beginning with the 1988 and 1989 broods, a third stock from the King Salmon River has been added, with the goal being to provide eggs from this stock to several facilities in northern Southeast Alaska. In 1989, a total of 210,000 1988 brood smolts were coded-wire tagged for release in spring 1990. Coded tags recovered from adult chinooks returning to LPW in 1988 and 1989 were also analyzed. Salmon enhancement technology developed at LPW assists more than a dozen public and private production facilities in Southeast Alaska.

At Auke Creek, a cooperative study with ADF&G aimed at rebuilding the depressed sockeye run continued in 1989. A total of 48,000 sockeye were marked and released into either Auke Lake (fry) or Auke Bay (age-0 smolts). About 90,000 1989-brood eggs were collected for release in 1990. A highlight in 1989 was the return of both 1-ocean and 2-ocean sockeye adults from age-0 hatchery smolt releases in prior years. These are the first such returns ever recorded, and they open the way for major breakthroughs in sockeye salmon enhancement. Age-0 smolts could become an important factor in low-cost production of the most highly valued common property salmon fisheries in Alaska.

Early Ocean Salmon Studies

Under the U.S.-Canada salmon treaty, catch quotas are established for chinook salmon that impact on coho fisheries where incidentally caught chinook must be released. Undersize chinook must also be released whenever they are taken. A significant number of these incidentally captured chinook do not survive. Therefore, the ABL initiated studies to examine the feasibility of modifying trolling gear (hook and lure sizes and shapes) so as to reduce this chinook mortality. Data collected in 1988 were analyzed in 1989 to determine the degree of hooking mortality and the fishing efficiency of different lures on legal and sublegal chinook salmon. Results will be published soon.

Early Ocean Salmon (EOS) Program staff continued field work for the Auke Bay Salmon Recruitment Study in 1989. This study addresses whether or not different parts of a salmon run survive at different rates within a given year and provides new insight into early marine migration patterns, food requirements, and temporal components of specific stocks. At Auke Creek, threefold differences in marine survival of pink salmon were measured between early and late run components of the same year class. Techniques developed by EOS staff in the Auke Bay Recruitment studies were also applied in 1989 towards determining the effects of the *Exxon Valdez* oil spill on seaward migrating juvenile salmon. This became a major component of ABL's oil spill impacts studies, in part, due to the estimated 2 billion juvenile salmon in PWS that were expected to migrate through heavily oiled areas. About half of these young salmon were produced from PWS hatcheries. Concern over well-being of PWS salmon stocks became a major focus of the oil impacts studies.

AUKE BAY FISHERIES LABORATORY - 1989

DIRECTOR: Snyder
DEP. DIRECTOR: Simpson
SECRETARY: Mynarski

** Program Manager
* Task/Project Leader
T Temporary

US/CANADA SALMON ISSUES

SALMON INTERCEPTIONS
**Olsen

STOCK ASSESSMENT
- *Carlson
- Eiler
- Nelson, B. (T)
- Bradshaw (T)
- Carpenter (T)

STOCK IDENTIFICATION
- *Helle
- Hoffman
- *Gharrett(1)
- Kondzela (T)
- Guthrie (T)
- Wilson (T)

INTERCEPTIONS ANALYSIS
- *Pella
- Masuda (T)
- Nelson, S. (T)

(1) On detail from University of Alaska to manage ABL's Genetics Unit.

SALMON ENHANCEMENT, DISTRIBUTION & SURVIVAL
**Heard

CHINOOK ENHANCEMENT
- *Martin - LPW
- Thrower
- Heintz
- Budke
- Joyce
- Tavoliero (T)
- Greiner (T)
- Skinner (T)
- Stehlik (T)

EARLY OCEAN DISTRIBUTION & HOOKING MORTALITY
- *Wertheimer
- Jaenicke
- Landingham, J.
- Celewycz
- Mortensen
- Orsi
- Sturdevant
- Gish (T)
- McGregor (T)

AUKE CREEK STUDIES
- *Taylor

HABITAT INVESTIGATIONS
**Rice

FRESHWATER HABITAT/DEBRIS
- *Koski
- Murphy (Lab Safety Officer)
- Johnson, S.
- Thedinga
- Lorenz

PHYSIOLOGY/PATHOLOGY
- *Moles
- Chan (T)
- Brouillette (T)

ON DETAIL
- Fletcher (From NOAA Corps)

MARINE ECOLOGY/OIL
- *O'Clair
- Carls
- Freese (Lab Diving Officer)
- Stone (T)

COASTAL HABITAT/OIL
- *Babcock
- Brodersen
- Korn
- Rounds (T)
- Stinnett (T)
- Barr (T)

CHEMISTRY/OIL
- *Short
- Sharp-Dahl (T)

MARINE FISHERIES ASSESSMENT
**Dahlberg

HIGH SEAS SALMON INTERCEPTIONS
- *Dahlberg
- Fowler

HIGH SEAS SQUID FISHERIES
- *Ignell

MARINE RESOURCE ECOLOGY
- *Haynes
- Wing
- Haight
- Krieger
- Rutecki
- Karinen
- Maloney (T)

MARINE GROUNDFISH ANALYSES
- *Fujioka
- Clausen
- Heifetz
- Sigler
- Varosi

PROGRAM SUPPORT

ADMINISTRATION
- Admin. Officer - Rathbone
- Personnel - Jones
- Procurement - Dunaway
- Property - Garrett
- Secretarial - Morris, Sondrud

INFORMATION SERVICES
- Library - Johnson, P.
- Computer Network - Lynk
- Editorial - Alcorn, Funaro
- Illustrator - Landinghamm E.

PHYSICAL PLANT
- Maintenance - Johnson, N.
- Electrical - Shrack
- Subport - Dress, Weinlaeder (T)

NATIONAL MARINE MAMMAL LABORATORY (NMML)

During 1989, NMML research focused on long-term studies of endangered, depleted, and recovering marine mammal populations and their interactions with fisheries in the Antarctic, Arctic, Bering Sea, Gulf of Alaska, California Current, and North Pacific ecosystems.

Antarctic Ecosystem

Field studies were carried out 7 January to 15 March 1989 on the reproduction, abundance and feeding ecology of Antarctic fur seals (*Arctocephalus gazella*), chinstrap penguins (*Pygoscelis antarctica*), and macaroni penguins (*Eudyptes chrysolophus*) on Seal Island in the South Shetland Islands, and crabeater seals (*Lobodon carcinophagus*) on the pack ice near the Antarctic Peninsula. These studies are an integral part of the U.S. Antarctic Marine Living Resources (AMLR) effort, and focus on the ecology of top-level predators in the Antarctic ecosystem.

Thirty Antarctic fur seals were fitted with radio transmitters (15 of these were also fitted with time-depth-recorders, TDRs). Fur seals fed up to 75 km northwest of Seal Island, primarily between 2000 and 0500 hours; the deepest dive was 80 m. Six adult chinstrap penguins were fitted with TDRs, and 39 with radio transmitters; an additional 4 TDRs and 6 radio transmitters were attached to macaroni penguin adults. Both species foraged between 6 km and 35 km northwest of the island in the same area as the fur seals. Krill was the predominant prey taken, although fish were twice as abundant in the penguin's diet in 1989 (50%) as in 1988 (23%). Compared with 1988, chick production decreased 42% in chinstrap penguins in 1989 and 10% in macaroni penguins. The minimum percentage of chinstrap chicks banded in 1988 and observed alive on land in 1989 was 6.5%. Satellite tags were attached to three crabeater seals in Marguerite Bay in January 1989. The three seals were tracked for 6 weeks, 2 months, and 6 months, respectively, near the tip of the Antarctic Peninsula in the Weddell Sea along the pack-ice edge using the Service Argos System on NOAA-10 and NOAA-11 satellites.

Arctic Ecosystem

Low altitude aerial photographs were taken of bowhead whales (*Balaena mysticetus)* 15 April to 4 June 1989, as they migrated into the Chukchi and Beaufort Seas near Barrow, Alaska. The purpose of this study is to measure the lengths and identify individual whales to help determine calf production, calving intervals, and juvenile survival, and to estimate abundance. Approximately 10,000 photographs have been taken since 1985

for use in measuring, calibrating, and identifying individual whales, and to carry out systematic matches of photographs.

Other staff analyzed the photogrammetric database and estimated that approximately 40% of the bowhead population is sexually mature (> 13 m in length). A comparison of reidentified whales between years suggests that yearly growth for adult whales may be only 0.25-0.33 m per year. This means that an animal measuring 13 m long might be greater than 10 years of age. Further analysis of estimating historical population size from current population size suggests that age at sexual maturity is 9 years old or greater. The initial population size (prior to 1848) is estimated to be 14,000-27,000 and is not sensitive to current population size estimates. The level of reduction of the current population compared to its initial size ranges from 24 to 66% (mean = 40.9%, 95% Confidence Interval = 39.9-42.0%) with 94 of the 96 simulation runs (98%) falling below the presumed maximum net productivity level of 60% of the 1848 population size.

Two baleen plates (30 test samples from each) were analyzed for their ^{14}C and $\delta^{13}C$ carbon isotopic ratios, an experimental method to age bowhead whales. Intervals of ^{14}C appeared in mature animals as if $\delta^{13}C$ was being laid down in an approximately annual basis. However, there is considerable scatter in the data, especially for animals less than 9 m in length, suggesting that this method of ageing is unreliable.

Bering Sea and Gulf of Alaska Ecosystems

Steller Sea Lion

NMML staff conducted a range-wide survey of Steller sea lions *(Eumetopias jubatus)* in June and July 1989. A total of 24,953 adult and juvenile sea lions were counted from the western Gulf of Alaska to the western Aleutian Islands. In 1985, 67,617 sea lions were counted over the same area; thus, a decline of 63% (over 42,000 animals) took place in 4 years. Pup production declined 66% at the five major rookeries in the study area (from 10,593 in 1985-86 to 3,625 in 1989). The combined adult and juvenile population in Alaska (except Southeast Alaska) has declined about 77% since 1960, and in the eastern Aleutian Islands, levels have fallen 94%. The greatest rate of change in the Gulf of Alaska and western Aleutian Islands has occurred since 1985, whereas in the eastern Aleutian Islands the decline was greatest in the 1970s.

Northern Fur Seal

Field studies on northern fur seals (*Callorhinus ursinus*), in 1989 consisted of monitoring pup production and counting adult males on the Pribilof Islands (St. Paul and St. George) and Bogoslof Island of Alaska, and San Miguel Island, California. On St. Paul Island, NMML staff also documented the rate of debris entanglement of juvenile seals and changes in rookery space utilization, and radio-tagged pups to determine their timing and migration through the eastern Aleutian Islands after the breeding season. A comparison of several population parameters between the 1950s and 1980s demonstrated that the Pribilof Islands fur seal population has declined about 60%. For example, on St. Paul Island both the amount of space used by fur seals on rookeries and pup production declined 62%, and the number of territorial males declined by 59%.

