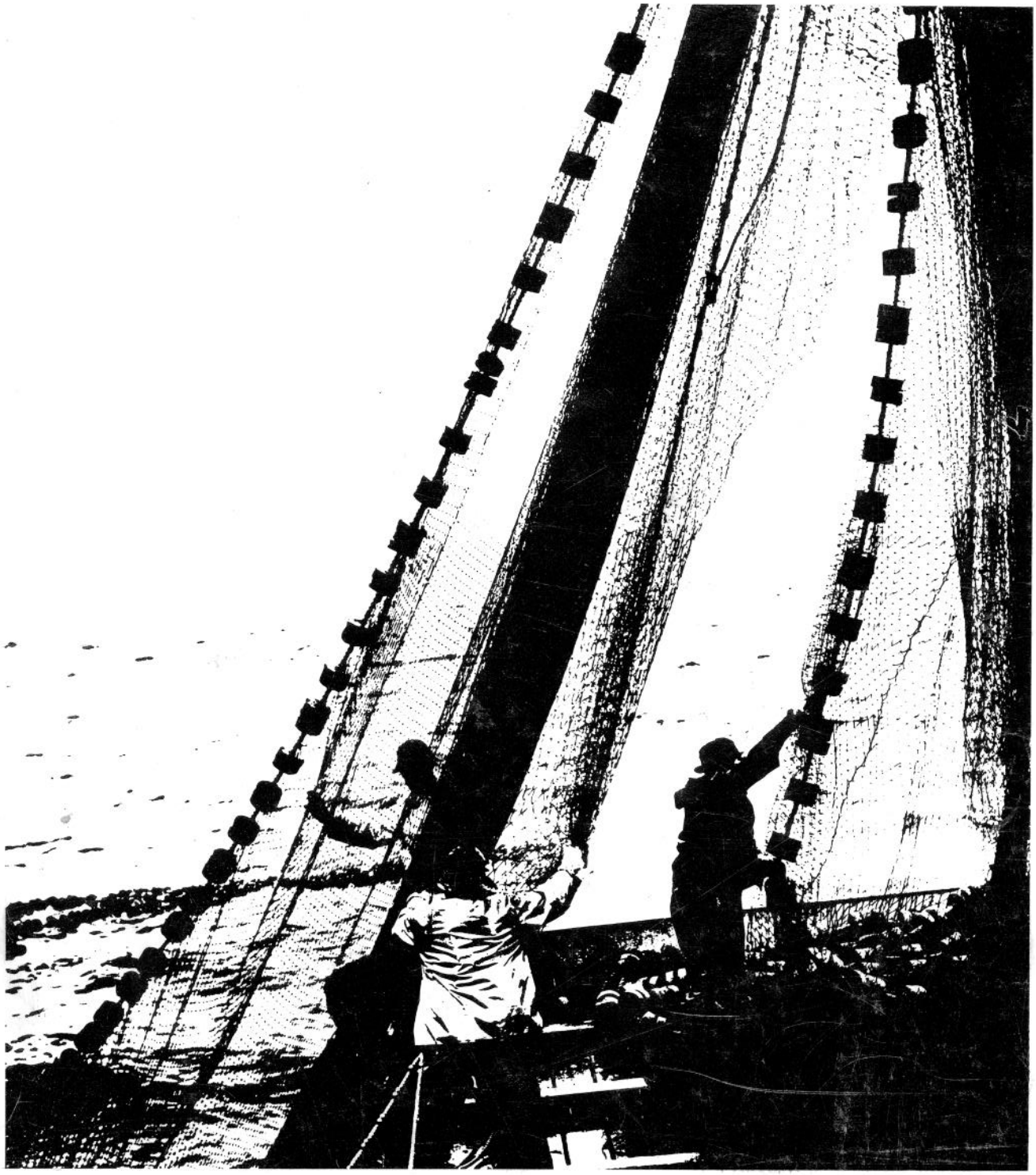
U.S. DEPARTMENT
OF COMMERCE

National Oceanic
and Atmospheric
Administration

National Marine
Fisheries Service

Fifty Years of Cooperation and Commitment: 1931-81

The Northwest and Alaska
Fisheries Center



The National Marine Fisheries Service (NMFS) does not approve, recommend or endorse any proprietary product or proprietary material mentioned in this publication. No reference shall be made to NMFS, or this publication furnished by NMFS, in any advertising or sales promotion which would indicate or imply that NMFS approves, recommends or endorses any proprietary product or proprietary material mentioned herein, or which has as its purpose an intent to cause directly or indirectly the advertised product to be used or purchased because of this NMFS publication.

NOAA Technical Memorandum NMFS F/NWC-34

Fifty Years of Cooperation and Commitment: 1931–81

The Northwest and Alaska Fisheries Center

Edited by
Rae R. Mitsuoka, Roger E. Pearson,
Laura J. Rutledge, and Samuel Waterman

October 1982

U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary

National Oceanic and Atmospheric Administration
John V. Byrne, Administrator

National Marine Fisheries Service
William G. Gordon, Assistant Administrator for Fisheries

Northwest and Alaska Fisheries Center
William Aron, Director

Contents

Introduction 1
William Aron

History of the Northwest and Alaska Fisheries Center

Fishery Studies on the Pacific Coast, 1887-1931 5
Clinton E. Atkinson

The Northwest and Alaska Fisheries Center, 1971-1981 9
George K. Tanonaka

The Montlake Laboratory and its Biological Research 19
Clinton E. Atkinson

Biological Research at Auke Bay Laboratory 47
Robert R. Simpson

Research on Effects of Chemical Contaminants 55
Neva L. Karrick and Sin-Lam Chan

Marine Mammal Research 63
George Y. Harry, Jr.

Technological Research 81
Maurice E. Stansby and John A. Dassow

Exploratory Fishing and Gear Development 107
Melvin R. Greenwood

Research Support 129
Donald D. Worlund

Presentations at the 50th Anniversary Symposium, 26–27 October, 1981

Effects of Environmental Stress on Fisheries Use and Enjoyment: A Historical Overview 133
Donald C. Malins

Effects of Environmental Degradation on the Freshwater Stage of Anadromous Fish 147
Wesley J. Ebel

Environmental Stress and the Use and Enjoyment of Marine Resources: The Future.....181
John S. Gottschalk

Utilization Research, 1931-1981: A Historical Overview.....193
John A. Dassow

Future Fishery Utilization.....207
James A. Crutchfield

Structure of the Fisheries of Alaska and the Pacific Northwest and Situations that Lead to Development.....217
William P. Woods, Jr.

Economic Aspects of Processing and Marketing the Northwest's Fish Products.....223
John Peterson

History and Perspective of Exploratory Fishing.....227
Dayton L. Alverson

Future of Exploratory Fishing and Gear Research.....235
Steinar Olsen

Fisheries Management: A Historical Overview.....243
Clinton E. Atkinson

Future of Fisheries Management or the Diverging Paths of Theory and Practice.....269
Peter A. Larkin

Banquet and Luncheon Speeches

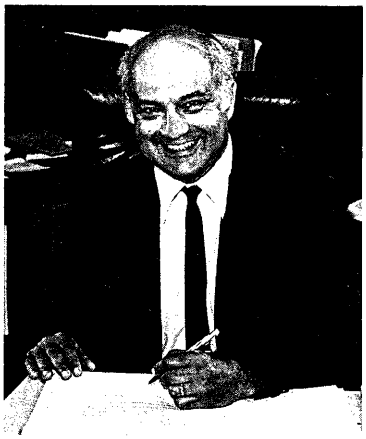
A Review of the Northwest Fisheries in Relation to the Northwest and Alaska Fisheries Center.....283
John V. Byrne

The Challenge of Being Administrator of the National Marine Fisheries Service.....289
William G. Gordon

Acknowledgements.....293

Introduction

William Aron [1]



Good luck, rather than careful planning, has allowed me the opportunity to introduce this volume commemorating the 50th anniversary of the research organization currently called the Northwest and Alaska Fisheries Center. Becoming Center Director is almost akin to donning the royal mantle. Following the footsteps of illustrious predecessors is both a humbling and challenging task, but one made easier by the excellence of the staff and the strong relationship that the Center has built within the community of those concerned with fish and fisheries problems.

This volume traces the history of the Center, its people, and its accomplishments. The first part covers the inception and development of the Center. This section is strongly anecdotal and has depended on the excellent memories of many individuals who were there "at the creation." The second part of the volume details many accomplishments of the Center during its half century of existence. This section looks into the future in an attempt to provide some guidance on the directions that should be taken to assure that the second 50 years will be at least as fruitful as the first.

1/ Director, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, 2725 Montlake Boulevard E., NOAA, Seattle, WA 98112.

The third, and last, part of the volume contains the speeches of Dr. John V. Byrne, Administrator, National Oceanic and Atmospheric Administration (NOAA), and William G. Gordon, Assistant Administrator of NOAA for Fisheries. The talks were presented at a banquet and luncheon, respectively, to commemorate the Center's 50th anniversary and honor the past and present workers of the Center.

Unlike biological systems that evolve through the interplay of Mendelian genetics and Darwinian selection, an organization such as the Center survives and succeeds through Lamarckian techniques. We cannot depend on the roll of genetic dice to give us the characteristics that meet our responsibilities. We must determine and understand the needs of our constituents. We must agressively seek out and acquire the characteristics that will meet these needs.

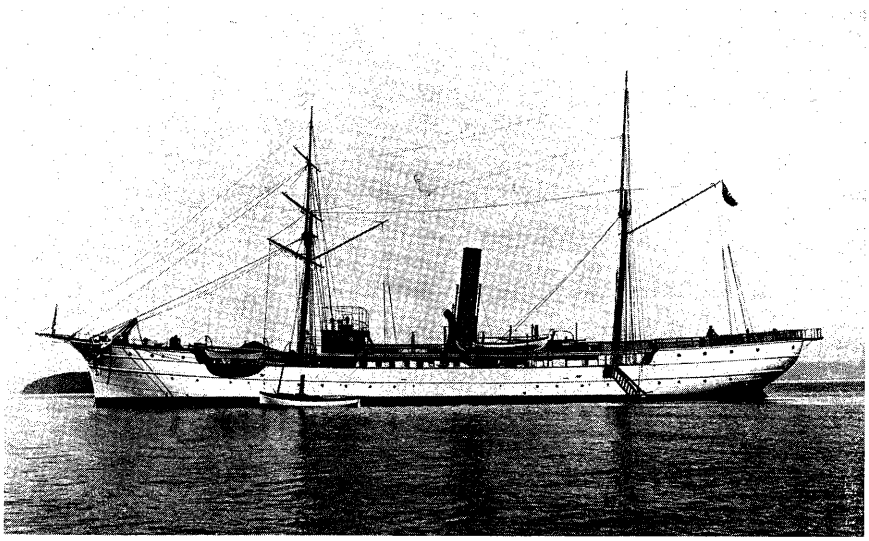
The theme of our 50th anniversary was "Cooperation and Commitment." Through the continued and energetic pursuit of this theme we will assure our evolution and our future. The Center must remain a focus of expertise; it must work with the full community of those concerned with fisheries problems; and it must be accessible, so that its findings may be implemented in ways that allow the wisest use of our living resources.

History of the Northwest and Alaska Fisheries Center

Fishery Studies on the Pacific Coast, 1887-1931

Clinton E. Atkinson [1]

Charles Gilbert, Professor of Biology at Stanford University from 1880 to 1927 was active in determining the life history of salmon in Alaska. From 1909 to 1927, Gilbert was in charge of summer salmon investigations of the Bureau of Fisheries. His pioneer work on fisheries of the North Pacific and Alaskan coastal areas did more than that of any other individual to lay a firm basis for subsequent biological investigations not only in the Bureau of Fisheries, but in many other scientific operations as well.



Steamer *Albatross* which conducted surveys of fish in the North Pacific and along the Alaskan coast from 1888 to 1906.

In the maze of problems that face fishery scientists and administrators today, we soon forget that the birth of fishery biology and management on the Pacific coast began a little over 100 years ago with the establishment of the U.S. Bureau of Fisheries in 1871. The investigation, construction, and operation of the first Pacific salmon hatcheries in the United States began on the McCloud River in northern California in 1872 and in 1877 and 1878 on the Clackamas and Rogue Rivers in Oregon. In their search for suitable hatchery sites, the early investigators provided a description of the local salmon fishery, the size and

1/ Former Director, Seattle Biological Laboratory, Bureau of Commercial Fisheries, U.S. Fish and Wildlife Service; present address: 4055 21st Ave. W., Seattle, WA 98199.

distribution of the runs, and other information.