Between 1976 and 1981 pup production on St. Paul Island declined 40%, but from 1981 to 1989 no significant trend is apparent; pup production on St. George Island continues to decline at about 6% per year. The entanglement rate of juvenile fur seals in 1989 was about 0.3% (the same as in 1988), a 25% decrease from the period 1976-86. In October and November 1989, 80 pups and 10 mother-pup pairs were fitted with radio transmitters to monitor their migration out of the Bering Sea. Six radio receivers were stationed in the eastern Aleutian Islands to record and store the radio receptions. A study of tooth weights and body lengths of juvenile fur seals showed a density dependent relationship during population declines. Other work showed that aquatic copulations occur in fur seals; something suspected but not previously documented. Lastly, NMML staff found that nonbreeding fur seals do not avoid prolonged airborne construction sounds (peak of 85 dB at source) or ground vibrations from heavy equipment operating within 100 m.

A conservation plan for northern fur seals was written which outlines research and management needed to assess the status and recovery of the population. The plan reviews the status of the Pribilof Islands population, possible causes of past declines, current threats to the population and its habitat, and critical information gaps, and recommends research and management actions to evaluate whether the population is recovering. Highest priority information needs are to determine why fur seals are dying at sea (especially juveniles), survival and recruitment of females, and the causes of pup mortality on and near the rookeries.

Exxon Valdez Oil Spill

The *Exxon Valdez* oil spill on 24 March 1989 affected hundreds of miles of shoreline that included haul-out and rookery space used by Steller sea lions and harbor seals

(Phoca vitulina), as well as large areas of Prince William Sound used by cetaceans for feeding and rearing their young.

The NMML's initial role beginning 25 March was to document what pinnipeds and cetaceans were present, their relative abundance, and their general habitat use at the time of the spill. Aerial and vessel surveys were conducted to document marine mammal encounters with oil, locate haul-out and rookery beaches, and identify stranded animals for necropsy. NMML staff also assisted in developing protocols for rehabilitating harbor seal pups by providing advice on where, when, and how cleanup operations should proceed where pinnipeds are found, and helped coordinate the large public information effort needed in Valdez, Alaska.

Five research projects were initiated to assess the damage to marine mammal populations, one each on killer whales (*Orcinus orca*), humpback whales (*Megaptera novaeangliae*), Steller sea lions, and harbor seals, and one on necropsying stranded cetaceans. Seven killer whales were found to be missing from the resident AB pod and two from the resident AE pod. (The first letter "A" stands for Alaska, and the second letter designates the particular pod.) The number of missing AE whales is within the expected annual loss for any one pod. The number of whales missing from AB pod, however, is significant because this rate (19%) is about six times higher than any previously reported. The causes for the missing whales is unknown. There was no difference in the number of humpback whales using Prince William Sound in 1989 compared with 1988. There was, however, a significant shift in their movements and habitat use in the sound after the oil spill. The preliminary conclusion is that the humpback whales may have been disturbed by the increased vessel traffic and oil cleanup activities.

Steller sea lions were present during the oil spill, but those observed did not avoid contact with the oil. Seventeen sea lions were analyzed for histopathology and tissue hydrocarbon content, but the analyses have not been completed. Harbor seals were regularly seen on oiled beaches, and over 70% of the seals in oiled areas were oiled. The carcasses of 39 seals were necropsied. One oiled adult harbor seal showed severe damage to the central nervous system, liver, and trachea. Fluorometric analysis of bile from two other oiled harbor seals showed that they had assimilated petroleum hydrocarbons, whereas an unoiled seal in the sound had not. Tissues from another oiled seal had high levels of polycyclic aromatic hydrocarbons, products associated with inhaling toxic fumes from recently spilled oil. Aerial surveys of haul-out areas in autumn 1989 showed a 45% decrease in the number of harbor seals in oiled areas between 1988 (pre-oil spill) and 1989, but only a 16% decline in unoiled areas. Both the Steller sea lion and harbor seal populations are declining in the Gulf of Alaska from

other indeterminate causes, and thus an assessment of the damage to these populations may be difficult to make.

The carcasses of 37 cetaceans were found on beaches near Prince William Sound. Tissues collected from seven animals were submitted for analysis (three gray whales, *Eschrichtius robustus*, three harbor porpoises, *Phocoena phocoena*, one minke whale, *Balaenoptera acutorostrata*). Most of the 37 animals had either died before the spill or showed no external signs of contact with oil. One stranded gray whale near Kodiak Island had come in contact with oil, but the preliminary evidence suggests that the animal had not ingested any oil. The analyses for hydrocarbons on the other whales have not been completed.

California Current Ecosystem

Northern Elephant Seal

Five adult male elephant seals (*Mirounga angustirostris*), on San Miguel Island were tagged with micro- processor-controlled TDRs to determine their migratory and feeding behavior from March to July 1989. This newly designed processor records geographic position using sea-surface light intensity and seawater temperature, besides the usual hydrostatic pressure for depth of dive. The average time at sea for all five animals was 115 days, with modal dive depths at 400 and 750 m in water generally averaging 4,000 m. The deepest dive recorded was approximately 1,500 m. Two animals migrated to the eastern Aleutian Islands to feed, two migrated to the Gulf of Alaska, and one remained in offshore waters off central California for 4 months of feeding.

Harbor Porpoise

The incidental take of harbor porpoise in the coastal salmon set-net fishery in Washington State was studied from 1987 to 1989 in cooperation with the Makah Indian Tribe. The number of harbor porpoise incidentally killed, from a population of unknown size, was estimated to be 100 in 1987, and observed to be 102 in 1988 and 23 in 1989. About 60% of the porpoises taken in the fishery (1987-89) were juveniles; adult males and females were represented in about equal numbers. The level of incidental take in 1989 was less because of a significantly reduced fishing effort that year. From 27% observer coverage of the fishery in 1989, an estimated 36 porpoises were taken throughout the fishery. Based on simple population recruitment projections (using the so-called "2% rule"), there would need to be 5,000 harbor porpoise in the population to sustain a take of 100 per year. A preliminary population estimate of about 700 har-

bor porpoise was obtained in 1989 for an area from 50 km north and south of the fishery offshore to about 20 km.

California Sea Lion

The NMML has studied the predation of California sea lions *(Zalophus californianus)* on steelhead trout (*Oncorhynchus mykiss*) at the Hiram M. Chittenden Locks and fish ladder, in Seattle, since 1984. The escapement rate of steelhead has declined by more than 50% in the past 5 years. In cooperation with the Washington Department of Wildlife, U.S. Army Corps of Engineers, Northwest Regional Office of the NMFS, and others, the NMML initiated a sea lion capture and relocation program in 1989 to increase the escapement of the native stock of steelhead by reducing predation by the sea lions. A total of 37 sea lions were captured and moved by truck and horse trailer to the outer coast of Washington State between 17 February and 19 April 1989. All animals were permanently marked by hot branding and flipper tagged to help track them throughout their life. Each sea lion was also fitted with a radio-tag for tracking after they had been relocated. Twenty-nine of the 37 sea lions returned to Puget Sound within an average of 15 days; 5 animals were recaptured three times. Eleven animals were observed in California between June and September 1989. Steelhead escapement rates did not increase in 1989.

North Pacific High Seas Ecosystem

Between June and December 1989, nine U.S. and five Canadian scientific observers were placed on Japanese commercial squid driftnet vessels to document incidental take of nontarget species and marine mammals. The U.S. and Canadian observers monitored 498 retrievals and Japanese observers monitored 791 retrievals. Marine mammals were incidentally taken, but by mutual agreement with Canada, Japan, and the United States, the data will not be released until they have been fully analyzed.

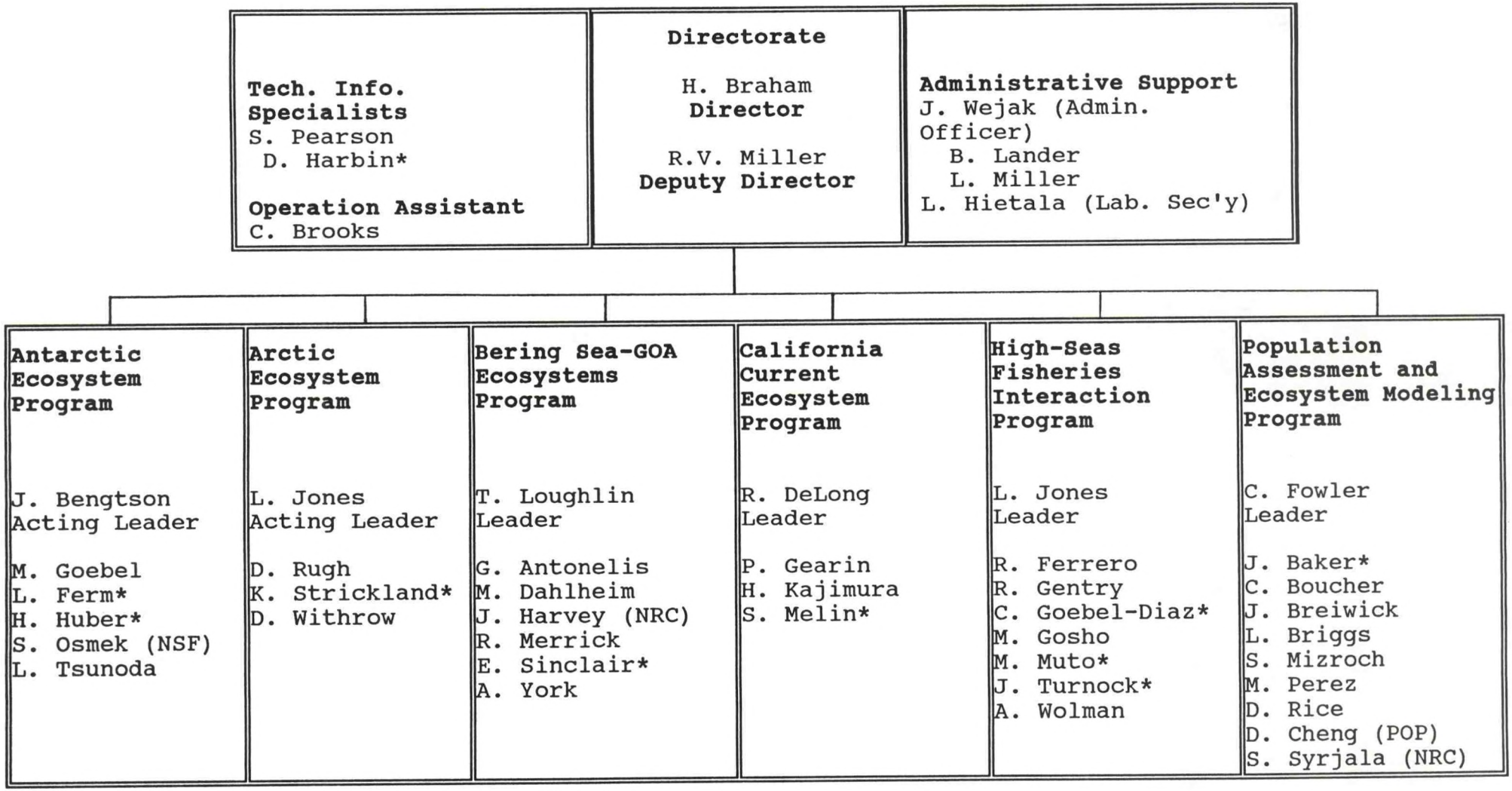
International and Other Activities

U.S.-U.S.S.R. Marine Mammal Project

The primary goal of this cooperative research program is to study the biology, ecology, and population dynamics of marine mammal species of interest to both countries, with the objective of fostering effective management of these animals. NMML staff chaired the project for the U.S. side and helped to organize a total of six major exchanges during 1989, including the second joint sea otter (*Enhydra lutris*) workshop and a series of joint walrus (*Odobenus rosmarus*) studies carried out by the U.S. Fish and Wildlife Service.