The first comprehensive surveys of the fisheries along the Pacific coast and in Alaska were part of the 1880 U.S. Census. Dr. David Starr Jordan, the President of Indiana University, and Charles H. Gilbert, a young biologist at Indiana University, were chosen to write the first description of salmon fishing and canning interests of the United States, with Dr. Tarleton Bean preparing a section on cod and halibut. In this section Dr. Bean pointed out that cod and halibut were being fished in only a few known places in the Bering Sea and around the Aleutian Islands and that "very little is known of the extent and characteristics of the Alaskan fishing grounds; only a comparatively few soundings had been made to ascertain the depths of water at any distance from land, and the limits of the continental shelf were almost completely undetermined."

In 1885 Jordan was appointed the first President of the newly opened Leland Stanford University, and Gilbert followed him to become head of the Biology Department. Their influence, along with the recommendations of Bean, was instrumental in arranging for the Albatross, a U.S. Fish Commission vessel, to continue a series of annual surveys in the Aleutian Islands, in the Bering Sea, along the coasts of Washington, Oregon, and California, and even into distant waters off Japan and Hawaii. Frequently Jordan, Gilbert, or Barton Warren Evermann would accompany the vessel during its cruises, taking numerous soundings, temperatures, bottom samples, and other oceanographic tests.

Because Jordan and Gilbert had written the first description of the salmon fisheries on the Pacific coasts, it was quite natural for Jordan to be chosen to head a select committee appointed by the President in 1903 to investigate the causes for the decline in the salmon fisheries of Alaska. Then in 1909 Gilbert was named scientist in charge of the Pacific Fishery Investigations of the U.S. Bureau of Fisheries. For the next 22 years, the Bureau's research center for fisheries of the Pacific coast and Alaska remained at Stanford University, and the influence of Jordan, Gilbert, Evermann, and Kohn Otterbein Snyder and the contributions of their students dominated all fishery surveys and investigations made in the North Pacific and beyond.

In 1915 Dr. William F. Thompson, an early student of Jordan, began his study of the halibut fisheries of British Columbia. Later he became the director of investigations for the International Fisheries Commission (Halibut), the International Pacific Salmon Fisheries Commission, and the Fisheries Research Institute of the University of Washington.

About 1918 Dr. Willis H. Rich, another of Jordan's students, was appointed as field assistant to work with Gilbert on Alaska salmon problems. In 1922 he became chief of the Division of Scientific Inquiry for the Bureau of Commercial Fisheries, then he went on to become head of the Pacific Fishery Investigations at the Bureau's Stanford station, and later Director of the laboratory at Montlake for a short time.

Elmer Higgins, who took over in 1927 as the chief of the Division of Scientific Inquiry for the Bureau of Commercial Fisheries, was the third student of Jordan's to play an important role in the research programs at our Montlake Laboratory.

Although each of these early scientists became experts in their own fields, all obtained their inspiration and their professional discipline from Dr. David Starr Jordan - considered by many to be the dean of all American fishery scientists.

During this period, the influence of the College of Fisheries at the University of Washington began to be recognized. Arnie Suomela, probably the first student from the College of Fisheries to be employed by the Bureau, worked during the summer of 1922 while a junior at the University as a fish warden, because there were no openings for biologists. His first job was to help install a fish weir at Olga Bay (Kodiak, Alaska), where he ended up tagging pink salmon for the next 3 years. Arnie served in a variety of management and research jobs, received a Master's Degree from the University of Washington and would have been among the first group of scientists at Montlake had he not been placed in charge of the management of the Pribilof fur seals in the spring of 1931.

There were three other fishery biologists on the staff of the Pacific Fishery Investigations at Stanford who received Bachelor Degrees from the University of Washington and continued with graduate study at Stanford: Thomas Barnaby, George Kelez, and Edward Dahlgren. Thomas Barnaby received a Master's Degree from Stanford in 1929 and was placed in charge of the Karluk investigations, George Kelez was placed in charge of the Chignik investigations in 1933, and Edward Dahlgren was placed in charge of the Alaska herring studies in 1935.

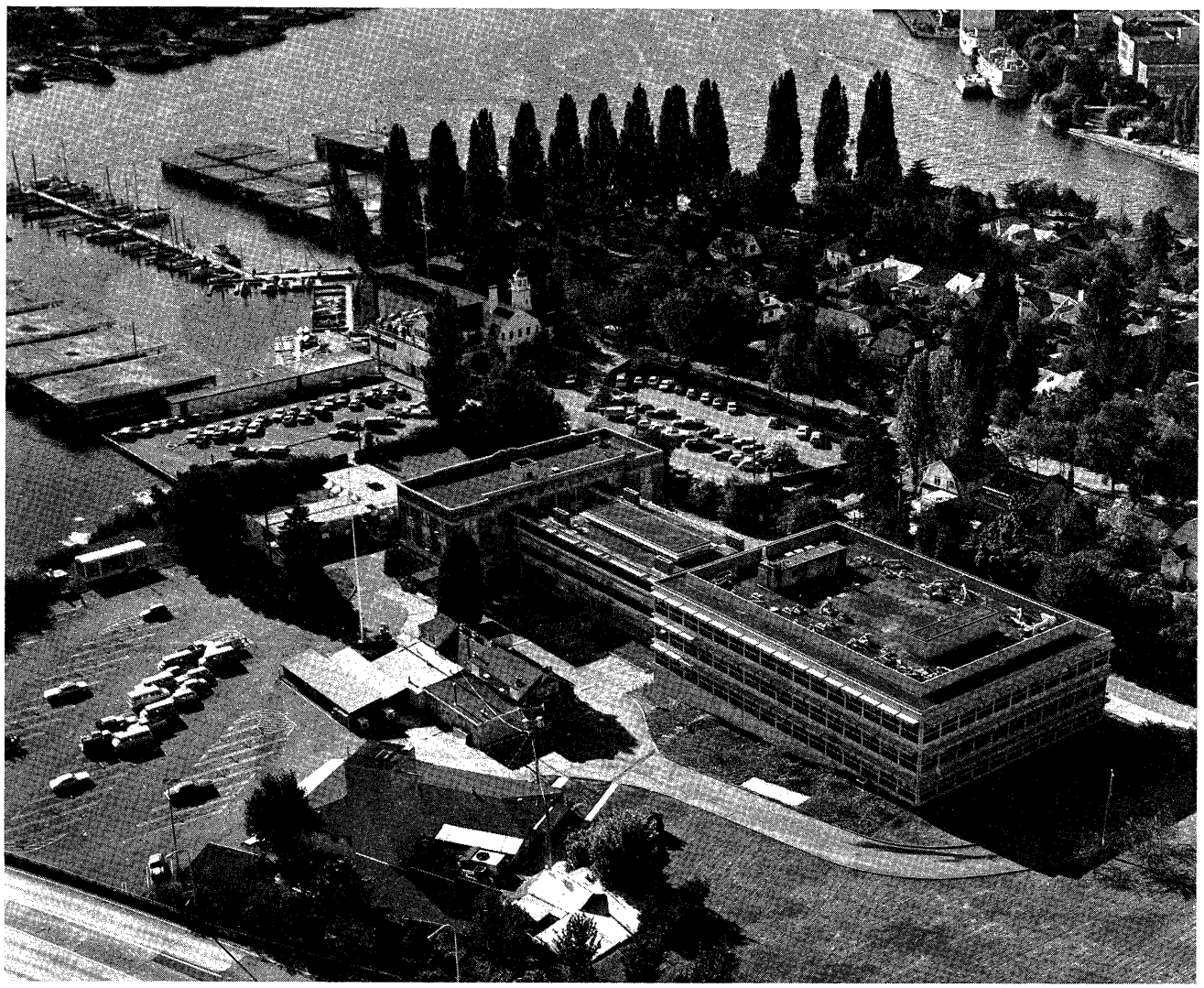
It is difficult to pinpoint the actual beginning of the research program at the Montlake biological laboratory. The staff of the International Fisheries Commission (Halibut) had been well established in Fisheries Hall Number 4 at the University of Washington since 1923 or 1924, and the results of their work were already being published. At about the same time, Henry O'Malley, who at the time was both the commissioner of the Bureau of Fisheries and a member of the Halibut Commission, felt that the Bureau should have a laboratory in Seattle. In 1924 O'Malley sent Harlan Holmes to Seattle to find working space for the Bureau in Fisheries Hall Number 4, also. Arnie Suomela worked in 1924, 1925, and 1926 on the southeast Alaska salmon-tagging program; Edward Dahlgren, then a student at the College of Fisheries and a part-time employee of the Bureau, counted herring vertebrae here in 1927-28 as part of the Bureau's Alaska herring research program. Several "oldtime" employees of the Bureau were reported to have worked here in the pre-Montlake period although the dates are unconfirmed. Harlan Holmes who played an especially important role for the Bureau during the construction of the Montlake Laboratory by ordering equipment and taking care of other details in preparation for moving the biological research staff to Montlake in 1931.

The biological research program that came to the Montlake Laboratory in 1931 was actually a continuation of studies on salmon begun about 10 years previously by Rich on the Columbia River (in cooperation with the Oregon Fish Commission), and by Charles Gilbert in Bristol Bay and on Karluk River and Karluk Lake in Alaska. In 1926, more salmon studies were added for Chignik, Alaska, under Harlan Holmes. In 1929 new investigations were begun on the sockeye salmon in Bristol Bay under Alan Taft, and on the Copper River under Seton Thompson;

other investigations were begun on the pink salmon of southeastern Alaska under Fred Davidson. Studies on the herring fisheries of southeastern Alaska and Prince William Sound began in 1925 under George Rounsefell. All of these studies were under the direction of Rich, Director of the Bureau's Pacific Fisheries Investigations, until his resignation in 1929, and all of the project leaders were graduates of Stanford University.

The Northwest and Alaska Fisheries Center, 1971-1981

George K. Tanonaka [1]



Developments in fisheries studies, beginning in the late 19th century, led to the establishment in 1971 of the Northwest Fisheries Center (NWFC), now the Northwest and Alaska Fisheries Center (NWAFC). Scientific programs of the several agencies which eventually came together in 1971 to form the Center were described earlier.

The Northwest and Alaska Fisheries Center is one of four research centers administered by the National Marine Fisheries Service. The Center's work is a part of the federal research effort of the National Oceanic and Atmospheric Administration (NOAA), an agency of the Department of Commerce.

1/ Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

The Center is staffed by personnel trained in fishery biology, wildlife biology, oceanography, chemistry, physiology, histology, serology, genetics, mathematics and statistics, computer operations, electronics, engineering, veterinary medicine, and economics. Administrative support activities are handled by staff personnel with training in accounting, procurement, and personnel matters. In addition, persons with training and experience related to planning, programming, budgeting, graphics, technical writing, and public affairs contribute to the overall management of the Center.

The Center consists of two principal laboratories: the Seattle Laboratory, which is sometimes called the Montlake laboratory and the Auke Bay Laboratory. The Seattle Laboratory consists of six research divisions and the National Marine Mammal Laboratory; the Auke Bay Laboratory is divided into four major investigations. NOAA-owned research vessels supporting fisheries research are the responsibility of the National Ocean Survey's Pacific Marine Center.

CENTER FACILITIES

Center facilities are located in Washington, Oregon, and Alaska; a detailed description follows.

Washington

Seattle Laboratory.--NWAFC headquarters occupy a multi-building facility located on 7.2 acres bordering Portage Bay, Lake Union. The research complex includes a 17,000 ft^2 office and laboratory building with connecting walkways to a 72,000 ft^2 library and auditorium and a 65,000 ft^2 office and laboratory. The facilities also include an adjacent 3,000 ft^2 office annex, a technological pilot research building, and aquaculture facilities. Housed at this facility are the staffs for the Center Director's Office and the six divisions: Resource Assessment and Conservation Engineering (RACE), Resource Ecology and Fisheries Management (REFM), Environmental Conservation (EC), Fisheries Data and Management Systems (FDMS), Coastal Zone and Estuarine Studies (CZES), and Utilization Research (UR). The National Marine Mammal Laboratory (NMML) occupies 19,000 ft^2 of office and laboratory and storage space at Sand Point. The conservation engineering and hydroacoustics tasks of the RACE Division and the electronics and machine shop of the CZES Division, are also located at Sand Point.

Manchester Biological Field Station (CZES Division).--An aquaculture and fisheries enhancement research facility located on 22 acres at Clam Bay on Puget Sound. This facility consists of several buildings which provide 1,900 ft^2 of laboratory space, 2,100 ft^2 of office space, 1,000 ft^2 of shop space, 8,000 ft^2 of storage space, and saltwater rearing pens.

Mukilteo Biological Field Station (EC Division).--This 7,000 ft^2 combined laboratory and office, where research is conducted to determine the effects of various pollutants on marine organisms, is located 25 miles north of Seattle in a facility leased from the U.S. Air Force.

Pasco Biological Field Station (CZES Division).--This leased laboratory, office, shop, and storage space, totaling 23,000 ft^2, is used for research related to the ecological effects of dams on anadromous fish in

the Columbia River Basin.

Clarkston Biological Field Station (CZES Division).--This facility consists of 1,000 ft^2 of leased office and storage space where research related to the ecological effects of dams is administered.

Oregon

Hammond Biological Field Station (CZES Division).--Located on the Columbia River estuary, studies are conducted on fish, benthic invertebrates, and physical parameters of the Columbia River mouth and estuary in relation to man-caused environmental disturbances. The facility consists of 3,200 ft^2 of laboratory and office space, and 3,500 ft^2 of storage space.

Newport Aquaculture Laboratory and Support Facility.--This laboratory is made up of 60,000 ft^2 adjoining the Marine Science Center of Oregon State University (OSU), Newport, Oregon. The research program is conducted and funded primarily by OSU, while NWAFC supports the Laboratory Administrator, provides operation and maintenance funds, and carries out a small research program in cooperation with OSU. A primary responsibility of the Laboratory Administrator is to supervise and help coordinate the NWAFC research efforts with those of OSU scientists.

Prescott Field Station (CZES Division).--This floating laboratory, on two 32 x 110 ft barges moored in the lower Columbia River, serves as laboratory and support facility for in situ environmental research.

Rufus Biological Field Station (CZES Division).--This station consists of 2,200 ft^2 of office, shop, and storage space used for research and administration of research related to ecological effects of dams on anadromous fish in the Columbia River.

Alaska

Auke Bay Laboratory.--This is the major NMFS facility in Alaska, located 12 miles north of Juneau on 3.2 acres bordering a saltwater bay and adjacent to a salmon stream flowing from nearby Auke Lake. Both the bay and the stream serve as natural freshwater and estuarine experimental areas and provide water for fresh and seawater laboratory systems. The main laboratory building has 10,000 ft^2 with space for approximately 50 staff members. An annex, located one-half mile from the ABL, provides 2,000 ft^2 of office and laboratory space for 16 staff members; a Butler building provides an additional 7,200 ft^2.

Little Port Walter Field Station (ABL).--This is the major salmon aquaculture research station in Alaska, located approximately 90 miles southeast of Sitka near the tip of southern Baranof Island. It is situated in a compact estuarine environment adjacent to Chatham Strait near the open Gulf of Alaska. There are numerous nearby lakes for testing fishery enhancement concepts. The station comprises six buildings totaling 9,000 ft^2 with experimental hatcheries and rearing facilities served by a controlled water source capable of delivering 900 gallons per minute. In the spring of 1939, with the aid of a 20-man Civilian Conservation Corps work force provided through the Alaska Forest Service, a steel and reinforced concrete, salmon counting weir was constructed in the mouth of Sashin Creek. This large structure permits biologists to observe

and count both the adult upstream migrating salmon and the very young downstream migrating fry. These upstream and downstream counts have been made each year since 1939; they provide valuable information on the survival of salmon in freshwater and marine environments. (Also see Little Port Walter in the Biological Research at Auke Bay section).

Kasitsna Bay Field Station (ABL).--Located on 27 acres on lower Kenai Peninsula near Homer, Alaska, this station serves as a year-round, on-site facility for studying shellfish resources of lower Cook Inlet. It is currently used by the University of Alaska under a Memorandum of Understanding.

King Salmon Field Station (ABL).--This station is a staging area for field operations and research on sockeye salmon in the Naknek Lake watershed area. It is maintained by the U.S. Fish and Wildlife Service under a Memorandum of Understanding.

Kodiak Field Station (RACE and UR Divisions).--Investigations of the RACE and UR Divisions are located in a renovated building on the U.S. Coast Guard Base, Utilization Research activities occupy 5,000 ft^2 of laboratory and office space with a 3,000 ft^2 pilot plant located at Gibson Cove. The Resource Assessment staff occupies 19,000 ft^2 of office, laboratory, and storage space.

The multi-disciplinary research programs of the Seattle Laboratory and the Auke Bay Laboratory are designed to provide: 1) a better understanding of living marine resources of the northeast Pacific Ocean and Bering Sea and the environmental quality essential for their existence and 2) options for utilization of these resources consistent with national needs and goals.

Seattle Laboratory

Resource Assessment and Conservation Engineering.--Resource surveys to monitor variations in abundance and distribution of fish and shellfish populations in the North Pacific Ocean and eastern Bering Sea are conducted by the Resource Assessment and Conservation Engineering Division (RACE). Data collected provide fundamental information to establish the status of stocks being harvested, to enhance the ability of U.S. citizens to use underutilized resources, and to develop policy on man-caused effects on marine resources.

The resource assessment activities of RACE are divided into four components: groundfish assessment, pelagic fish assessment, shellfish assessment, and latent resource assessment. Resource surveys are conducted from NOAA ships and chartered commercial fishing vessels. These surveys provide information on distribution, abundance, and availability of selected stocks and on important parameters such as age, growth, mortality, and recruitment.

Fisheries gear technology research, aimed at enhancing the NMFS goals of full efficiency and wise utilization of marine resources, is the mission of the conservation engineering and fishery development unit of RACE. Primary thrusts are in the areas of: 1) development and introduction of selective harvesting systems to conserve non-target species or to provide a higher quality product to the consumer, 2) development of fishing systems to harvest latent resources and to eliminate resource waste, and 3) development and interpretation of

sampling systems.

Resource Ecology and Fisheries Management.--The Resource Ecology and Fisheries Management Division (REFM) conducts research on the biology, ecology, and utilization of marine resources to assist in development of management policies for both U.S. and foreign fisheries in the northeastern Pacific Ocean and Bering Sea.

The REFM Division is composed of two major elements: 1) research on the status of stocks for development of management recommendations and 2) research on resource ecology. The status-of-stock element provides real-time estimates of the condition of fishery resources for immediate management application. Recommendations are based on single-species models with input from assessment programs within the RACE Division, ongoing observer programs aboard foreign vessels, and analysis of domestic and foreign catch statistics. Much of the work of the resource ecology element is theoretical and developmental. These studies serve as guides to planning; results applicable to fisheries management are expected at a later date. Environmental information is utilized to explain certain biological phenomena, but it eventually provides the basis for predictive management.

Some specific activities of REFM include

- A scientific observer program aboard Japanese, Soviet, and Polish vessels to determine the incidental catches of species reserved to U.S. fishermen, to verify catch statistics and compliance with provisions of fishery management plans as required by the Magnuson Fishery Conservation and Management Act of 1976 (P.L. 94-265), and to collect biological data.
- Management studies which incorporate biological information with information from economics and other social sciences to develop models pertaining to optimum yield--the basis for management under the Magnuson Fishery Conservation and Management Act of 1976.
- Analysis and documentation of status of all principal species of the Bering Sea and northeastern Pacific Ocean for use by the Pacific and North Pacific Fishery Management Councils in making management decisions.
- Development of ecosystem models to quantify the interrelationship of marine mammals, fish, plankton, and the physical environment.

Utilization Research.--The major objective of the Utilization Research Division is providing the technological knowledge needed for full use of fishery resources. Research emphasizes solving problems of expanding the domestic fisheries for underutilized species and their use for food.

Tasks include: 1) improving preservation, storage, and processing methods; 2) determining the characteristics and composition of the species and the nutritive value and safety of the fishery products; 3) measuring changes in fish quality and their significance to processing alternatives; and 4) providing information as needed for science, industry, and consumer use.

Research problems include

- Methods of handling and preservation at sea and ashore with industrially underdeveloped species (e.g., walleye pollock).
- Determination of quality changes by sensory, chemical, and microbiological criteria.

- Chemistry and characteristics of the muscle and proteins of various species.
- Evaluation of product concepts and use of fish in a variety of processed food systems.
- Determination of nutritional values such as composition, proteins, trace elements of nutritional and health concern, and organic contaminants from the environment.
- Microbiological research on pathogens in fish with emphasis on Clostridium botulinum growth and toxin formation, and development of safe processing methods for smoked fish and intermediate processed products.
- Aquaculture feeds, nutrition, and disease including alternative protein sources for salmonid feeds, low-energy processed feeds from fish waste, nutritional imbalances related to trace element availability, and salmonid botulism and disease related to environment.

Coastal Zone and Estuarine Studies.--Research activities of the Coastal Zone and Estuarine Studies Division (CZES) are separated into three tasks: ecological effects of dams, habitat investigations, and fishery enhancement.

The Ecological Effects of Dams Task undertakes applied research relating to migration of anadromous fish between spawning areas and the sea. Research is focused on the Columbia River watershed which covers an area of 259,999 sq. mi. in Washington, Oregon, Idaho, Nevada, Wyoming, Montana, and Canada. Studies are carried out on the effects of water resource developments on the river ecology, on passage and survival of various stocks of anadromous fish, and on the development of systems for alleviating adverse effects.

The focal point for research activities of the Habitat Investigations Task is the Columbia River estuary. This unique body of water covers about 150 mi^2 and extends from the Pacific Ocean to about River Mile 46. The estuary is an extremely important and complex area involving a variety of biological and physical interactions. It is an important link in the life cycle of some of the Northwest's most important food fishes, e.g., salmon and steelhead. It is also an area subject to changes, both subtle and drastic, brought about by man's activities.

Through the Habitat Investigations Task, the Division monitors the biological effects of changes and predicts the consequences of contemplated actions by evaluating of pilot programs. The expertise of the staff is sought by agencies such as the U.S. Army Corps of Engineers and Portland General Electric Co., whose activities such as dredging and cooling have potential impact on the estuary.

The Fishery Enhancement Task is located in Puget Sound, an inland sea with over 2,300 miles of shoreline. Research is directed toward the development and improvement of fresh and saltwater fish rearing systems and the detection and prevention of fish disease in these systems. Other research is designed to assess the status of smoltification and fitness for ocean survival of chinook and coho salmon and steelhead and to identify salmon stocks in mixed-stock fisheries.

Environmental Conservation.--Research conducted by the Environmental Conservation Division (EC) is directed toward determining the impact of environmental changes and the effects of contaminants on life processes of marine resources in the northwestern United States. This research is being

conducted at Seattle and Mukilteo, Washington.

The analytical capabilities provided by the EC Divison are enhanced by the NOAA National Analytical Facility (NAF) and the Electron Microscopy (EM) Unit. Foremost among the services provided by the NAF is the capability to measure and identify contaminants at low levels found in environmental samples. Both a transmission and scanning electron microscope are used in the EM Unit to assist in determining initial stages of abnormal developments in fish and shellfish.

National Marine Mammal Laboratory.--The National Marine Mammal Laboratory (NMML) conducts research on principal marine mammal species of concern to the United States, thus ensuring maintenance of the various populations at satisfactory levels. This research meets the requirements of the Marine Mammal Protection Act of 1972 and is the rationale for U.S. participation in international contractual obligations within the International Whaling Commission and the North Pacific Fur Seal Convention.

Marine mammal species currently being studied include pinnipeds (northern fur seals of the Pribilof Islands, harbor seals, two species of sea lions, and the northern elephant seal); cetaceans (bowhead, killer, sei, sperm, gray and humpback whales); and the Dall's porpoise.

International obligations and the Marine Mammal Protection Act require continuing information on the status of fur seal stocks of the Pribilof Islands. Research by the NMML entails population dynamics, counts of estimates of year-class size, abundance and age composition of the harvest, magnitude and causes of natural mortality, influence of disease on population size, and development of techniques to achieve desirable population levels.

Current pinniped research is expanding knowledge about the status of stocks and pelagic migration patterns, the effects of environmental contaminants and diseases, and observations of marine mammal-fishery interactions.

Data collected from whale research activities provide the basis for developing national conservation measures as well as international management proposals.