In 1989, Soviet researchers participated in U.S. aerial surveys of Steller seal lions in the Aleutian Islands and western Gulf of Alaska while American scientists participated in a survey of sea lions on the Kurile Islands on the Soviet research vessel *Rubezhnoe*. Aerial surveys of sea lions on the Kamchatka Peninsula were carried out by Soviet specialists under the U.S.S.R. program. The survey data from the Aleutian Islands and the western Gulf of Alaska indicate the population continued to decline since the 1985 survey.

NATIONAL MARINE MAMMAL LABORATORY
1989



* Temporary Appointment
NRC National Research Council Fellow
NSF National Science Foundation funds
POP Platforms of Opportunity Program Coord.

RESOURCE ASSESSMENT AND CONSERVATION ENGINEERING (RACE) DIVISION

The RACE Division continued its program of resource assessment to provide scientific information for the management of marine fish and shellfish. The Division's triennial samping emphasis was in the Washington-Oregon-California region but specific purpose surveys were conducted in the Gulf of Alaska and Bering Sea as well. The Division also continued to support for the third year the west coast mesh size experiment conducted by the Fisheries Research Institute, University of Washington, and funded by the Saltonstall-Kennedy Act, Alaska Fisheries Science Center, and now Washington Sea Grant. In addition, research continued on recruitment processes through the Fisheries-Oceanography Coordinated Investigations (FOCI) study in Shelikof Strait, as well as studies on fisheries pathology, ecology, acoustics, and sampling gear performance. These activities were supported by RACE data management and sampling gear maintenance groups.

Bering Sea Groundfish

The Bering Sea Groundfish Subtask, in conjunction with the Shellfish Assessment Task of the Kodiak Facility, conducts annual bottom trawl surveys to assess the condition of important groundfish and crab resources in the eastern Bering Sea (see later section on Shellfish Assessment for results of the crab research). About 1.6 million metric tons (t) of groundfish have been harvested from this region each year since 1985. Groundfish data from the surveys are used to provide the North Pacific Fishery Management Council (NPFMC) with fishery-independent estimates of the abundance and biological condition of commercially exploited stocks, to provide distribution and abundance information to commercial fishermen, and to develop a time series of data to study the population dynamics and interactions of groundfish species. The 1989 survey was the eleventh consecutive year in which a standard survey area, encompassing a major portion of the eastern Bering Sea continental shelf, has been sampled in this time series.

As per standard procedures, the 1989 survey was carried out aboard two chartered fishing vessels during the period from early June to early August. The two vessels sampled 400 stations in an area of about 465,000 km^2. The majority of this effort (354 stations) was to assess the groundfish and crab resources in the standard survey area. An additional 24 stations were sampled north of the standard survey area to provide assessment data for the snow crab (*Chionoecetes opilio*) resource in this area which has recently come under exploitation. In addition, 12 inshore stations were sampled along the Alas-

ka Peninsula to study trawl bycatch rates of crab and Pacific halibut (*Hippoglossus stenolepis)* for the NPFMC, and 10 inshore stations along the Alaska mainland were sampled to assess nearshore concentrations of yellowfin sole (*Limanda aspera*).

Results of the 1989 survey have shown that most groundfish in the eastern Bering Sea remain in excellent condition. The estimated biomass of walleye pollock *(Theragra chalcogramma*) in 1989 (5.9 million t) was one of the highest recorded; the sampled population consists of larger-older fish than in the past. This high biomass estimate reflects the high proportion of larger-older fish in the population which tends to occupy near-bottom water to a greater degree than younger pollock. Other evidence, such as data from age structured models, indicates that the abundance of pollock has been stable or has declined moderately, but still remains relatively high.

A several-fold increase in abundance of Pacific cod (*Gadus macrocephalus*) was documented by the bottom trawl data during the late 1970s and early 1980s. The abundance of cod remained at an observed high level of about 1.0 million t from 1981 to 1987. The 1988 and 1989 estimates were only moderately lower at 960,000 t.

There have also been increases in abundance of most species of flatfish during the 1970s and 1980s. The biomass of the flatfish species complex more than doubled between 1979 (2.7 million t) and 1989 (5.8 million t). Yellowfin sole and rock sole (*Lepidopsetta bilineata*), with increases of approximately 1.0 million t each, account for most of the increase. The biomasses of flathead sole (*Hippoglossoides elassodon*) and arrowtooth flounder (*Atheresthes stomias*) also increased 300,000 to 400,000 t. Some of the apparent increase in abundance of flatfish is the result of a new standard trawl adopted in 1982 which is considered more efficient for flatfish than trawls used in earlier years. Nevertheless, it is clear that the abundance of these species are at observed historic high levels.

The only flatfish species of concern is Greenland turbot (*Reinhardtius hippoglossoides*). The survey data has shown very low recruitment of juvenile Greenland turbot since the early 1980s and the 1989 survey results showed a continuation of this poor recruitment. However, the adult population which occupies continental slope waters is protected by the NPFMC through reduced catch quotas.

Biological data collected during the surveys have revealed that the fluctuations in abundance of eastern Bering Sea groundfish are mainly the result of variability in recruitment. Strong recruitment has been the primary reason for the improved condition of various flatfish species; recent recruitment appears to be high and should maintain the populations at a high level of abundance in the near future. Increases in abundance of Pacific cod and walleye pollock resulted from very strong year classes spawned in 1977

and 1978 and abundance has been maintained at high levels by moderately strong recruitment in 1982 and 1984. Year classes have been relatively weak for both of these species since 1984.

Gulf of Alaska Groundfish

The Gulf of Alaska Groundfish Subtask conducts assessments of groundfish stocks in the Gulf of Alaska and the Aleutian Islands. During 1989, these field research activities included a bottom trawl survey of the central Gulf of Alaska, a domestic longline survey of the Gulf of Alaska, and a cooperative Japan-U.S. longline survey of the Aleutian Islands, Bering Sea, and Gulf of Alaska. Subtask personnel presented results of these surveys to the International North Pacific Fisheries Commission (INPFC) and the NPFMC through status of stocks documents and other publications and presentations.

Bottom Trawl Survey of the Central Gulf of Alaska

On 26 October 1989, the fishing vessel *Pelagos* returned to Seattle after completing 55 charter days engaged in a special bottom trawl survey of a focused study area in the central Gulf of Alaska. A total of 108 stations were sampled to assess changes in the distribution and abundance of offshore groundfish stocks.

The survey area extended westward from 147° W longitude to 154° W longitude on the southeast side of Kodiak Island and southward to 57° 30' N latitude in Shelikof Strait at bottom depths ranging from 33 to 293 m. Due to fewer available vessel days for this special study, only about one-third of the area surveyed during triennial surveys of 1984 and 1987 was sampled in 1989. Sampling intensity in the subarea was also less (about one-third of that in 1984 and 1987) with 100 trawl hauls judged to be successful and included in the data analysis. The unsuccessful tows were generally due to excessive gear damage from attempting to sample over rough seabeds.

Biomass was calculated for each species encountered during the survey and compared to the same areas and depths assessed during the 1987 triennial bottom trawl survey. Of the nine most abundant species encountered during the 1989 survey, six had higher biomass estimates than observed during 1987. Walleye pollock increased 131% to 825,904 t, arrowtooth flounder 98% (839,528 t); Pacific halibut 27% (309,570 t), flathead sole 69% (164,586 t), and Dover sole (*Microstomus pacificus*) 13% (44,843 t). Species with estimated decreases in biomass included Pacific cod (*Gadus macrocephalus*) -33% (138,512 t), sablefish (*Anoplopoma fimbria*) -6% (103,607 t), and rock sole -38% (46,356 t).

U.S. Longline Survey

The third annual U.S. longline survey of the upper continental slope and deep gullies of the Gulf of Alaska was conducted aboard the longliner *Ocean Prowler* from 26 June to 12 September. This research was a cooperative effort with the Auke Bay Laboratory.

The primary survey objective was to determine the relative abundance and size composition of slope-resident groundfish species: sablefish, shortspine thornyhead (*Sebastolobus alascanus*), and shortraker and rougheye rockfish (*Sebastes borealis* and *S. aleutianus*). The second objective was to determine the relative abundance and size compositions of other species such as Pacific cod, grenadiers (*Macrouridae*), arrowtooth flounder, and Pacific halibut.

One hundred twenty-six longline sets were completed at 63 preselected stations. Forty-seven of these stations were sampled at the same sites, distributed from the Islands of Four Mountains (170°W longitude) to Dixon Entrance, that have been sampled annually since 1979 by the Japan-U.S. cooperative longline survey. The U.S. sampling gear was identical to that of the Japanese with respect to number of hooks, bait, and length of groundline, but differed in hook type, gangion length and thickness, and anchoring arrangement. Sampling in deep gullies was expanded to adequately assess the abundance and size composition of sablefish in those areas.

Sixteen kilometers of groundline containing 7,200 hooks baited with squid (*Illex* sp.) were fished at each station. Sablefish relative abundance indices (relative population number) decreased by 18% from 1988 to 1989, virtually the same decrease detected by the U.S.-Japan cooperative longline survey for the same period. Both decreases were statistically significant ($p \leq 0.05$). Rougheye and shortraker rockfish abundance in the longline catches increased 35%, but the change was not statistically significant. Shortspine thornyheads increased by a statistically significant 77%.

Cooperative Japan-U.S. Longline Survey

The eleventh annual Japan-U.S. cooperative longline survey was conducted in the Aleutian Islands, Bering Sea, and Gulf of Alaska. The Japanese longline vessel *Tsune Maru No. 31* sampled 107 stations with 7,200 hooks (8.6 nmi of groundline) at each station. The depths sampled by each set ranged between approximately 100 and 1,000 m.

The primary objective was to obtain indices of sablefish and Pacific cod abundance; assess other major catch components such as halibut, arrowtooth flounder, Greenland

turbot, rockfish, thornyheads, and grenadiers; tag sablefish; and collect biological information about sablefish. As in previous years, the cruise occurred from early May to mid-September. U.S. scientists participated in data collection activities aboard the vessel during all research operations. The Gulf of Alaska index of sablefish abundance (relative population number, RPN) for the upper continental slope decreased 17.5% from 1988 to 1989. This was virtually identical to the decrease detected in the same area by the 1989 NMFS longline survey reported above. Both the Aleutian Islands area and the southeast Bering Sea showed small increases in sablefish RPN, but due to killer whale depredation of hooked sablefish during the previous year's survey, it was not possible to compare the two annual results.

West Coast Groundfish

Four surveys were conducted off the west coast by the AFSC in 1989. They included the fifth in a series of coastwide triennial groundfish surveys, a trap survey to obtain indices of sablefish relative abundance off Washington and Oregon, and two replications of a bottom trawl survey of the continental slope waters (100-700 fathoms) off central Oregon in cooperation with the Southwest Fisheries Science Center.

1989 Triennial Survey of West Coast Groundfish Stocks

The fifth in a series of triennial comprehensive surveys of west coast continental shelf groundfish resources was conducted July-September. This survey series is designed to describe and monitor the distribution, abundance, and population biology of groundfish stocks off the U.S. Pacific coast. The specific objectives of the 1989 survey included describing and assessing the demersal component of the Pacific whiting resource with concurrent bottom trawl and echo integration surveys in conjunction with the Pelagic Resource Assessment Task; assessing the abundance of the prerecruit component of sablefish, specifically those 1.5 years old; and continuing to monitor the status of other groundfish stocks. The 90-day bottom trawl survey was conducted aboard two chartered commercial trawlers and 540 stations between Point Conception, California, and Nootka Sound, British Columbia, were successfully sampled between the depths of 55 and 366 m (30 to 200 fathoms). Temperature and CTD profiles were collected at selected stations throughout the survey range to relate oceanographic conditions with the distribution of groundfish species. The Pacific whiting abundance estimate from the bottom trawl survey was approximately 345,000 t in U.S. waters, of which 60% occurred in the INPFC Columbia area. Some indication of a moderately successful recruitment of the 1987 year class was seen in the size composition of the survey catches.

The overall whiting abundance estimate increased by almost 45% since the last survey in 1986. Estimates of sablefish abundance from this survey show an increase, especial-

ly in the areas north of San Francisco. The largest increase was seen in the Columbia area, where sablefish biomass estimates more than doubled. The 1989 estimate for the entire survey area exceeded the 1986 estimate by approximately 42%.

Although the 1989 survey design did not specifically include the objective of obtaining precise estimates of shelf rockfish abundance as it had in years past, estimates were derived for canary (*Sebastes pinniger*) and yellowtail (*S. flavidus*) rockfish. Canary rockfish abundance estimates followed the downward trend that has been observed in trawl survey abundance estimates since 1977, declining by about 25% since 1986 over the entire survey area. Yellowtail rockfish abundance estimates showed no notable changes since 1986 except in the U.S. portion of the INPFC Vancouver area, where the 1989 estimate was 3.5 times that in 1986. Pacific ocean perch abundance estimates showed a similar upturn in the U.S. Vancouver area, increasing by over six times. The statistical significance of apparent changes in biomass estimates from year to year have not been determined.

Sablefish Abundance Indexing

The monitoring of sablefish relative abundance using standardized CPUE from trap sets has continued since 1979. Sampling is conducted on alternate years between the Washington-Oregon and California regions. In 1989, eight index sites off Washington and Oregon were sampled. Strings of 10 conical traps each were fished twice at each of 6 standard depths (275, 411, 549, 686, 823, and 960 m) and 6 additional deeper sets were made at selected sites. Catch rates were highest at the 411 and 549 m depths and mean lengths increased with depth. Catch rates for all eight sites combined were approximately 14 and 68% lower than those from 1987 and 1985 surveys, respectively. Sablefish distribution by depth changed between 1987 and 1989. Catch rates in the three shallowest strata (150-300 fm) increased by about 12%, while catch rates in the deeper strata declined by approximately 54%. Mean fork length of sablefish caught during pot index surveys has generally decreased from 56.7 cm in 1979 to 52.6 cm in 1989. The mean lengths for both sexes (51.7 cm for males and 54.3 cm for females) are, as in 1987, very close to lengths at 50% maturity for sablefish in this region. These results indicated that only approximately 53% of the males and 35% of the females captured in the 1989 survey were sexually mature. In 1989, 1,260 sablefish were tagged and released, continuing the Center's research on distribution and movement of this species.

1989 NMFS AFSC/SWFSC Cooperative Sablefish and Dover Sole Continental Slope Research

Two replicate surveys were completed in 1989 assessing the demersal fish and shellfish species of the upper continental slope (183-1,280 m) off central Oregon. These surveys were identical to others, completed in 1984 and 1988, which examined the seasonal effects on maturity, distribution, abundance, and community structure and added late winter and early fall data sets to that collection. In February-March 1989, the NOAA research vessel *David Starr Jordan* successfully collected information from 41 stations and in September the chartered trawler *Golden Fleece* completed successful sampling at 46 stations. Sablefish was an important catch component in all depth strata. Pacific whiting, Dover sole, arrowtooth flounder, and shortspine thornyhead were important in samples shallower than 550 m and were replaced in deeper samples by Pacific grenadier (*Coryphaenoides acrolepis*), longspine thornyhead (*Sebastolobus altivelis*), grooved Tanner crab *(Chionoecetes tanneri*), and giant grenadier (*Albatrossia pectoralis)*. Southwest Fisheries Science Center scientists collected muscle tissue samples from Dover sole for an investigation of water content and flesh quality.

Pelagic Resource Assessment

The primary activity of the Pelagic Resource Assessment Task is to assess the pelagic fisheries resources by using hydroacoustic-midwater trawl survey techniques. Associated activities include ongoing development of the data collection system, its standardization, and further research into other factors affecting the accuracy and precision of survey results. The Task has conducted triennial surveys of Pacific whiting along the west coast (Washington, Oregon, and California 1977-89), of walleye pollock in the Bering Sea (1979-88), and annual surveys of pollock in the Gulf of Alaska (mainly Shelikof Strait, 1981 and 1983-89). Joint U.S.-Japan (Far Seas Fisheries Research Laboratory of the Fisheries Agency of Japan) surveys of pollock spawning aggregations were conducted in the Aleutian Basin during January and February 1988 and 1989 and in parts of the Bering Sea shelf in 1989.

Aleutian Basin and Bering Sea Shelf Surveys

A joint U.S.-Japan survey of the Aleutian Basin and part of the Bering Sea shelf was conducted during 20 January-8 February and 15-February-7 March. The U.S. effort amounted to approximately 6,000 trackline miles and 27 midwater trawl hauls. Few walleye pollock were observed in most of the surveyed portion of the Aleutian Basin. A dense spawning aggregation was found between Bogoslof Island and the Islands of Four Mountains on the southeast side of the basin. On the shelf, an extensive aggregation of moderate density was found northwest of Unimak Island, and a smaller, denser

aggregation was observed a few miles to the southeast of St. George Island. Pollock from near Bogoslof Island were larger than those from the shelf area. The mean lengths of the two groups were 48.6 and 45.1 cm, respectively. The opposite trend held for length-at-age. Among fish 8 years and older, average length-at-age was greater for shelf pollock than for those from the Aleutian Basin. Pollock aggregated near Bogoslof Island spawned during the last week of February. Shelf pollock were found to be mostly prespawning (mature but not yet spawning) during the survey. Spawning appeared to occur later and over a longer time period on the shelf than it did in the basin. Pollock sampled in the northwestern portion of the survey area, south of St. Matthew Island, were in a developing stage, and were not expected to spawn in late winter-early spring, 1989. Average size and age of pollock increased from northwest to southeast across the shelf.

The biomass estimate for Bogoslof spawning pollock aggregations was 2.1 million t, slightly lower than in winter 1988 (2.4 million t). The 1978 year class accounted for 42% and the 1982 year class accounted for over 11% of the total biomass.

Pollock biomass was estimated for four eastern Bering Sea shelf regions in winter 1989. The north shelf estimate was 277,000 t, with 41 and 33% of the biomass composed of the 1984 and 1982 year classes, respectively. Aggregations near the Pribilof Islands had an estimated biomass of 284,000 t. Forty-one percent of this biomass was from the 1982 year class, and 11% was from 1984 year-class pollock. In a mid-shelf region east of the Pribilofs, pollock biomass was estimated to be 123,000 t. Finally, a biomass estimate of 535,000 t was obtained for pollock from the southeast shelf region. This biomass was composed of 41% 1982 year-class fish and 17% pollock from the 1984 year class.

Gulf of Alaska Survey

The annual echo integration-midwater trawl survey of Shelikof Strait plus surveys of Davidson Bank (south of Unimak Island), the Chirikof Island area (southwest of Kodiak Island, at the shelf break), and Marmot Bay (between Kodiak and Afognak Island) were conducted 11-31 March. The pollock biomass estimated for the entire surveyed area was 324,000 t. The biomass and relative proportions found in the four subareas amounted to 290,000 t (0.895) in Shelikof Strait, 32,000 t (.098) in the Chirikof region, and 2,000 t (.007) in Marmot Bay. No pollock were found on Davidson Bank.

West Coast Survey

The fifth triennial hydroacoustic-midwater trawl survey of the west coast (1977-89) Pacific whiting resource was completed during 22 July-4 August and 7-22 August in conjunction with the West Coast Groundfish Subtask. A series of parallel east-west

transects spaced 10 nmi apart were run between the 55 m (30 fathoms) and 365 m (200 fathoms) depth contours from Point Conception, California, to near the north end of Vancouver Island, British Columbia, Canada. The total estimated biomass of the pelagic portion of the stock was 1.27 million t; 5- and 9-year-old Pacific whiting represent 50% of the population and 79% of the biomass, respectively. Final analyses of the survey data are currently in process and a final report will be completed by mid-1990.

Shellfish Assessment

Research conducted in 1989 by the Shellfish Assessment Task at the AFSC Kodiak Laboratory included continued assessment of eastern Bering Sea commercial crab stocks, monitoring of shrimp abundance, life history and ecological studies of commercial species of crabs near Kodiak, and biological studies of invertebrates that have established or potential commercial importance.

Eastern Bering Sea Crab Survey Results

With the exception of golden king crab (*Lithodes aequispina*), which frequents untrawlable grounds, all commercially important crab stocks of eastern Bering Sea crabs south of 62°N latitude were surveyed. Red and blue king crab (*Paralithodes camtschatica*, *P. platypus*) stocks remain at low levels relative to the history of the survey and there are no definite signs of recovery. Tanner crab (*Chionoecetes bairdi*) abundance has shown remarkable recovery from low levels in the mid-1980s that led to fishery closures in 1986 and 1987. Eastern Bering Sea snow crab (*C. opilio*), which is currently the most commercially valuable species in nationwide crab landings, remains at high and apparently stable levels, having recovered from the low abundance that characterized 1981 through 1983. Entering the 1990s, eastern Bering Sea crab fisheries will be dominated by Tanner and snow crab, although some recovery of king crab stocks is possible.

The Bristol Bay red king crab stock has suffered from poor recruitment throughout the 1980s and remains at historically low levels. The estimated abundance of legal males increased from 6.4 million crab in 1988 to 11.9 million in 1989. This increase was reflected in landings of 7.4 million pounds ($37.7 million) in 1988 and 10.3 million ($51.5 million) in 1989. Since the catch per pot lift in the fishery was stable at eight crabs, there is concern about the precision of survey estimates. The survey estimate of prerecruit abundance showed no significant improvement. There is little indication of recovery in this stock which historically dominated eastern Bering Sea crab fisheries.

Blue king crab stocks inhabit waters near the Pribilof Islands and near St. Matthew Islands. Prerecruit blue king crab inhabit rocky, untrawlable grounds in both areas and,

as a result, little information is available on recruitment trends. The abundance of legal crab in both stocks remains low. In the Pribilof Islands estimated abundance of legal males was 220,000 and has not exceeded 1 million crab since 1983. Too few prerecruit crab have been captured in 1987 to 1989 trawl surveys to establish any possible recruitment trend. The Pribilof fishery has been closed to commercial fishing since 1987 and is unlikely to reopen in 1990. Estimated abundance of legal males near St. Matthew Island increased from 0.8 million in 1988 to 1.5 million in 1989. Although this was the highest estimate of legal abundance in 1984, it should be interpreted cautiously since an unknown portion of legal crabs inhabit untrawlable grounds. Landings were 1.3 million pounds ($4.1 million) in 1988 and 1.2 million pounds ($3.4 million) in 1989, but the catch per pot lift of 13 crabs in 1988 fell to only 8 crabs in 1989. Improvements in the St. Matthew stock are not expected in the near future.