Research on endangered species of pinnipeds is conducted to determine the status of stocks, to collect data for international negotiations, and to prepare management recommendations for these species.

Fisheries Data and Management Systems.--NWAFC tasks encompass a broad range of studies on marine fish and shellfish, environmental conservation, marine mammals, coastal zone and estuarine resources, and international fisheries problems. These studies involve the design of experiments and analysis of large sets of scientific and fishery data. The Fishery Data and Management Systems Division (FDMS) provides assistance in biometric and statistical methodology and theory.

Additional technical services provided by FDMS include preparation of the Center's Monthly Report, preparation of scientific illustrations and graphic material, editing technical reports and manuscripts prepared by Center scientists, and operation of the Seattle Laboratory Library.

Office of Fisheries Information Systems.--The Office of Fisheries

Information Systems (OFIS) reports to the Center Director. OFIS directs the fishery information network and computer system of the NWAFC and responds to the need to facilitate fishery management, regional consolidation, and timely analyses of fisheries data on Alaska and Pacific Northwest resources. Services include: 1) data entry; 2) computer processing, computer graphics, and data storage and retrieval through operation and maintenance of in-house computer systems; 3) data communications with computers at Kodiak and Auke Bay, Alaska, and with numerous other interactive terminals on site and in the field; 4) programming consultation, assistance and training for users; and 5) data base maintenance and report generation. Users include NWAFC personnel, NMFS's Alaska and Northwest Regional Offices, and fishery agencies in California, Washington, and Oregon.

Auke Bay Laboratory

Anadromous Fishes Investigation.--Research at the Auke Bay Laboratory (ABL) to enhance Alaska salmon resources, with particular emphasis on ocean ranching, is divided into four areas of activity: incubation systems, supplemental rearing systems, natural rearing systems, and genetic problems.

Spawning and incubation systems emphasize the development and evaluation of low-cost gravel and plastic substrate incubators which produce fry that compare favorably with wild fry in terms of their capacity to grow and survive at sea.

Supplemental rearing systems emphasize the development and evaluation of floating feedlots (pens and raceways) designed for low construction and operating costs. Natural rearing systems of immediate interest are lake and inshore marine nursery waters.

Genetic problems are probably the cause of greatest uncertainty concerning long-term feasibility of salmon ocean ranching. Understanding basic genetic adaptations of wild salmon is essential for proper management of salmon stocks as well as development of cultured stocks.

Environmental Impact Investigations.--Environmental impact studies are conducted at ABL to determine effects on marine resources of environmental alterations resulting from industrial developments in Alaska. Research includes both laboratory experiments and collection and analysis of data at locations throughout Alaska.

Multidisciplinary studies involve exposing a variety of Alaskan species to oil and monitoring biological responses in a variety of ways. Studies are also being conducted to determine the effects of logging on aquatic ecosystems.

Biometrics and Resource Assessment Investigations.--Biometrics and resource assessment investigations provide population dynamics analyses of fisheries as well as development of the statistical estimators required to provide information to management on growth, mortality, reproduction, and population estimates for Alaskan fisheries. Experimental designs are developed and used for research conducted by all ABL investigations to assure the statistical validity and precision of experimental results.

Marine Investigations.--Marine investigations at the ABL involve studies on the biology, ecology, distribution, and population dynamics of Pacific herring and other pelagic

and demersal fish of commercial importance in southeastern and central Alaska.

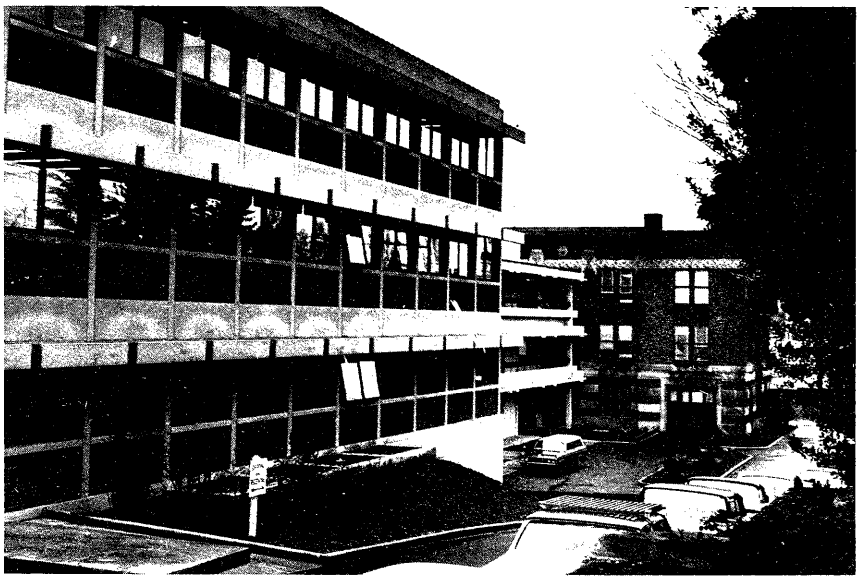
Information on abundance, distribution, and movements of herring stocks in southeastern Alaska is being gathered to provide biological rationale for regulations that would help sustain the yield of this resource. Other marine organisms that share the same environment with herring are being identified and their ecological relationships established to aid in forecasting trends in herring abundance.

Fishery oceanography research supports various anadromous fish, marine fish, and environmental investigations through analyses of natural and man-induced environmental conditions affecting fish abundance, behavior, and distribution.

The Montlake Laboratory and its Biological Research

Clinton E. Atkinson [1]

Construction of the new addition during the summer of 1963.



The completed addition on January 1, 1965.

In the Beginning

On 22 May 1931, the new laboratory of the U.S. Bureau of Fisheries opened on Montlake Boulevard in Seattle. An "Open House" was held just before the actual occupancy of the building. Those present included Henry O'Malley of the Bureau of Fisheries and the International Fisheries Commission, Miller Freeman, editor of the Pacific Fisherman, and U.S. Senator Wesley Jones, author of the Jones Act. No doubt others prominent in fisheries in the Pacific Northwest and Alaska were present also, along with the local

1/ Former Director, Seattle Biological Laboratory, Bureau of Commercial Fisheries, U.S. Fish and Wildlife Service; present address: 4055 21st Ave. W., Seattle, WA 98199.

staff members of both the Bureau and the International Fisheries Commission, commonly known as the Halibut Commission.

The report of the U.S. Commissioner of Fisheries for 1930 notes, "The completion of the new laboratory at Seattle provides the much needed facilities for the Pacific coast biological staff of the Bureau as well as for certain of its other personnel and the staff of the International Halibut Commission." In the report for 1931, there is the succinct statement, "On May 22, 1931, the personnel and equipment of the Stanford field station were transferred to the new Fisheries Biological Laboratory at Seattle, including all of the Bureau's Pacific biological investigations dealing with Pacific coast fishery problems, except shellfish and the cooperative work on California trout."

The actual move did not occur all at once; the period between May and June was the beginning of the summer's work on salmon in Alaska and on the Columbia River, so most of the staff had left or were in the process of leaving for the field. Ed Power, the newly appointed statistical agent for the Pacific Northwest and Alaska, was among the first to move into the building. George Rounsefell and Edwin Dahlgren of the Alaska Herring Investigations were early occupants. Joseph Craig, the new director of the Pacific coast laboratory, was there also, working out problems of space and operating expenses, as well as initiating the one new investigation for Montlake--the study of salmon fisheries on Puget Sound.

The halibut Commission moved into the Montlake facility in July 1931. At the time, all of the junior staff members were in the field and two of the senior staff were at the University of Washington's Biological Station at Friday Harbor for the summer, leaving Heward Bell in charge of the Seattle office. While the others were away, Bell was given the task of moving the files and belongings of the staff into their new quarters at Montlake. It took months, so the story goes, before the absentees could locate and reorganize their records and personal effects.

The First Decade: the Depression Years

Even these first years, the Montlake laboratory was the training ground for a number of future leaders in fisheries research and management. Dr. Richard VanCleve, who eventually became Dean of the University of Washington's College of Fisheries, and Dr. John Kask, who has served as head of several fishery agencies in the United States and Canada, both attained their advanced degrees at the University of Washington while working for the International Pacific Halibut Commission at Montlake. Dr. Lauren Donaldson, known throughout the world for his work in the selective breeding of trout and salmon, worked part time at Montlake reading salmon scales--he really did not find the job too interesting, but it provided a means of support during his first years at the College of Fisheries in the depth of the depression.

With one exception, the biological research program at Montlake remained the same as when the work was conducted from Stanford University. The one new program, initiated in 1931, concerned a study of the biology of Puget Sound runs of sockeye salmon under the direct supervision of the laboratory director, Joseph Craig. A small, short-term

operation, tagging Rogue River steelhead trout, was started in the winter of 1930-31 and completed the same year.

Continuing programs at the new laboratory consisted of six programs on Alaskan fish: four dealing with sockeye salmon, one with pink salmon, and one with herring. Specifically, these programs were: 1) Karluk sockeye salmon under Thomas Barnaby, 2) Chignik sockeye salmon under Harlan Holmes assisted by George Kelez, 3) Copper River sockeye salmon under Seton Thompson assisted by Morris Rafn, 4) Bristol Bay sockeye salmon under T. L. Schulte; 5) Alaska pink salmon under Dr. Frederick Davidson assisted by S. J. Hutchinson; and 6) Alaska herring under George Rounsefell assisted by Edwin Dahlgren.

Work also continued on a program to obtain information for the Bureau of Fisheries to help the U.S. Army Corps of Engineers design a new dam on the Columbia River that would offer minimal interference with salmon runs. This program dealt largely with fish-ladder and fish-screen design for various localities. It was under direction of U. B. Gilroy, a civil engineer, with guidance from Shirley Baker, a San Francisco consulting engineer, who had originally headed this program.

In 1933 Dr. Davidson was appointed laboratory director. He was particularly aware of the importance of statistical analysis in the interpretation of the results of fishery research. During his first months as director, he hired Elizabeth Vaughn as the laboratory's statistical analyst. About the same time, Dr. Thompson and the staff of the Halibut Commission began to apply Baranof's theory of fishing to the regulatory problems of the halibut fishery. These were firsts in fishery research. During this same period, Dr. Davidson and Eugene Shostrom also undertook a study of the physical and chemical changes that occur in salmon during migration upstream and spawning.

The pink salmon program soon evolved towards studies of freshwater survival of the eggs and young. In 1934, Samuel Hutchinson, the first permanent biologist to be employed at Montlake and later the Regional Director, was placed in charge of establishing a new field station for pink salmon survival studies on Sashin Creek near the Little Port Walter field station in southeastern Alaska. The U.S. Forest Service set aside 2,000 acres, covering the entire drainage of Sashin Creek, as a reserve. Building materials, Bureau supplies, and equipment were brought in on the Heron with the help of Edward Dahlgren and LeRoy Christey. The "little green shack" that was built on Sashin Creek in 1934 was used by biologists stationed there until larger and more permanent facilities were constructed in the fall of 1940, also in 1934, Christey began his studies of the fluctuations in the catch of pink salmon in southeastern Alaska and in the movement of these fish within the commercial fisheries.

Much credit is due to Dr. Davidson and Hutchinson for their wisdom and labor in establishing the experimental station on Sashin Creek. Soon this station will also reach its 50-year mark. Over the years it has provided innumerable studies and experiments on salmon and other fish and has contributed much to our understanding.

Although the details are not well known, permanent quarters were also built on Kodiak Island at Karluk near the outlet of the lake. There were similar problems in getting materials

and supplies to the building site. In this case, the means was a barge up the Karluk River which in itself is quite an accomplishment!

It was also during this period (1932) that a very extensive tagging program was begun on the herring in southeastern Alaska, using the new metal "belly" tag which can be recovered by a magnetic detection system on the conveyer belts at processing plants. The tagging of herring with internal magnetic tags was first undertaken during the summer of 1932 in Chatham Strait, southeastern Alaska, near Port Alexander. Using the motor vessel Heron and a floating herring pot as the tagging facility, Dr. George Rounsefell, Edwin Dahlgren, and Samuel Hutchinson tagged and released some 5,000 herring. Many of these tagged herring were caught in the commercial fishery and the tags recovered by electric magnets at the herring reduction plants. It was Ed Dahlgren's ingenuity and extraordinary inventive instincts that led to the development of the internal metal belly tag for tagging herring. He also devised and developed the electronic and magnetic systems for recovering the tagged herring or the tags as they passed through the reduction plant. This was an outstanding research development for determining the magnitude and distribution of the various herring populations in Alaska.