Tanner crab abundance has increased in each of the last three surveys. Estimated legal male abundance was 17.4 million crab in 1988 and 42 million in 1989. Prerecruit abundance is also improving. Tanner crab fisheries open in January and survey estimates should reflect improvement in prerecruit abundance in the following year. In 1989, landings were 7.0 million pounds worth $20.3 million and preliminary Alaska Department of Fish and Game (ADF&G) data indicate that landings will exceed 20 million pounds in 1990. Continued recovery of the eastern Bering Sea Tanner crab stock is expected.

Snow crab, which were once a less important crab fishery in the eastern Bering Sea, is now the Nation's most valuable crab fishery. New record landings have been taken in each year since 1984. Male crabs larger than the 102 mm carapace width are acceptable for processing, hence, the term "commercial males." Estimated commercial male abundance was 171.0 million crab in 1988 and 187.1 million in 1989. Although the increase was insignificant relative to the precision of the survey, this stock remains at historically high levels and shows no sign of decline. However, it should be noted that a disease called "bitter crab" is present in the population. This disease is caused by a blood dinoflagellate and epizootic infections have caused drastic declines in Tanner crab populations in parts of southeastern Alaska. Rates of infection are being monitored during the survey by taking blood smear and histological samples for analysis by the Fisheries Resource Pathology Task. The 1989 fishery produced landings of 149.6 million pounds ($112.2 million) and preliminary ADF&G landings indicate that landings will probably remain high in 1990. While abundance is expected to remain high in the near future, this stock has shown considerable and rapid fluctuations in the past.

The hair crab (*Erimacrus isenbeckii)* has been one of the less abundant stocks in the eastern Bering Sea, although landings reached 2.4 million pounds ($2.0 million) in 1980. Declines in estimated abundance have been recorded in each survey since 1981.

Estimated abundance of commercial size males (no legal size limit) was 0.6 million in 1988 and 0.4 million in 1989. Landings are largely incidental to Tanner crab fishing and have not exceeded 100,000 pounds since 1984. Size frequency information from 1988 and 1989 surveys, however, indicates that this stock may increase in the next several years. Hair crab are highly prized in Japan where all past landings have been marketed.

Shrimp Research

The annual survey of Pavlof and Volcano Bays was conducted in August. This survey series began in 1972 and represents the longest continuous assessment of a shrimp stock in Alaskan waters. The 1989 survey consisted of 20 tows and included 5,900 measurements for size-frequency analyses. The average catch rate increased from 12 pounds per nautical mile in 1988 to 18 pounds per nautical mile in 1989. Shrimp were also larger (135 per pound) in 1989 than in 1988 (174 per pound). Pink shrimp (*Pandalus borealis*) is the primary species in the two bays and made up nearly 100% of the 1989 catch. The estimated biomass of pink shrimp increased from 160,000 pounds in 1988 to 380,000 pounds in 1989 but remains insignificant relative to the 1977 peak estimate of 53,170,000 pounds. As has been true throughout the 1980s, finfish dominated survey catches in 1989, making up an average 89% of the total weight in trawl catches. Flathead sole, Pacific cod, and walleye pollock together made up about 86% of the finfish catch. Results of the 1989 Pavlof Bay survey have been distributed to industry.

Samples of shrimp taken incidentally in the 1989 eastern Bering Sea trawl survey have also been processed. Although trawls used in the Bering Sea survey are insufficient to catch shrimp, catches provide the only available annual index for the area. Foreign fleets harvested 95,000 t of shrimp from 1961 to 1968 in the Bering Sea. Since that time there has been little fishing, although recent interest has been expressed by U.S. industry. Unfortunately, analyses of 1989 survey data do not indicate that eastern Bering Sea shrimp stocks are recovering.

Juvenile King Crab and Sea Urchin Research

Divers continued research on growth and behavior of red king crab in Womans Bay, growth of the green sea urchin (*Strongylocentrotus droebachiensis*), and a contracted study of critical habitat for juvenile red king crab. The critical habitat study results from response to the Kodiak Island Borough's desire to select a possible site to attempt rehabilitation of Kodiak red king crab stocks. Objectives of this study are to determine: 1) abundance and distribution of first and second year juveniles, 2) habitat characteristics, 3) associations with habitat elements, 4) areal extent of habitat, and 5) prevalence of known diseases or parasites. Preliminary results have shown a strong association of

juveniles with sea stars, particularly *Evasterius troschelii*. Results of continued studies of growth and behavior were presented at the International Symposium on King and Tanner Crab in November. The developing sea urchin fishery in Kodiak was curtailed somewhat by the oil spill cleanup effort in Prince William Sound, but interest continues with 28 commercial divers landing 45,000 pounds ($36,000) in 1989. Field work on sea urchin growth was completed this year. Additionally, a NOAA-owned Nitrox system was transferred to Kodiak and NMFS divers were trained to operate the system. Use of the Nitrox system increases safety and enhances repetitive dive capability.

Other Invertebrates

In response to the growing interest in the pharmaceutical potential of marine organisms, the Kodiak Laboratory, over the past 2 years, has been making collections in cooperation with laboratories involved in such research. The Laboratory's interest is in the possibility of developing commercial fisheries and in obtaining information on the chemical composition of invertebrates that may be useful ecologically. Samples of invertebrates, including bryzoan, tunicates, sponges, nudibranchs, and sea pins, have been analyzed for lipid content by the Cancer Research Institute at Arizona State University, where extracts are also being tested for antineoplastic activity. Samples of echinoderms (*Psolus* sp., *Diplopteraster* sp., *Evasterias troschelii*, and *Lethasterias naniminses*) were sent to the University of Illinois School of Chemical Sciences and preliminary results indicate that extracts are cytotoxic to mouse leukemia cells. Various samples have also been sent to the Harbor Branch Oceanographic Institution and Smith Kline and French Laboratories. Collections will continue in 1990 during the eastern Bering Sea trawl survey and in the vicinity of Kodiak.

Recruitment Processes

Fisheries-Oceanography Coordinated Investigations (FOCI), a NOAA cooperative research program between the Recruitment Processes Task of the RACE Division and the Pacific Marine Environmental Laboratory (PMEL), is designed to investigate the causes of recruitment variations in commercially important fish and shellfish. The program's focus is the well-defined spawning population of walleye pollock in Shelikof Strait. The program consists of several areas of research, including field studies of eggs and larvae in relation to zooplankton and the physical environment, biochemical methods for assessing larval starvation and predation, and pollock behavior.

During the spring of 1989, FOCI conducted four cruises. The first, in early April, investigated the abundance and the horizontal and vertical distribution of eggs. The second, in late April-early May, studied hydrography and transport of early larvae; the third cruise, in mid-May, mapped the distribution of larvae from the Shelikof spawn-

ing; and the fourth cruise, in late May-early June, measured growth and mortality of the larvae. During the third cruise, scientists from the Atlantic Oceanographic and Meteorological Laboratory (AOML) in Miami, Florida, joined RACE scientists to use special samplers to investigate the vertical distribution of pollock eggs and larvae and their zooplankton prey.

Laboratory studies on environmental factors which influence survival and distribution of walleye pollock larvae are continuing at the Mark O. Hatfield Marine Science Center in Newport, Oregon. The focus of studies has been to examine the behavioral responses of larval walleye pollock to various physical factors that may potentially play a role in vertical movements and distribution. Diel periodicity in vertical distribution was evident and appeared to be under external control. During the day, larvae moved downward from the surface and then, as light decreased during evening twilight, larvae moved upward. At night, under total darkness, they continued to swim upward, with no cues to guide them other than their response to gravity (negative geotaxis). Changes in vertical distribution occurred concomitantly with changes in activity, orientation, and behavior. The presence of a thermocline caused larvae to move upward and away from the cold water. Turbulence at the surface elicited an avoidance response, resulting in the larvae moving downward. Findings were compared to those from the field and suggested how behavioral responses to a number of physical and biological factors can affect vertical movement and distribution.

From 1980 through 1987, 10 ichthyoplankton surveys were conducted off Washington, Oregon, and northern California coasts. Task personnel are now analyzing the results from these surveys to establish annual patterns of occurrence of fish eggs and larvae of the region and how these relate to local oceanography. A major emphasis of the Task in 1989 was to increase the ability to identify fish eggs and larvae collected. A summary of these findings entitled "A Laboratory Guide to Early Life History Stages of Northeast Pacific Fishes" was published as NOAA Technical Report 80 in 1989. Research is being continued to establish early life history series through rearing and examination of plankton samples particularly for rockfishes (*Sebastes*) and poachers (*Agonidae*).

Fisheries Resource Pathology

Task personnel participated in the eastern Bering Sea crab and groundfish survey and the west coast February-March slope and triennial surveys in 1989. During this period, 1,212 fish and crab samples were collected for histopathology. An additional 1,500 blood smears were prepared from *C. bairdi* and *C. opilio* to determine the prevalence and distribution of bitter crab disease (BCD) in the eastern Bering Sea. Tissues from 15 marine mammals were also submitted by the NMML for examination.

The Fisheries Resource Pathology Task continued its cooperative study with the Kodiak Laboratory (NMFS) and the Fishery Rehabilitation and Enhancement Division (FRED) of the ADF&G in Juneau to determine the distribution and prevalence of BCD in *C. opilio*. Results of the 1988 survey (Fig. 1) were completed and presented to the Kodiak Laboratory. Results from 1988 demonstrated that the causative parasitic dinoflagellate, *Hematodinium* sp., was widely distributed north of 62° latitude, especially between St. Lawrence and St. Matthew Island in the Bering Sea where disease prevalences ranged from 5 to 40%. *Hematodinium* was found less frequently in *C. opilio* south of 62° latitude, but preliminary 1989 field observations indicate that the disease is becoming more prevalent in this area.

No infections of *C. bairdi* have been confirmed, but studies will continue to monitor the status of this important resource. The distribution ranges of these two Tanner crab species overlap and there is concern regarding the possible susceptibility of *C. bairdi* to *Hematodinium* infection, particularly because BCD was first diagnosed in *C. bairdi* from southeast Alaska.

The Task continued its ongoing investigations on the diseases of red and blue king crab. Prevalences of the microsporidian disease continue to remain low since the recorded high levels of 1985. However, preliminary 1989 results indicate that the prevalence of the Herpes-like virus that infects the antennal gland of red and blue king crabs is increasing. The virus was not observed in the 1987 and 1988 samples. No new potentially important infectious agents have been identified.

Tissue samples from 11 marine mammals (8 northern sea lions, *Eumetopias jubatus*; 1 harbor seal, *Phoca vitulina*; 1 spotted seal, *P. largha*; and 1 northern fur seal, *Callorhinus ursinus*) were collected by NMML personnel from the Kuril Islands, U.S.S.R., and submitted for disease studies. The spotted seal and all eight northern sea lions presented mild respiratory stress, probably resulting from parasitic infections. The harbor seal was moderately infected with lungworms and presented corresponding parasitic pneumonia. The northern fur seal was unremarkable.