However, the most significant expansion of the fisheries programs in the early years of the Montlake laboratory occurred on the Columbia River, related to the development of the system of dams proposed for that River. Since 1928, the Bureau of Fisheries had been studying problems and methods of fish passage at various water diversion projects along the Pacific coast, but the effort was not adequate to satisfy the needs of the proposed dams on the Columbia River; Rock Island Dam had already been built, Bonneville was under construction, and Grand Coulee was planned for construction beginning in 1934.

Because of some previous experience in fish counting and fish passage problems at Rock Island and Lewis River dams, Harlan Holmes became the Bureau's fish passage expert. He, along with representatives from Oregon and Washington and the Army Corps of Engineers, solved numerous problems arising from the construction of the Bonneville Dam. It is difficult to describe the character of Harlan Holmes. He was completely dedicated to his work, had a very inquisitive mind, and was continually setting up hypothetical situations which he, or members of his staff, would then try to solve. Milo Bell, who worked with the Washington Department of Fisheries and later became one of the top fishery engineers in the world, tells of the time that Holmes swam up the Rock Island fishways (and almost made it) just to prove that if a man can swim up a fishway, then a salmon should have no problem!

Holmes was transferred to Portland in 1933 or 1934, ostensibly to be close to his work and the offices of the Army Corps of Engineers, although the real reason was simply to get paid. In those days, it was impossible to transfer funds from the Corps to the Bureau; to solve the problem, Harlan simply transferred to the Corps. He remained in Portland until Bonneville Dam had been completed.

In 1939 he returned to the Montlake laboratory as Biologist-in-Charge of the new Hydraulic Engineering Section, working on the Bureau's growing fish-passage problems in the Columbia River

system. The section was to review all federal power permit applications and to develop, design, and restore fish-passage structures and devices including fish-screens throughout the Columbia River where needed, such as at dams and diversions.

Ole Lindgren was Holmes' design engineer for a short time, and he was succeeded by Scott Bair. Clifford Burner, a University of Washington graduate student hired by Craig and Suomela in early 1938 to do salmon spawning surveys, joined the staff as an engineering draftsman and troubleshooter. Holmes was delighted! When tests were needed, it was now Burner who swam through flumes, ladders, weirs--even the new Burkey electric fish screen--while Holmes took notes from the bank and signaled directions with eloquent whistles and arm-waving. Many of the Columbia River fish-screens were massive, rotary-drum types requiring a field maintenance crew. This crew was headed by Robert Holcomb working out of shops in Yakima, Washington. Russell Lambert, an engineer, was added to the Hydraulic Engineering Section at Montlake, and when Burner was called by the U.S. Navy, Ronald and Esther Barker joined the project as draftsmen.

Holmes and Bair, along with Milo Bell of the Washington Department of Fisheries, became recognized nationally and internationally as an expert team of consultants in the field of "fish hydro" problems. Bair later became design engineer for the Chelan Public Utility Department on Rocky Reach Dam near Wenatchee, Washington.

In 1941 Harlan Holmes succeeded Dr. Davidson as Laboratory Director, but typical of his interest and tireless energy, he retained direction of the Hydraulic Engineering Section. Principally for his research in this field, Holmes received the Department of Interior's Distinguished Service Award, its highest honor, with a gold medal, when he retired in 1958.

The first major increase in funds for the Bureau's work at Montlake came in 1934 with the initiation of the very extensive Columbia River Investigations, which were closely associated with the water-use development program for the Columbia River basin. Joe Craig was placed in charge of the new program and his position as Director of the Montlake laboratory was turned over to Dr. Fred Davidson.

The Columbia River Program was sparked by the well known "308 Report" of the Army Corps of Engineers (1933) which outlined the basic plan for the development of a series of multi-purpose dams on the Columbia and Snake Rivers and their tributaries. Information was needed almost immediately to provide the basis for a complete program of maintenance and rehabilitation of the fisheries on the Columbia River. In addition to Joe Craig, who was in charge of the program, Willis Rich served as consultant in the various studies and Robert Hacker compiled the background history and other information on the development of the Columbia River fisheries.

A major part of the Columbia River Program during the first years was the comprehensive survey of all accessible salmon streams in the river system. This survey determined the present condition of the various tributaries and their availability and usefulness for the migration, spawning, and rearing of migratory fishes (i.e., salmon and steelhead). Arnie Suomela, who at his own request had returned to

Montlake earlier in 1934, was named head of the Columbia River survey and was actively assisted in the work by Mitchell Hanavan and Zell Parkhurst. There were at least 15 other Bureau employees who over the next several years were associated with this program.[2/] This sudden increase in activity and staff brought with it a need for additional space at the laboratory and thoughts quite naturally turned to the "15 room units" occupied by the International Fisheries Commission (later to be named the International Pacific Halibut Commission).

There were many factors associated with the termination of the joint occupancy of Montlake by the Bureau and the International Fisheries Commission. On 18 March 1936, William Thompson wrote the following letter to the U.S. Commissioner of Fisheries, Frank T. Bell:

> The removal of the International Fisheries Commission from the Bureau's laboratory at 2725 Montlake Boulevard is now virtually completed. May I express to yourself and Mr. Higgins our appreciation of the courtesy and friendliness with which we have been treated while guests of the Bureau. I am sure that there has been the utmost good feeling on both sides, something which we hope will persist in the years to come.

Thus ended the period of joint occupancy in the history of the Montlake laboratory.

Although Bonneville Dam was of major concern to the fishery agencies because it was the first dam to be encountered by anadromous fish in their ascent of the Columbia River, the real problem for the salmon fisheries of the Columbia occurred at Grand Coulee Dam located in the middle section of the Columbia River. The dam, claimed to be the largest man-made structure in the world, was some 320 ft high (forebay to tailrace) precluding any hope of either passing the adult salmon over the dam or the young migrants downstream. Thus more than 1,000 miles of spawning and rearing grounds for salmon above the dam were eliminated.

In 1939 a study was carried out by the Washington Department of Fisheries to determine the possible means of preserving the salmon runs that would be blocked by the dam. In due time a plan was developed, reviewed by a board of consultants, and finally approved by the various agencies. Since the U.S. government had jurisdiction over "navigable waters," the Bureau of Fisheries was given the responsibility for the salmon rehabilitation program--somewhat to the dismay of those who had developed the plan.

However, many of the state and federal fishery biologists had gone to school together, had worked together on a number of other projects, and helped organize the informal meetings of the Pacific Fishery Biologists at which they met at least once a year. Thus, throughout the project there was much

---

2/ The following were named by Willis Rich (1948) as having participated in the stream surveys at one time or another: Charles Baltzo, Floyd Bryant, Roger Burrows, LeRoy Christey, David Frey, Frank Jobes, Lawrence Kolloen, Ray Langton, Milton Lobell, William (Mark) Morton, Robert Peterson, Richard Shuman, Kingsley Weber, Richard Whiteleather, James Wilding, and Paul Zimmer. Later, Clifford Burner, Willard Brewington, Leonard Fulton, and Harold Gangmark also became a part of this program. Sudden increase in activity and staff brought with it an almost immediate need for additional space at the Montlake laboratory, and thoughts quite naturally turned to the "15-room units" occupied by the International Fisheries Commission (Halibut).

personal cooperation between the staffs of the two agencies.

As an amusing example, one night Wilbert Chapman, always an energetic and capable biologist, was apprehended for murder in Leavenworth, Washington, the center of the Grand Coulee project. There had been a murder in the area and the alert local constabulary noted blood trickling from the trunk of Wib's car. The blood, of course, was salmon blood but Wib had little identification with him and the local police simply could not believe that anyone would be interested in collecting dead salmon. Arnie Suomela, who was in charge of the Grand Coulee project for the Bureau and who just happened to be in Leavenworth at the time, had to convince the local authorities that Wib was really a state employee and the salmon were a necessary part of his work!

The Grand Coulee fish maintenance project continued for nine years (1939 to 1948) and was the first attempt at massive transplants of salmon runs from their native streams to new, quite distant spawning and rearing areas. There were numerous problems, especially in the early years. The salmon were trapped at Rock Island Dam and hauled by truck to the new "home" streams which appeared to be best suited to the particular species: Nason Creek (Wenatchee River) for spring-run steelhead and chinook salmon, Wenatchee and Entiat rivers for summer-run chinook salmon and fall-run steelhead, and Lakes Wenatchee and Osoyoos for sockeye salmon. Biologists often accompanied trucks and ran chemical analyses for pH, oxygen, carbon dioxide, and methyl orange alkalinity on the water in trucks, rivers, and lakes. As reflected in the counts at Rock Island Dam, salmon that have returned to the area of transplant have generally not only maintained their original levels of abundance but have increased two- to three-fold.

Although not really part of the biological program, the Division of Hatcheries of the Bureau of Fisheries shared in the management of the Grand Coulee fish maintenance program. The Division was responsible for all fish culture operations at the hatcheries and for the physical trapping and transportation of adult fish at Rock Island Dam. Accordingly, in 1937 the Western Regional Office of the Division of Hatcheries was established at Montlake. Fred Foster served as the Regional Director, Clarence Lucas as the Assistant Regional Director, Al Kemmerich as Superintendent-at-large for hatcheries, Hanford Thayer as engineer, and Dr. Fred Fish as the fish pathologist. Dr. Lauren Donaldson of the University of Washington's College of Fisheries was once again at Montlake as a troubleshooter for the hatchery program, and Dr. Robert Rucker, who later became head of the Western Fish Disease Laboratory, began his career at Montlake under a fellowship program.

The center of the fish culture activities relating to the Grand Coulee projects was at Leavenworth, Washington where there was a very large hatchery complex which included some 288 troughs, about 70 rearing ponds, and an elaborate system for the collection of fish. Dr. Fish was in charge of the laboratory at the Leavenworth station to do research on holding adult salmon, artificial spawning, rearing eggs and fish, nutrition, and the control of diseases. In addition to Leavenworth, two substation hatcheries were located on the Entiat and Methow Rivers, where similar research was carried out by Dr. Fish's staff.

Other salmon fishery concerns began to surface during this period. For almost

a half century, there had been recurring conflicts between the Canadian and U.S. fishermen in Puget Sound and the Gulf of Georgia, where they competed for sockeye salmon bound for the Fraser River in British Columbia, Canada. Finally, in May 1930 the Sockeye Salmon Fisheries Convention was signed, but questions about the role of the Commission in regulation of the fishery, the division of catch between the fishermen of the two countries, and the agency or agencies responsible for the investigations remained unresolved. In order to provide background information needed by the U.S. government before ratification, a new study was begun on the sockeye salmon fisheries of Puget Sound; as noted previously, Joe Craig was in charge of this project simultaneously with his appointment as head of the Montlake laboratory. After his transfer to the Columbia River program, George Rounsefell, who had been in charge of the Alaska herring studies for some 6 years, took over the Puget Sound sockeye salmon study. Shortly thereafter, on 16 June 1936, the convention was ratified by the U.S. Senate; documents of ratification were exchanged on 23 July 1937. The Commission was formally established in October 1937, with Dr. W. F. Thompson as Director of Investigations and an independent staff, similar to the organization of the Halibut Commission.

Results of the Puget Sound sockeye salmon study were eventually published by Rounsefell with George Kelez as co-author, but unfortunately they became available 2 or 3 years after the Commission's own research program had been established.

A related program was also started in 1934-35 on the coho salmon fisheries of Puget Sound under the direction of George Kelez. This was one of the early studies made by the Bureau on the relation between the release time of young from the hatcheries and the ultimate number of returns of adult coho salmon.

The first major expansion of the Alaskan fishery research program at the Montlake laboratory occurred in 1938 when funds were made available for the beginning of a large, comprehensive program of study on the salmon runs in the Bristol Bay area of the Bering Sea. The program which developed was divided into two major parts. One part of the study was on the freshwater life history of the Bristol Bay sockeye salmon and the environmental factors that would affect their survival. A field station and experimental area was established on Brooks River, near the outlet of the lake. This was a beautiful site for study in the Bristol Bay area; it was accessible by float plane from King Salmon, and the lake and river were large enough to provide normal access and spawning and rearing conditions, yet the site was small enough to allow studies of environmental conditions in some limnological detail. During the first year of study, an adult counting weir was installed in Brooks River, near the outlet of the lake, and the collection of samples of downstream young migrants was started, not only for Brooks Lake but in four other river systems of Bristol Bay as well. George Kelez was transferred from Chignik to take charge of this phase of the Bristol Bay studies.