Data from the first 2 years (1986, 1987) of the juvenile walleye pollock (< 110 mm standard length) disease studies were published in "Pathology in Marine Science," the Proceedings of the Third International Colloquium on Pathology in Marine Aquaculture. Prevalence rates indicate that a microsporidian, *Pleistophora* sp., that infects skeletal muscle may play an important role in the population dynamics of this commercially important fish species (Fig. 2). Prevalences of this potentially fatal parasite increased rapidly in 40-60 mm fish, then markedly declined to 10% or less in fish greater than 75 mm.

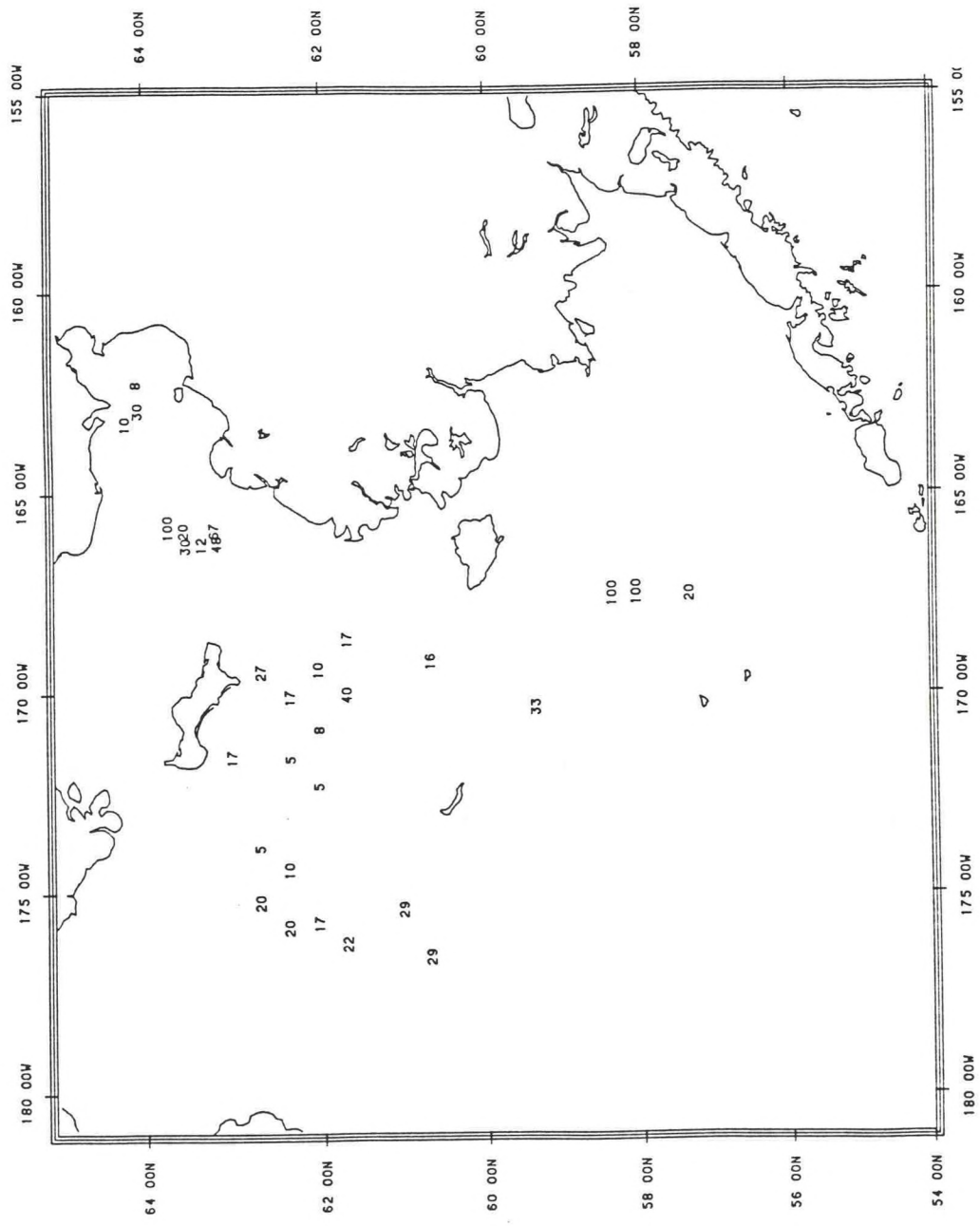


Figure 1. 1988 distribution and prevalence (%) of bitter crab disease.

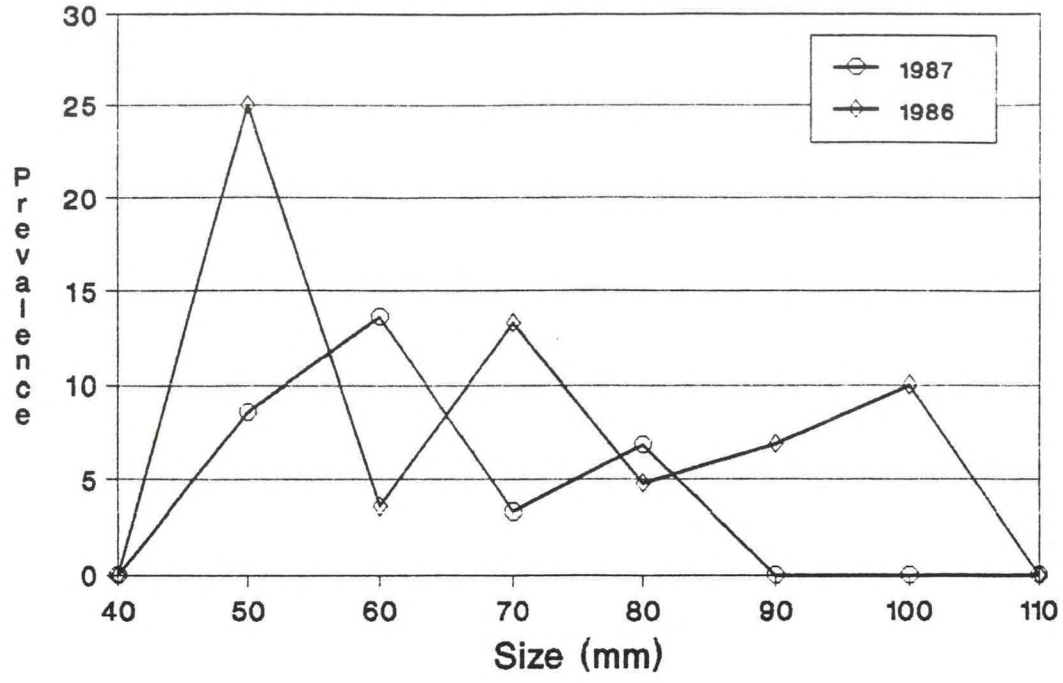


Figure 2. *Pleistophora* prevalences in juvenile walleye pollock.

Foreign Cooperative Research

Twelve foreign fisheries research vessels operated in North Pacific waters in cooperation with the Center during 1989 (Table 1). Research objectives were varied. The U.S.S.R. placed emphasis on groundfish species, and Japan dealt primarily with salmon and groundfish. U.S. investigators participated aboard four Soviet vessels and four Japanese vessels.

The Japanese continued their annual involvement in monitoring changes in the abundance and biological features of Alaska groundfish. They participated in a trawl and acoustic survey in the Bering Sea using the *Kaiyo Maru* and in the annual longline survey of sablefish in the Gulf of Alaska, Aleutian Islands, and Bering Sea aboard the *Tsune Maru No. 31.*

In 1989, the Soviets provided their research vessel, *Mys Babushkina*, for a survey of young walleye pollock in the Bering Sea and Gulf of Alaska, as well as the *Nemirov* and *Novokotovsk* for salmon studies.

Table 1.--Scheduled U.S. Cooperative Research with Foreign Governments - 1989
Northwest and Alaska Fisheries Centers, NOAA, Seattle, WA.

Vessel	Nation	Operating area	Dates	Research program	U.S. scientists	Ports of call	
MYS Babushkina	USSR	Bering Sea Gulf of AK	10-7/3	Groundfish	Benjamin Miller Kessler	Kodiak Dutch Harbor	4/10-12 5/17-18
Poseydon	USSR	WA, OR	August	Groundfish	TBN	Vancouver, B.C.	August
Nemirov	USSR	N. Pacific	April-July	Salmon (Seine)	Haaga Nenth	Dutch Harbor Kodiak	4/26-27 6/29
Novokotovsk	USSR	N. Pacific	4/28-5/15	Salmon (Trawl)	Leopold	Astoria	April 4/5
Rubezjnoye	USSR	Aleutians Kuriles	6/1-7/20	Marine Mammals	Merrick Baker	Dutch Harbor	6/4, 7/20
Oshoro Maru	Japan	N. Pacific Bering Sea	6/3-8/11	Gill net, Longline	Meyers Rogers	Dutch Harbor Vancouver, B.C.	6/26-30 7/21-26
Shin Riasu Maru	Japan	N. Pacific	6/1-7/22	Gill net, Longline	Davis	None	
Hokuho Maru	Japan	N. Pacific	6/6-7/28	Gill net, Longline	None	None	
Hokushin Maru	Japan	N. Pacific	6/1-30	Gill net	None	None	
Iwalo Maru	Japan	N. Pacific	6/1-7/10	Gill net	None	None	
Kaiyo Maru	Japan	Aleutian Basin	12/88-3/20/89	Trawl	Traynor Benjamin Nunnallee	Dutch Harbor	2/8-11 3/5-8
Tsune Maru No. 31	Japan	Bering Sea Gulf of AK	5/10-9/10	Longline	Payne	Dutch Harbor Kodiak Seattle	7/22-24 8/17-19 9/16

Conservation Engineering

The Conservation Engineering Task continued its vital role of fabrication, reconstruction, and supply of survey fishing gear to a fleet of NOAA and chartered research vessels working from California to the Bering Sea. This included support of research by NMFS laboratories in Seattle, Kodiak, Auke Bay, Honolulu, Tiburon, and La Jolla.