The other part of the Bristol Bay program was in many ways more exciting because it was the first real study in the United States of the ocean life history of salmon. Tom Barnaby, a veteran of the Karluk studies, was placed in charge of the marine phase of the program. The oceanographic part of

the work, an essential part of the study, was done in close cooperation with the U.S. Coast Guard and involved the use of the cutter Redwing. In the second and subsequent years, U.S. purse seiners were chartered to explore the availability of salmon on the ocean. These vessels fished with ocean-type salmon gill nets, similar to those used in the Japanese high-seas fisheries. This work was funded primarily by the U.S. Department of State, which sought additional information on the extent of Japanese operations in the eastern Bering Sea and the Aleutian Islands.

It is somewhat ironic that these studies had to be terminated in 1941 with the outbreak of World War II and the invasion of the Aleutian Islands by the Japanese. The general study plan was to begin work in Bristol Bay and each year to fish farther and farther offshore. At the time the work was cancelled, the distribution of salmon over the continental shelf of the eastern Bering Sea as well as around some of the Aleutian Islands had been established, but the more distant waters of the central Bering Sea and the North Pacific Ocean had not yet been explored. Had the work continued for another year or two, the United States would likely have had the information it needed for post-war negotiations at the International North Pacific Fisheries Convention with Japan and Canada in 1952.

The Second Decade: 1941-51--World War II and the Post-War Readjustment

The first 10 years of Montlake's history was marked by the very rapid expansion of the biological and related research programs and a comparable growth of a competent staff of young biologists, led by a group of the top fishery scientists of the time. The programs were new and there was the excitement of discovery and the momentum that would carry the various programs through periods of difficulties. The Montake laboratory, in a very short period of time, had become well established among the fishery biological laboratories along the Pacific coast, and the staff had gained the respect of their colleagues in other agencies.

The next 10 years, however, saw the gradual disintegration of the research program and the dispersion of the staff. This change began even before the U.S. declared war in December 1941. In 1939, in accordance with the President's Reorganization Plan No. II, the Bureau of Fisheries was transferred from the Department of Commerce to the Department of the Interior, and in 1940 it was merged into the newly formed U.S. Fish and Wildlife Service. At that time, the Western Regional Office of the Hatchery Division, with Fred Foster, Al Kemmerich, and others, was moved to Portland and became part of the Regional Office of the Fish and Wildlife Service. Then in 1941, Dr. Fred Davidson resigned as Director of the Montlake laboratory and from the Bureau. Harlan Holmes was appointed to succeed Davidson, but he soon developed a distaste for the job and asked to be replaced. Dr. Willis Rich then served as director (1943-44).

In 1943, Fred Foster, who had been transferred from Montlake to the Regional Office in Portland 2 or 3 years earlier, was appointed the Director of Fisheries for the State of Washington by the newly elected Governor, Arthur Langlie. He almost immediately persuaded two of his old friends and hunting companions at Montlake to join his staff, Joe Craig

as Director of Research, and Arnie Suomela as Managing Biologist. Foster served as director until early 1945. Later that year he received an appointment as Director of Fisheries for the Fish Commission of Oregon. He returned to Washington, D.C., in 1954 as Assistant and later Associate Director of the U.S. Fish and Wildlife Service.

These were war years--1941 to 1945. Following the attack on Pearl Harbor on 7 December 1941, George Kelez, who was in the Navy's Reserve Officer Training Corps (ROTC) Reserve, was called up immediately and Clifford Burner and others on the staff soon followed. Ralph Ferrandini, Victor Samson, Sam Hutchinson, and other members of the staff were assigned to the Office of the Coordination of Fisheries or similar wartime agencies. Funds were kept to a minimum, the use of vehicles was curtailed, and supplies and equipment became increasingly difficult to obtain.

Although many of the research programs were maintained at basically a "standby" level, there were exceptions. In 1942, Tom Barnaby, in George Kelez's absence, took over the Bristol Bay program to finish construction of the field station at Brooks Lake and continue the series of counts at the weir of Brooks River and the sampling throughout Brooks Lake. The Grand Coulee fish maintenance program continued to transplant salmon into new "home" streams through 1943, with 4 years of evaluation afterwards. However, the work in general was limited and there was not the excitement of the first decade.

In 1944 Tom Barnaby was named the new Director of the Montlake laboratory. In the following year, Dr. Lionel Walford replaced Elmer Higgins as Director of Research for the Bureau of Commercial Fisheries in Washington, D.C. Elmer Higgins had been head of biological research programs for the Bureau in Washington since 1927 and played a key role in the selection of the site and construction of the Montlake laboratory and in the development of the research program at Stanford and at Montlake. He was especially interested in the problems of the salmon fisheries of the Pacific Northwest and Alaska. He frequently visited these areas and developed a research program aimed directly at problems of management. Higgin's professional career was almost entirely in the administration of fishery research and he was a very good administrator.

Dr. Walford's background and experience were completely different from Higgin's; he was a graduate of Stanford University and had received his doctorate from Harvard. He was a scientist in every sense of the word and his primary interest was in the marine sciences and the marine fisheries. Dr. Walford was not happy with most of the research programs of the Bureau of Commercial Fisheries at the time he was appointed Director of Research; he deplored the lack of publications and set about to reorganize the entire research program. He was almost obsessed with the policy of creating "new and exciting" research programs and of bringing into the scientific staff new blood with new ideas. He encouraged transfers of scientific staff between laboratories and programs or into other Divisions of the Bureau.

Sam Hutchinson transferred to the Portland Office in 1945 to become the Assistant Regional Director for Fisheries. As a result of Hutchinson's transfer, Mitchell Hanavan was placed in charge of all pink salmon research

at Little Port Walter and southeastern Alaska. Eugene Maltzeff and Paul Zimmer also transferred to Portland in 1945, Bill Peck and Mark Morton in 1949, and finally Tom Barnaby, Harlan Holmes, and Zell Parkhurst in the early 1950s. Ed Dahlgren transferred to Washington, D.C., in 1950 to become Chief of the Marine Fisheries section in the Division of Research under Dr. Walford.

In the latter part of this period, new faces began to appear at the Montlake laboratory. Ralph Silliman transferred in 1945 from the California Sardine Investigations at Stanford University to be in charge of a study funded by the U.S. Army Corps of Engineers on the population dynamics of salmon spawning in the tributaries of the Columbia River with John Hodges, Harlan Johnson, and Mark Morton. The project ended in 1949 and Silliman moved back to Washington, D.C., to become Chief of the Anadromous Fisheries section in the Division of Research.

Ken Mosher, who had a long experience with the determination of the age of fishes on the Pacific coast, transferred to Seattle in 1949 to read and analyze the large collection of salmon scales accumulated from previous Alaskan and Columbia River studies.

Dr. Gerald Collins was employed at Montlake in 1950 to begin his program on the passage of salmon at dams on the Columbia River.

In 1951, when Tom Barnaby transferred to the Regional Office of the Fish and Wildlife Service in Portland, Cliff Burner became the Director of the Columbia River program and Acting Director of Montlake, and Mitchel Hanavan became Director of Alaskan Investigations.

Some changes occurred in the research program at Montlake in 1950-51. Phillip Nelson began a study of the fertilization of Bare Lake, a small lake on Kodiak Island, in cooperation with Dr. Edmundson of the University of Washington, and new studies were started at Sashin Creek, in the vicinity of Little Port Walter, on the intertidal spawning of pink salmon. There was no change in the research in Bristol Bay or in the herring studies. The research program on the Columbia River was almost entirely oriented towards problems of fish passage at dams, especially in the diversion of downstream migrants away from the turbine intakes and in other sources of mortality.

During the latter half of this decade, the Alaskan research activities were further affected by the development of a highly competitive research organization on the University of Washington campus--the Fisheries Research Institute (FRI) of the College of Fisheries. In 1943 Dr. W. F. Thompson had resigned as Director of Investigations of the International Pacific Salmon Fisheries Commission. He was retained, however, by the Commission to complete his reports on the obstruction to salmon migration at Hell's Gate on the Fraser River, British Columbia, and to serve as a consultant to the Commission. The Alaska Salmon Industry Inc., an association of Alaskan salmon packers, approached Dr. Thompson in 1944-45 to undertake a series of extensive investigations of the salmon fisheries of Alaska, that was well-financed by a self-imposed levy on their annual pack. The research was done by a group of well-chosen graduate students from the University of Washington. Finally, in 1947, the FRI was accepted as a research unit of the University of Washington and formally established

within the College of Fisheries.

There is no question that results from the research program of the Fisheries Research Institute were of high scientific quality and were well received among their colleagues in the Bureau of Fisheries and other agencies. Unpublished information from FRI's field studies, however, began to be injected by the Alaska salmon industry into the regulations proposed each year by the Alaska Management Division of the Fish and Wildlife Service and gradually became a source of embarrassment to the Bureau and at times a source of almost violent animosity towards the policies (but not the staff) of the FRI - perhaps a fitting end to the chaotic second decade of biological research at Montlake.

The Third Decade: 1951-60--Pacific Salmon Investigations and the North Pacific

In 1952, Dr. Walford of the Bureau's Division of Research began to reorganize the biological program at Montlake, and in February of that year, he selected Clinton Atkinson as Director of the laboratory. Atkinson was a graduate of the College of Fisheries at the University of Washington, had worked for a short time for Dr. W. F. Thompson at the International Pacific Halibut Commission, and then was employed by Thompson as a member of the scientific staff of the International Pacific Salmon Fisheries Commission in 1938. He left the Commission 10 years later, to join the Bureau of Commercial Fisheries as Chief of Middle and South Atlantic Investigations. He was involved at the time with a new research program on the shad fisheries along the Atlantic coast and in rehabilitating the Bureau's biological laboratory at Beaufort, North Carolina, and had little thought of ever returning to the west coast or to salmon.

The instructions given to Atkinson by Dr. Walford were simple: revitalize the research program at Montlake, create an environment for productive research by the staff, and enhance the prestige of the laboratory through cooperation with other fishery agencies and the industry.

In heading up the new salmon program at the laboratory, Atkinson was asked to develop a research program that would provide a better understanding of the biology and the environment of salmon. However, it was not to include any "management biology," which was the responsibility of the Bureau's Fishery Management Office in Juneau, nor was it to conflict with or duplicate work that was already being done by other fishery agencies along the Pacific coast. After considerable discussion, it was decided that the salmon research program of the Bureau should be combined into a single unit for better coordination of staff and funds. The new organization was to be called Pacific Salmon Investigations, and Clifford Burner was appointed Assistant Director for this program.

The major changes that occurred under the Pacific Salmon Investigations were 1) the establishment of an experimental chinook salmon study area on Mill Creek on the Sacramento River;
2) modification of the Columbia River program into a more comprehensive study of the relation of temperature and water quality to the migration and survival of salmon in the Columbia River, and the initiation of study of

predation by squawfish on young salmon in the Columbia River--especially below dams; and 3) survey of the Cook Inlet area prior to establishment of a more permanent study area. The research program developed by Dr. Gerald Collins in 1951 for the study of fish passage at Columbia River dams remained unchanged, as did the existing research underway at Bare Lake, Karluk Lake, Brooks Lake, Sashin Creek, and the studies on Alaskan herring.[3/]

In 1951 the Army Corps of Engineers prepared a preliminary prospectus entitled "Columbia River Fisheries Engineering Investigations and Research Programs"--a broad program designed to provide design criteria for more economical and more efficient fish passage facilities at the Corps' projects on the Columbia River. Subsequently, a technical committee was formed consisting of the heads of the various research units within the several state fishery agencies and representatives from the Fisheries Research Institute of the University of Washington and the Pacific Salmon Investigations at Montlake. There were many meetings of this committee over the next 3 years. The relative importance of the criteria was discussed at length in an attempt to determine the best experimental approach to obtain the needed results. There was considerable controversy at times within the committee since each agency and investigator had their pet projects and each was competing for a share of the funds available from the Corps.

Dr. Collins was convinced that most of the problems troubling the Corps on the upstream migration of salmon over the dams could only be solved by building a large experimental flume where full-scale fishways could be constructed. As envisioned, salmon, in their normal migration up a fishway, could be diverted into test fishways of various designs, and researchers could compare their speed and ease of passage. Finally, in 1955, Dr. Collins' proposal was approved by the committee and the Corps. A test facility was built for his research program adjacent to the north shore fishway of Bonneville Dam.

The results from this laboratory were truly amazing, contributing more to the understanding of the movement of salmon and steelhead in fishways and over dams than any previous research. The results were immediately applicable to the design of fish passage facilities in the mid-Columbia and lower Snake Rivers at a considerable savings in construction cost.[4/]

Less successful were the attempts to develop means of guiding the young, downstream migrants away from the

---

3/ The staff working on the various freshwater studies of the Pacific Salmon Investigations (1952-1960) were: Harold Gangmark (Mill Creek, California) with R. Broad, H. Meyer, and later R. Bakkala; Kingsley Weber (Columbia River Environment) with C. Abegglen, D. Craddock, J. Gauley, B. Pullias, and later R. Major and R. French; R. Thompson and Galen Maxfield (Predator Studies and Control) with Dr. T. Duncan, B. Patten, K. Liscom and G. Osterberg; Mitchell Hanavan (Pink Salmon Spawning, Southeast Alaska) with Bernard Skud, Willard Brewington and Jerold Olson; Philip Nelson (Fertilization Studies, Bare Lake, Kodiak Island) with W. Edmondson, Carl Abegglen, Charles Hunter and Clark Thompson; George Eicher (Brooks Lake, Bristol Bay) with C. Weaver; Carl Elling (Cook Inlet Studies) with C. Weaver and K. Liscom; and others. In addition to the environmental study program, Larry Kolloen was in charge of the Alaska Herring Studies with Carl Elling and Bernard Skud; Elizabeth Vaughan was the statistical analyst during the first year of investigations.

4/ Assisting Dr. Collins in these studies were: Carl Elling, J. Gauley, C. Weaver, R. Holcomb, J. Johnson, C. Long, H. Raymond, and others.

turbine intake and other areas of high loss. The use of sound over a wide range of frequencies had little effect on the movement of the young fish, nor did the use of a moving series of lights.[5/]

The most promising method for guiding the downstream migrating salmon, and one with proven application, was the use of a pulsating electrical current to divert fish, into areas of safe passage. The costs, however, were high and generally impractical for use in large areas of water with any appreciable flow.[6/]

Another valuable development at the Montlake laboratory was the sonic tag--a small capsule with a battery-operated, sound-emitting device which is attached to a fish for continuous tracking in a stream or in the ocean.[7/] Also significant was the development of the electronic fish counter which was found to be quite accurate in counting the numbers of salmon ascending the fishways at the Hiram M. Chittenden Locks in Seattle.[8/]

There were a number of "fringe benefits" that came out of the electrical guiding/electronics laboratory at Montlake during this period. It is now remembered as a mildly unconventional unit, always coming up with some new device or idea. Many still recall Chuck Volz's demonstration of a headless fish swimming across the tank on a pulsating electrical current. But there was also the experimental application of electronic sensors for monitoring water quality at remote locations, in fresh water or at sea, and the little device that would indicate the freshness of fish. None of these developments reached the stage of practical application--they were regarded as 20 years too early--but they did open the eyes of the fishery biologists to the application of electronics to their work, and this was a valuable contribution.[9/]

The other new phase of research at the Montlake laboratory was on the high seas of the North Pacific and was under review by the U.S. section of the International North Pacific Fisheries Commission. This treaty was negotiated in 1952 and ratified in 1953, but the Commission was not formally organized until February 1954. In January of that year the biological laboratory at Montlake received a call from Washington, D.C., requesting that it devise, almost overnight, a research program for the U.S. portion of the work, that is, a program to determine the areas and degree of intermixing of Asian and North American salmon in the North Pacific. The program which it proposed on such short notice was the obvious one, focusing on distribution, movement or migration, and identification of stocks of salmon and the oceanographic factors that affect all of these.

5/ Sound studies were conducted by Clifford Burner and Harvey Moore; moving light studies were by conducted Leonard Fulton.

6/ Laboratory studies on electrical guiding were conducted under Gerald Collins with H. Newman, A. Groves, G. Monan, C. Long, and S. Dole; field studies were carried out under James Mason with H. Garrett, C. Hunter, G. Maxfield, K. Liscom, G. Esterberg, G. Monan, J. Hughes, J. Smith, and others.

7/ Fish tracking was under the direction of Parker Trefethen, J. Johnson, G. Monan, and K. Liscom with J. Hughes, C. Volz, G. Esterberg, D. Thorne, and C. Bartlett.

8/ Fish counting was under the direction of Dr. Julius Rockwell with R. Bergstrom and G. Lucich.

9/ C. Volz, H. Dale, R. VanHagen, D. Thorne, K. Compton, C. Gillespie, and others.

After considerable discussion at the first meetings of the U.S. section of the Commission, it was finally agreed that the research tasks would be divided between the biological research group at Montlake and the University of Washington as follows: studies of movement and migration of salmon by the Fisheries Research Institute, studies of oceanography by the Department of Oceanography, both of the University of Washington, and studies of distribution and identification of salmon by the staff at Montlake. This decision united the work and the staffs of the Bureau and the Fisheries Research Institute and closed the gap that had gradually developed between the two groups over the preceding years.

Preliminary explorations for salmon in the offshore waters of the Aleutian Islands were made in 1953 by the John N. Cobb, mainly to develop the techniques of fishing for salmon with gill nets on the high seas. The first survey to determine the distribution of salmon in the eastern North Pacific Ocean was made in the spring of 1955, again by the John N. Cobb, and was followed later that year by similar cruises of two chartered halibut schooners, the Mitkof and the Paragon. Wherever these vessels fished in the northern part of the Gulf of Alaska or along the Aleutians (north of about latitude 48°N and out to longitude 175°E), salmon were taken. Studies of the distribution of salmon continued with the use of the John N. Cobb and various chartered halibut schooners, and by 1961 the general distribution of salmon in the North Pacific Ocean and the Bering Sea had been firmly established.[10/]

The probability that the biologists at Montlake could identify and separate stocks of North American and Asian salmon was less certain. It was true that in previous studies, differences had been found between certain stocks of fish, but in general, these differences were lost when all the stocks in the fishery were mixed together. Fortunately, the major concern of the United States was protecting the sockeye salmon of Bristol Bay, and this species, because of its characteristic history of remaining in different freshwater environments for a year or more before going to sea, have the greatest probability of detectable differences. Therefore, the first studies at Montlake were on this species.

Although the 1955 results were preliminary, there were indications that the Japanese high seas mothership fleet was taking significant numbers of Bristol Bay sockeye salmon. This was based on an analysis of growth patterns in scales examined by Kenneth Mosher, an expert in scale analysis who transferred from the Bureau's sardine studies at Stanford University in 1949. Although both the Japanese fishermen and the scientists had apparently been aware of the dominance of a different sockeye salmon in the mid-Aleutians, which was "probably North American in origin and probably from Bristol Bay," the findings by Mosher and the rapid progress being made in the other studies of the North Pacific came as a shock to the members of the Japanese section of the International North Pacific Fisheries Commission. Japan increased active participation in the

---

10/ The Ocean Salmon Studies were under the direction of Mitchell Hanavan with Richard Hajny, George Tanonaka, Douglas Weber, Richard Johnson, Eugene Hill, Dr. Robert Ting, and others.

Commission's research program almost immediately.[11/]

Scales alone, however, were not adequate to separate North American and Asian stocks of sockeye salmon with any acceptable degree of accuracy. Accordingly, the research program for the identification of salmon stocks was built around a very comprehensive study of differences in the anatomical structures of salmon, e.g., number of fin rays, vertebrae, scales along the lateral line. A large number of these characteristics were examined and finally 7 were chosen that would provide the greatest degree of separation between North American and Asian sockeye salmon.[12/]

Because of the amount of data required and the complexity of the analysis itself, the only possible way to obtain the results was by use of a computer. Computer systems were not too common in those days and it required much discussion, correspondence, and justification before Montlake got its computer, probably the first fisheries biological laboratory to begin the regular use of automatic data processing equipment for storing and analyzing data.[13/]

Two other methods were used at the Montlake laboratory to support and confirm the identification and separation of the salmon stocks on the high seas. First, the development and use of serological techniques allowing researchers to identify stocks through the presence or absence of certain antibodies in the blood of the fish. Second, the then-new method of electrophoretic analyses allowing researchers to examine the protein composition of blood and tissue; a method now commonly used in the genetic studies of fish and in implants of genetic tags.[14/]

As noted earlier, a very important part of the North Pacific salmon studies was the tagging program carried out by the Fisheries Research Institute of the University of Washington (under a Bureau contract).[15/] The initial problem was how to capture salmon on the high seas leaving them uninjured and suitable for tagging. A method of purse seining for salmon on the high seas was developed which proved to be especially effective in this particular study. In 5 years, 1956 to 1960, the Institute tagged more than 60,000 salmon north and south of the Aleutian Islands and lesser numbers in the northern part of the Gulf of Alaska. The returns from both Asia and North America defined the patterns of intermixing for the various species of

---

11/ Kenneth Mosher was Project Leader with Ray Anas, Mabel Casterlin, and the part-time assistance of Dr. Ted Koo and Richard Hajny. James Mason joined this unit later.

12/ The Sampling Unit for Racial Studies was under the direction of Alvin E. Peterson with R. Duncan, L. Nakatsu, W. Meyer, C. Fiscus, and others.

The Analytical Unit for Racial Studies was under Dr. Francis Fukuhara, with Sueto Murai, Jack LaLanne, George Slusser, Roger Pearson, George Beam, and others.

13/ The original Biometric Unit was under the direction of R. Fredin, with Robert Lander, Donald Worlund, and others (later, Sueto Murai and Murray Amos were transferred into this group).

14/ Dr. George Ridgway was project leader with G. Klontz, L. Holmes, and others.

15/ The tagging program was under the direction of Allan Hartt and Benjamin Jones with Albert Palmer and others.

salmon across the North Pacific and in the Bering Sea.[16/]

In the following years the results from the work carried out at Montlake and the FRI revealed the extent of the catch of Bristol Bay sockeye salmon by the Japanese high-seas salmon fisheries in the mid-Aleutian area. Understandably, the Japanese section of the Commission was quite reluctant to accept the findings of U.S. scientists because of the impact on their fishery; in general, the Japanese maintained that definition of "areas of mixing" applied to all species combined. Finally in 1960, based on the results obtained by U.S. scientists and their counterparts in Canada and even Japan, the Commission agreed to consider the areas of mixing on a species by species basis, opening the way for recognition of the preponderance of Bristol Bay sockeye salmon subject to capture by the Japanese high-seas fisheries.

In 1956 the U.S. section of the Commission began to question the contribution being made towards the U.S. portion of the Commission's research on the North Pacific problems and decided to terminate the University's contract. The Montlake laboratory's scientists were left in somewhat of a dilemma. First, they recognized that there was a relationship between ocean conditions and the distribution of salmon on the high seas: a temperature barrier to salmon both to the north and to the south had already been detected and needed further study. Second, Japan, Canada, and the Commission were giving considerable attention to oceanography in their research programs, and it was essential that the United States participate in these studies. Thus, in a few months and with other funds, an oceanographer, Dr. Felix Favorite, was added to the staff and an oceanography program was underway at Montlake.[17/]

Two other research projects were assigned to the Montlake biological staff by the U.S. section of the Commission. The first was to develop proof that the U.S. stocks of salmon, halibut, and herring were being managed properly and were fully utilized in order to qualify for abstention from fishing by Japan and Canada. The results of these studies were subject to endless arguments with the Japanese scientists over the adequacy and interpretation of the data. Finally, however, the staff was able to show that while salmon and halibut did indeed fulfill all of the treaty requirements for abstention, herring, due to economic and other problems had not been fished commercially to any extent since World War II or before, and did not qualify.[18/]

The second research project dealt with king crab stocks in the eastern Bering Sea. This work was not an original part of the tripartite treaty between Japan, Canada, and the United States but was requested by the United States at the organizational meeting of the Commission in February 1954 and was limited to study only. The request for the study was the result of efforts by Lowell Wakefield, a member of a

---

16/ Dr. W. Royce, a former, long-time employee of the Bureau (Woods Hole, Honolulu, and Juneau), was appointed Director of the Institute upon the retirement of Dr. W. Thompson in 1958. Subsequently, Dr. Thompson served as Consultant to the Montlake laboratory's biological program until 1965.