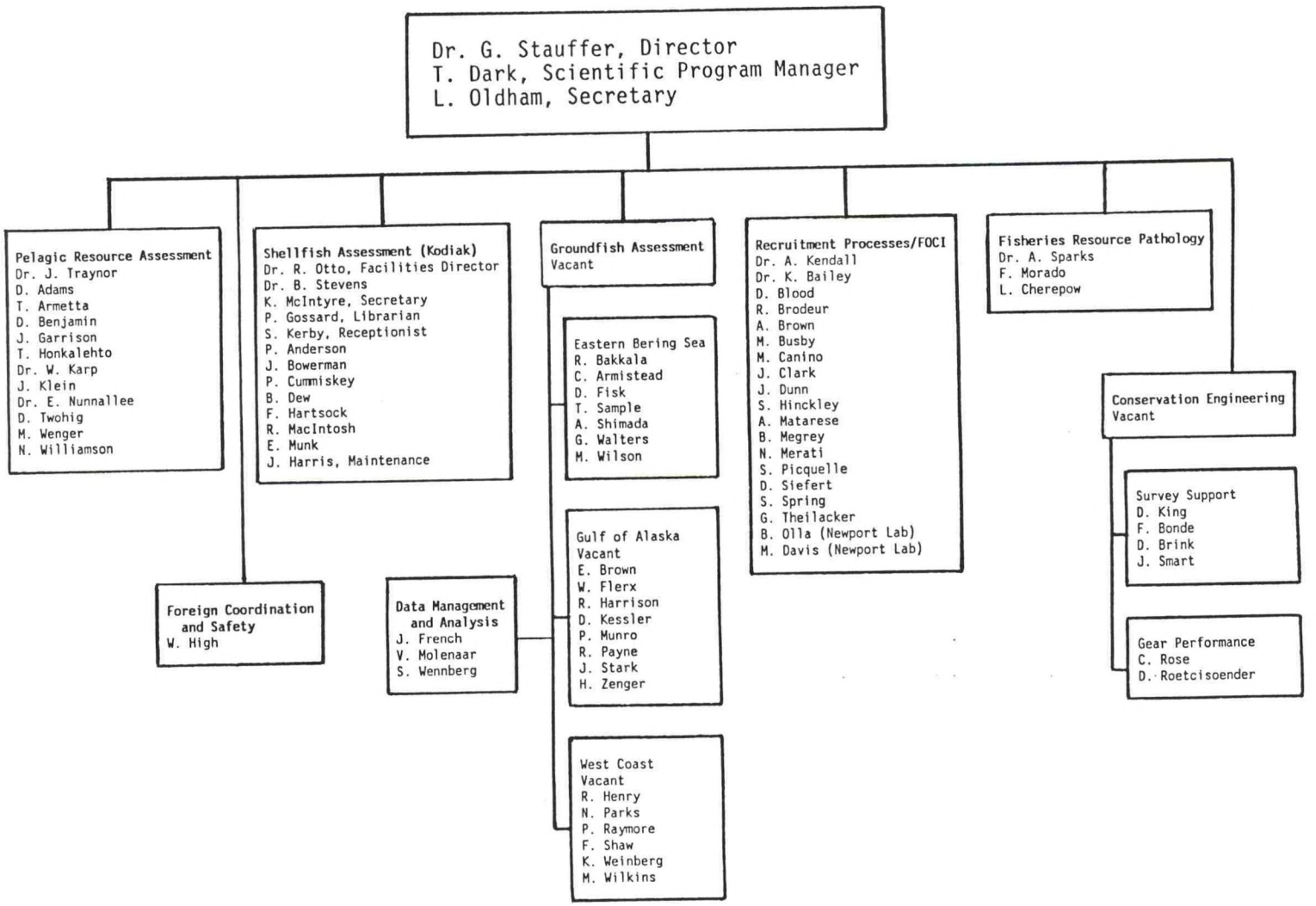
Recent work focused on determining the effects of variable operating dimensions of bottom trawls on survey results. Extensive use of acoustic trawl mensuration equipment, both during the surveys and in experimental work, has shown that the trawl's shape can vary considerably within and between stations in both width and height.

In addition to their use for standardizing the survey areas, these data have been analyzed to determine the best predictors of this variation and to evaluate its effects on survey results. A strong association has been found between trawl width and the length of cable used to tow the trawl (scope), with longer scopes associated with wider trawl openings and lower heights. Since longer scopes must be used in deeper water, trawl openings tend to be wider in the deeper areas covered by the surveys.

The traditional practice of using a single mean width to estimate the area swept by the trawl at each station overestimates that area in shallow water and underestimates it in deep water. Since the estimator of fish abundance at each station is the catch divided by the area swept, estimates of shallow water populations are negatively biased, while those in deep water have a positive bias. This bias has been corrected by measuring trawl widths on most tows and using those data to derive a function of width and scope and using it to estimate widths for those tows where measurements are not available. A series of simulations are being done to evaluate the trade-offs between the effort and expense of collecting comprehensive width data and the risk of biased results.

A 7-day cruise in December 1989 studied the effects of differences in trawl width on catching efficiency. Restricting lines between the towing cables were used to control the spread of a survey bottom trawl. Catches of paired tows using wide and narrow configurations were compared to test for catchability differences. Placing restricting lines between the warps at a point 25 fathoms in front of the doors allowed enough variation that some comparison pairs had to be discarded due to insufficient width differences. Attaching the restrictors at the doors provided extremely stable and controllable widths but had a higher potential of affecting fish behavior. Total paired sample size for this cruise was insufficient to detect significant changes in catchability with width.

RESOURCE ASSESSMENT AND CONSERVATION ENGINEERING DIVISION
1989



RESOURCE ECOLOGY AND FISHERIES MANAGEMENT DIVISION (REFM)

The REFM Division conducts research on the biology, ecology, and utilization of living marine resources to assist in the management of fishery resources in the Northeastern Pacific Ocean and the Bering Sea. Activities are organized under the fisheries observer program, age and growth studies, ecosystems modeling, food habits studies, status of stocks, and socioeconomic tasks.

Fisheries Observer Program

The Observer Program places scientific observers on foreign and domestic vessels fishing in the U.S. Exclusive Economic Zone (EEZ) of the northeastern Pacific Ocean and Bering Sea. The observers collect data which provide the basis for in-season management of foreign, joint venture, and domestic fisheries, and a means for evaluating and developing management strategies. Observers play important roles in monitoring compliance to U.S. fishing regulations and provide information that is useful in promoting development of the U.S. fishing industry.

The year 1989 was the 13th year that foreign and joint venture fisheries operated under the Magnuson Fisheries Conservation and Management Act (MFCMA). During 1989, the program deployed 163 observers to sample aboard vessels from 5 countries--Japan, Republic of Korea, U.S.S.R, Poland, and the People's Republic of China. The observers spent about 8,700 days sampling in the Bering Sea, the Gulf of Alaska, and in waters off Washington, Oregon, and California. Observers covered 95% of the foreign and joint venture fishing effort. Coverage was 94% in the Bering Sea-Aleutian Islands region and 97% in the Washington, Oregon, and California coasts. There was no joint venture or foreign fishing in the Gulf of Alaska in 1989.

In 1989, the program placed 35 observers on domestic vessels fishing in the groundfish fishery off Alaska. These observers were funded through a variety of sources including: funding by the domestic fishing industry, federal funding for implementation of the 1988 amendments to the Marine Mammal Protection Act, and funding from the North Pacific Fishery Management Council for the completion of their pilot domestic observer program.

The program was responsible for defining the sampling duties and data collection methods used by observers, training observers prior to deployment, debriefing observers upon their return, and editing and managing the resulting data. The work with

domestic observers and the domestic industry provided valuable experience for the implementation of an expanded domestic observer program in 1990 as well as data on the catches and operations of the domestic groundfish fishery.

Age and Growth Studies

The primary responsibility of the Age and Growth Studies Task is to age samples collected from commercially important groundfish species. This is achieved by counting annual rings on otoliths, scales, and fin-rays. The task must also establish ageing criteria for new species and examine problem areas where the generated ages appear questionable. Data from the Age and Growth Task are used by stock assessment scientists to model fish population dynamics.

In 1989, otoliths were used to age a total of more than 28,900 walleye pollock, Pacific whiting, Atka mackerel, sablefish, yellowfin sole, flathead sole, rock sole, Pacific cod, Pacific ocean perch, and northern and dusky rockfish. As a quality control measure, 20% of all production readings were aged independently by a second highly experienced age reader.

A sablefish ageing workshop was held from 14 to 17 February 1989, at the AFSC with age readers from the NMFS Tiburon Lab and the Canada Department of Fish & Oceans Pacific Biological Station, Nanaimo, British Columbia. The workshop was a follow-up to an otolith exchange in 1988 between these agencies. The workshop standardized ageing criteria for sablefish.

Ecosystems Modeling Task

The OSCURS (Ocean Surface Current Simulations) numerical model was established as a new tool for describing ocean variability. Activities involved running the OSCURS model for applications to variability studies in the Gulf of Alaska and the Bering Sea and also communicating preliminary results. Video animation unveiled the potential of this computer simulation approach to convey new insights into the immense time-space complexities in the ocean surface circulation.

Food Habits Studies

The Food Habits Task continued regular monthly observer training for collecting food habits information on key fish predators in the North Pacific. In 1989, 37 observers collected food habits data. In addition, Task personnel collected fish stomach samples during the summer NMFS resource assessment surveys in the eastern Bering Sea and off the west coast. Approximately 8,700 fish stomachs were collected in the Bering Sea

and 3,400 were collected off the west coast. Over 7,500 stomachs were examined in the laboratory. The Task initiated a 3-year plan to study the food habits of Pacific halibut in the Bering Sea and doubled the summer sampling coverage of the Bering Sea survey area.

The Task provided food habits information and analysis to others. For example, the Task examined the possible dietary origin of odors in pollock flesh and provided information about groundfish and crab trophic interactions. The group produced a videotape of the stomach sampling process and gave copies to instructors at the University of Washington. Student volunteers from Garfield High School interned in the laboratory and learned about basic taxonomy and fish food habits.

Research conducted this year included a statistical analysis of pollock stomach weight variability and flathead sole food habits. Our prey reference collection was expanded and an analysis of gill raker morphology was performed to improve the level of prey identification. Research results were published on interannual variability in cod predation on crab, walleye pollock and fur seal food web interactions, and interannual differences in walleye pollock cannibalism. Emphasis continues to be on interannual changes in predation that might provide insight into changes in year class strength or geographic distribution of prey species that are of commercial importance.

Status of Stocks Task

Alaska Fisheries

In 1989, the Status of Stocks Task continued to be actively involved in determining the condition of fisheries resources within the U.S. EEZ and developing strategies for their management. Groundfish research was conducted on commercially important stocks in the Bering Sea, Aleutian Islands, and Gulf of Alaska regions. Research included analysis of population dynamics, evaluation of management strategies, estimation of potential yields, and development of new assessment techniques. Three Task members served on groundfish management teams for the NPFMC, providing management recommendations for several important stocks. Task members continued studies of walleye pollock, yellowfin sole, Pacific cod, sablefish, Pacific whiting, and Pacific ocean perch; interregional productivity of Pacific ocean perch; analysis of voluntarily submitted joint venture logbook data; and the early life history of Pacific herring in the eastern Bering Sea.

The Task continued its third year of research programs to better understand the consequences of the intense unregulated fishery for walleye pollock in the international zone of the Bering Sea. The first objective of this effort was to review literature,

develop hypotheses concerning the stock structure, and initiate the testing of the hypotheses. The testing, a collaborative effort with the AFSC's RACE and NWFSC's CZES Divisions, focused on genetic, morphometric, and meristic features, and the otolith composition of samples taken in various parts of the Bering Sea. The second objective of the initiative is to estimate the biomass of the walleye pollock population in the Aleutian Basin, the deep water portion of the Bering Sea. Several international cooperative acoustic-trawl surveys were conducted in the basin during the spawning season. The third goal of the research is to determine the size and species composition of catches in the international zone. To achieve this, catch statistics have been requested from the various nations that fish in the zone. A voluntary observer program has also been implemented.

Studies concerning king and Tanner crab provided information that was used by management authorities in a variety of ways. Assessment information was employed by Alaska Department of Fish and Game (ADF&G) for establishing quotas for the Bering Sea crab fisheries. An analysis of the Bering Sea Tanner crab fishery was used by ADF&G to make decisions regarding the timing of fishery closures. Finally, work was completed on the effect of inaccuracies in the recruit data on spawner-recruit analyses, and research was started on size-based growth studies and an exploitation model for use in allowable biological catch (ABC) determinations.

Pacific Coast Fisheries

The Pacific coast groundfish group has a major role in estimating the productivity of groundfish stocks managed by the Pacific Fishery Management Council. The group's primary responsiblity is to prepare annual status of stock reports for Pacific whiting and sablefish. In addition, the group provides short-term technical support to Pacific coast fishery managers and conducts research designed to improve the accuracy of the annual stock assessments.

In 1989, the group developed a generalized version of the synthesis model for assessment of exploited fish stocks. This model shares some characteristics with other catch-at-age analysis techniques but has a greater ability to incorporate a variety of auxiliary information. The model simulates an exploited stock, derives expected values for the available data (fishery age or size composition, survey age or size composition, survey abundance, fishery effort), evaluates the deviations between the observations and expected values, and iteratively adjusts the parameters of the simulation model until the likelihood of the model's fit is maximized. This model was used in 1989 for assessing sablefish, Pacific whiting, and widow rockfish on the west coast, and walleye pollock in the Gulf of Alaska.

The Pacific whiting stock assessment was based on an age-structured version of the synthesis model, and contained a new evaluation of the optimum level of fishing mortality. Geographic and temporal changes in the age composition of the resource were described in order to better understand growth and migration. Environmental influences on growth were investigated in an on-going study designed to elucidate the cause of a declining trend in the body size of Pacific whiting.

The assessment of sablefish was conducted in collaboration with the Southwest Fisheries Center, and used the size-structured version of the stock synthesis model. New work on sablefish in 1989 emphasized the consequences of a change in the criteria for age determination in this difficult to age species.

Socioeconomic Task

The Socioeconomic Task was involved in providing economic information and assistance to the Pacific and North Pacific Fishery Councils, industry, NMFS, and other agencies. This included preparing reports and publications, participating on council plan teams in preparing draft regulatory impact reviews of fishery management plan amendments, and preparing and reviewing research proposals and programs.

Task members provided major contributions to the groundfish management plan amendments, and an update and revision of the west coast groundfish plan. The major issues included the bycatch problem in the groundfish fishery, pollock roe-stripping, and limited entry in the Alaska sablefish fishery and in the West Coast groundfish fishery. Task members were involved in implementing a comprehensive data collection program for the domestic fisheries off Alaska.

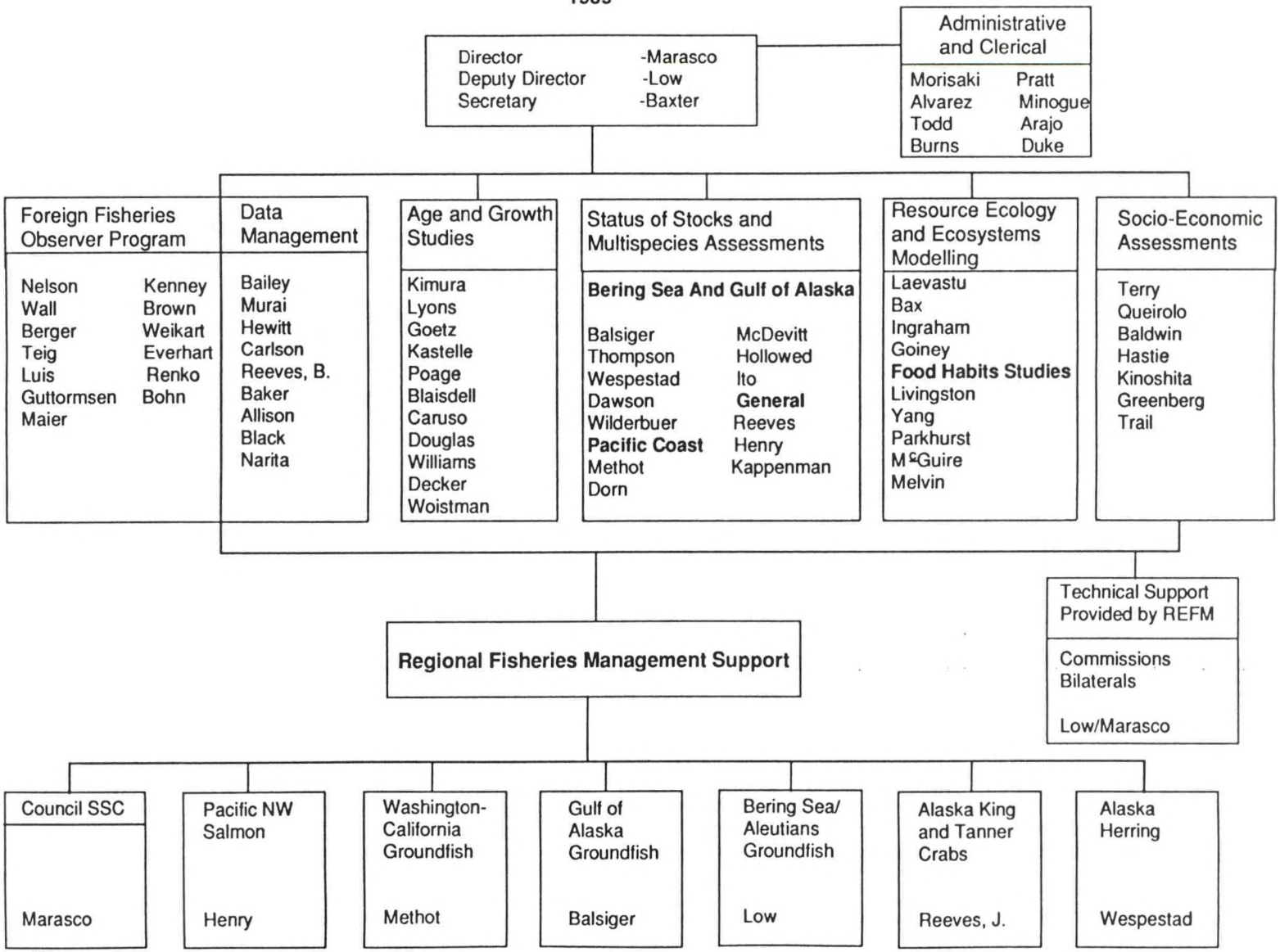
Task members contributed to 1) developing studies to evaluate economic effects of the *Exxon Valdez* oil spill in Prince William Sound; 2) reviewing Sea Grant and Saltonstall-Kennedy proposals; 3) assisting NMFS with guidelines for valuing commercial and recreational fisheries; and 4) providing database extracts for research projects conducted by others.

Resource Management Advisory Functions

The Division continued to serve as technical advisor in the fisheries management process. One scientist served as chairman of the Scientific Statistical Committee for the NPFMC. Several others served as team leaders or played key roles in the development of fishery management plans and regulations governing groundfish, herring, crabs, and salmon fisheries for both the NPFMC and PFMC. The Division also organized and conducted bilateral meetings with several foreign nations to coordinate

joint research and exchange data and views on the condition of stocks and their management. In addition, Division members provided scientific input to the Fishery Management Councils, the International North Pacific Fisheries Commission, the International Pacific Halibut Commission, and the U.S.-Canada Salmon Commission.

RESOURCE ECOLOGY AND FISHERIES MANAGEMENT DIVISION
1989



SPECIAL ITEMS CONCERNING NWAFSC STAFF

Awards and Honors

Dr. Michael Dahlberg was awarded a State of Alaska commendation by Governor Cowper for "helping to secure agreements under the Driftnet Act of 1987 to protect the living marine resources of the North Pacific and Alaska's fishing industry."

Patricia Livingston was awarded the 1989 Robert H. Pealy Prize for outstanding degree paper written for the master of public administration degree at the Graduate School of Public Affairs at the University of Washington.

The Outstanding Publications Awards Subcommittee of NMFS' Publications Advisory Committee nominated a Coastal Zone and Estuarine Studies (CZES) Division publication, "Genetic Estimates of Stock Compositions of 1983 Chinook Salmon, *Oncorhynchus tshawytscha,* Harvests off the Washington Coast and the Columbia River," by F. Utter, D. Teel, G. Milner, and D. McIsaac (1987), for the best publication appearing in a 1987 issue of the *Fishery Bulletin.* Although not selected for the NMFS Publications Advisory Committee's monetary award, it was considered deserving of the Committee's Honorable Mention Recognition. Only those papers constituting an outstanding original scientific work contributing to the NMFS mission were considered.

Anthony Novotny was awarded the American Fisheries Society's (AFS) Distinguished Service Award for 1988, in recognition of his long and active involvement in AFS activities.

Dr. Albert Giorgi was appointed to the Affiliate Faculty of the School of Fisheries, at the University of Washington, Seattle.

Earl Prentice received the Department of Commerce Silver Medal. This award, the second highest form of honorary recognition the Department bestows, was granted for meritorious contributions to the national fisheries program through Prentice's development and application of the passive integrated transponder (PIT) tag. Prentice was given this award by Robert A. Mosbacher, Secretary of Commerce, at the 41st annual Honor Awards program on 11 October 1989 in Washington, D.C.

Rolland Schmitten, Director of NMFS Northwest Region, presented each of the five members of the CZES Taiwan Sampling Team (Paul Aebersold, Nancy Davis, Matt Griswold, David Miller and William Waknitz) with a Special Recognition award. The Team recently returned from Taiwan where they sampled salmonids taken from two

Taiwanese ships held by the Taiwanese government for alleged illegal fishing on the high seas.

Howard Raymond, CZES retiree, received recognition by the American Institute of Fishery Research Biologists for the year's Best Paper in the North American Journal of Fisheries Management.

Diana Greene received a National Science Foundation Fellowship for Japanese Language Study, 1989-90.

Richard Methot was elected chairman of the Pacific Fishery Management Council's Groundfish Management Team.

Individuals Receiving Advanced Degrees

Martin Dorn completed a master's thesis in the University of Washington's Biostatistics Department. His thesis was entitled, "Conditional Logistic Regression Model for Onset of Riverine Salmon Migrations."

Keith Criddle, who had a graduate student appointment, received a Ph.D. in Agricultural Economics from the University of California, Davis, and is now an Assistant Professor of Economics at the University of Alaska, Fairbanks.

Rebecca Hoff received her Master of Science degree from the University of Washington on 9 December 1989.

Peter Munro received his Master of Science degree from the University of Washington on 12 June 1989.

NWAFSC Staff Detailed to Other Laboratories or Personnel From Other Laboratories Detailed to NWAFSC

Dr. Torbjorn Asgard from the Institute of Aquaculture Research, Sunndalsora, Norway, completed a 1-year-in-residence at the Center. Dr. Asgard's research was in the area of fish nutrition in the Utilization Research Division.

Dr. Tony Gharrett continued at Auke Bay Laboratory as the leader of the genetic stock identification studies for the U.S.-Canada Salmon Interception Program. This assignment was arranged through an Intergovernmental Personnel Act (IPA) between the University of Alaska Southeast, Juneau, and the Alaska Fisheries Science Center's ABL.

Ellen Varosi was detailed twice to the Regional Office Fishery Management Division to manage the 1989 Gulf of Alaska sablefish longline fishery, prepare statisics for the 1988 Fisheries of the United States, and manage the joint venture flatfish project in the Bering Sea-Aleutian Island management area.

Transitions

Tom Dark was appointed Deputy Director of the Resource Assessment and Conservation Engineering Division in April 1989.

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MULLIGAN, T. J.
WOOSTER, W. S.
YAMASHITA, Y.
YOKLAVICH, M. M.

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