17/ In the next several years, as the oceanographic program developed, J. Hebard, Dr. Timothy Joyner, Patsy McLaughlin, Betty Morris, and W. Ingraham were added to the staff.

18/ The cases for abstention were prepared by R. Fredin and others in the Biometrics Unit.

pioneering and well-known fishing family in Alaska who had acquired and outfitted a high-seas crab processing vessel, the Deep Sea, and was intent on developing a U.S. king crab fishery in the eastern Bering Sea. The Japanese had operated a king crab fishery in this area during the late 1930s and re-entered the fishery in 1952 after the signing of the peace treaty. Wakefield was anxious to develop a mechanism for exchange of information between the two countries and also to keep this fishery under the "umbrella" of the Commission, should problems arise.

Almost nothing was known of the biology and populations of king crab in the eastern Bering Sea or elsewhere in Alaska. But within an 8-year period (1956-64), the complete story (life history, rate of growth, migrations, survival, and numbers of crab in the area) was developed by the group at Montlake.

On one occasion during the research, the group was stymied in their efforts to determine the age and growth of the king crab. They had many samples of the very young and there was no problem in obtaining samples of the large crabs taken by the commercial fisheries. However, missing was a size group in between that eluded all conventional methods of sampling. Finally, early one spring, two scuba divers from the staff went to the area in the eastern Bering Sea where these crab were most likely to be found and were able to collect the necessary samples, like butterflies, of the missing group. This was one of the very early applications of scuba in biological studies.[19/]

As support for the staff of the expanded biological program at the laboratory (and especially for those working on international problems) grew, a literature research unit was established to assist the scientists in the search for and retrieval of literature needed in their studies. More importantly, the unit developed the capability for translating Japanese, Russian, and Chinese literature--a valuable aid in all of the studies on the North Pacific fisheries.[20/]

In 1956 Congress enacted laws reorganizing the Fish and Wildlife Service into two divisions: 1) the Bureau of Commercial Fisheries and 2) the Bureau of Sportfish and Wildlife. The plan also added a Commissioner of Fisheries and an Assistant Secretary for Fish and Wildlife. In 1957 Arnie Suomela, who had joined the Montlake laboratory's staff in 1934 and was a part of the early history of the laboratory, was nominated and confirmed as the first Commissioner of Fish and Wildlife and held this position until the change of administration in 1961 and his subsequent appointment as fishery attache in the American Embassy in Tokyo.

Under the new organization, the Alaskan operations were placed under the Administrator for Alaska Commercial Fisheries, Donald McKernan. As part of the reorganization plan, all biological research associated with the Alaskan

---

19/ The king crab research was under the direction of Dr. Fred Cleaver and Tak Miyahara with Henry Sakuda and others.

In many respects, the use of the vessel Deep Sea, provided without cost, was an integral part of these studies along with other help and the assistance of Lowell Wakefield.

20/ Paul Macy was in charge of literature research with Elizabeth Keyser, Sherry Pearson, Art Priddy, and others.

fisheries (with the exception of the research being performed for the International North Pacific Fisheries Commission) was transferred to Juneau. Some of the staff also transferred to Juneau at that time, but project leaders and most of the staff requested reassignment elsewhere. Subsequently, the Alaskan biological laboratory was established at Auke Bay, near Juneau (the establishment and subsequent development of the Alaskan research program is given in another section of this review).

So ended the third decade--one of the most exciting decades in the 50-year history of the Montlake laboratory. The period was marked by very rapid expansion of research programs, by the rapid accumulation and development of the staff, by new ideas and the application of those ideas, by a continuing critical review by scientists in other agencies both in the Pacific Northwest and Alaska and in Canada and Japan. The accomplishments by the staff are still classics in fisheries research today.

The Fourth Decade: 1961-70 Return to the Environment

By 1961 many of the major goals of the North Pacific and fish-passage research at the laboratory had been met, often under great pressure and urgency. The sixties became a time to evaluate the application and the value of completed research and to plan for the future. The research climate at Montlake became noticeably more relaxed and a number of new research facilities were constructed.

In 1962-63 the George B. Kelez, a converted U.S. Navy surplus vessel, was acquired which allowed, for the first time, our oceanographic and high seas salmon studies to be extended into the winter season. Previously, schooners and seiners had been chartered for spring and summer work, but they were too small for safe winter operations far offshore and they lacked adequate space for laboratory studies and for gear storage and repair.

In 1964 work began on the new addition to Montlake--a fully modern laboratory, library, and conference room/auditorium of some 65,000 ft^2. In 1967 a new 215-ft ocean research vessel, the Miller Freeman, was launched: it was carefully designed to provide laboratory space and equipment for the North Pacific studies. In addition, several field stations were established on the Columbia River and Puget Sound.

This was also a period of further analysis and the publication of summary reports of research results from the past 10 years of work. For example, the International North Pacific Fisheries Commission directed the scientists of the three countries to jointly prepare comprehensive reports on the accomplishments and interpretation of the results of the Commission's research programs since its first meeting in 1954. It was during the early part of this period that the Montlake laboratory initiated the massive compilation of all significant salmon research literature into a salmon compendium--probably the first attempt of its kind for a more efficient system of fishery literature search and retrieval.[21/]

In 1964 Ralph Silliman, who served as Chief of the Section of Anadromous

21/ The system was suggested by Dr. W. Thompson and compiled by Galen Maxfield.

Fisheries in Washington, D.C., from 1949 to 1961, was selected as one of six senior scientists by the Bureau of Commercial Fisheries, and in the next year he moved to the Montlake laboratory to continue his work on the population dynamics of fish--a series of basic studies on the relation between population size and the ultimate production or yield from a stock of fish. Silliman remained at Montlake until his retirement from the Bureau of Commercial Fisheries/National Marine Fisheries Service in 1973.

By the early 1960s the critical information required by the U.S. Army Corps of Engineers for the passage of adult salmon at dams had been obtained at the North Bonneville laboratory, and the attention of this unit shifted towards the more difficult problem of the downstream passage of the young, migrant salmon over the dams on the Columbia and Snake Rivers. The mortality of the young salmon passing through the turbines was evaluated, studies were started on the movement of the young fish in and through the large impoundments behind the dams, and the whole problem of diverting and/or collecting the young salmon at dams was reviewed. Perhaps most significant was the discovery of mass mortality caused by the supersaturation of gases, mainly nitrogen, in the tail waters below some of the dams. The unit also began exploring the feasibility of transporting the young fish by barge or truck around several of the dams in the Snake River.[22/]

At the same time, the research being done for the International North Pacific Fisheries Commission also began to change from the primary concern for the sockeye salmon taken each year by the Japanese high-seas fisheries to the distribution and fate of the chinook and chum salmon from the Yukon River and other streams flowing into the eastern Bering Sea. Around 1964 the Commission's scientists began to examine the groundfish fisheries of foreign vessels operating in the Bering Sea off Alaska.[23/]

In 1964-65 Atkinson served as Assistant Director for Research with the Bureau of Commercial Fisheries in Washington, D.C., and in 1966 he resigned as Director of the Montlake Biological Laboratory to become the fishery attache with the American Embassy in Tokyo, Japan. During this period, Clifford Burner was the Acting Laboratory Director at Montlake.

Shortly thereafter, Dr. Gerald Collins was appointed Director of the Laboratory and Dr. Francis Fukuhara, who had previously led the difficult research of identifying and separating North American and Asian sockeye salmon, was chosen to be the new Assistant Director. There was considerable reorganization within the program and staff to allow for a greater emphasis on research relating to the effect of the environment, both freshwater and marine, on the movements and survival of salmon and other fish.

With the new Miller Freeman and the George B. Kelez as a core, there was a marked expansion in the oceanographic programs at the laboratory.

22/ Although incomplete, the staff associated with the fish-passage studies in 1963 included Dr. Gerald Collins, Carl Elling, Joseph Gauley, Leonard Fulton, Parker Trefethen, John Hughes, Daniel Bates, Clifford Long, and Alan Groves.

23/ Although incomplete, the staff associated with the North Pacific research in 1963 included Dr. Francis Fukuhara, Robert French, H. Larkins, Charles Hunter, Jack LaLanne, Roger Pearson, Thomas Dark, Dr. George Ridgway, Fred Utter, Betty Landrum, Kenneth Mosher, and Raymond Anas.

A salmon aquaculture program was established at the Montlake laboratory in 1967 with a laboratory and field station at Manchester, Washington. The program of aquaculture research included all phases of rearing salmon in saltwater pens, e.g., nutrition, stock selection, and temperature control. Within a short time, this laboratory was able to demonstrate the rapid growth of coho salmon in saltwater rearing pens from 0.3 oz. to marketable size (0.5 lbs.) in about six months. Similar work has been done on other species.[24/]

Two new research units were established in 1968: studies on the physiology and biochemistry of fish, and the effect of thermal and petroleum products (and other environmental contaminants) on fish. In addition to the Montlake laboratory, a total of six field stations operated during this period for research on fish-passage and environmental problems: the Adult Fish-Passage Laboratory at North Bonneville, Washington; the Juvenile Migrant Biological Field Station at Pasco, Washington; the Environmental Field Laboratories at Prescott and Hammond, Oregon; and the Environmental Pollutant Laboratory at Mukilteo, Washington.

Although the fourth decade did not have the rapid development of new research programs experienced in the previous 10 years and perhaps lacked much of the associated excitement of discovery, the biological research program was anything but dull. The completion of the large new addition to Montlake with greatly improved laboratory facilities and the availability of a modern research vessel for ocean studies alone must have been an inspiration for the staff. The total staff at the end of this decade was almost 200, nearly double the number employed in 1961.[25/] However, of greater significance was the broadening and reorienting of the biological research programs at Montlake towards multi-species studies of the fisheries of the North Pacific and the development of environmental criteria for fish found in both fresh water and in the ocean. The results of this work provided perhaps a 10-year advantage to the fishery regulatory agencies of the Pacific Northwest and Alaska in enforcing several acts that would become effective in the next decade.

24/ The Aquaculture Station was under the direction of Conrad Mahnken, Anthony Novotny, Dr. Timothy Joyner, C. Hunter, and others.

25/ The Marine Research Program was under the direction of Dr. Francis Fukuhara with Herbert Larkins (Groundfish), Richard Major (Identification of Fish Stocks), Dr. Richard Thompson (Marine Behavior), Robert French (Ocean Distribution/Abundance of Salmon), Dr. Felix Favorite (Oceanography), and Dr. Harold Hodgins (Physiology and Biochemistry).

The Freshwater and Estuarine Research Program was under the direction of Carl Elling with Alan Groves (Behavior Laboratory), Daniel Bates (Fingerling Collection), Howard Raymond (Migration Rates and Timing), Clifford Long (Turbine Studies), Dr. George Snyder (Prediction of Environment), Leonard Fulton (Production in Inaccessible Area), James Johnson (Sonic Fish Tracking), Wesley Ebel (Transportation of Migratory Fish), and others.

The Service Units included Reynold Fredin (Biometrics Institute), Winston Farr (Engineering and Gear Development), Roger Pearson (Publication Unit), Gerald Monan (Staff Services), Ralph Sandvigen (Vessel Operations), and Beryl Mortensen (Administration). Roy Robeck and Harry Jacobsen were Masters of the George Kelez and the Miller Freeman, respectively.

The Fifth Decade: 1971-81 A Period of Change

The fifth decade is marked by major changes both in the organization of the U.S. Fish and Wildlife Service and the Bureau of Commercial Fisheries, and in the direction and demands of the biological research program at the Montlake laboratory by important new legislation.

On 3 October 1970, all functions of the Bureau of Commercial Fisheries (excluding certain freshwater programs such as the Great Lakes, work involving the Alaska pipelines, and similar investigations) were transferred from the Department of the Interior to the Department of Commerce and placed under a newly created agency, the National Oceanic and Atmospheric Administration (NOAA).[26/] The Bureau was recreated as the National Marine Fisheries Service (NMFS). One of the problems that arose during the early stages of reorganization concerned the structuring of the various research activities and laboratories within the NMFS. This was not a new problem. Although the biological and research laboratories had reported to Regional Offices since the reorganization in 1956, many of the programs carried out by these units were broad in scope, extending beyond regional jurisdiction and were even responsible, in some instances, to international organizations.

Shortly after the creation of the National Marine Fisheries Service, Dr. Robert White, the Administrator of NOAA, addressed the issue of organizing research. He appointed an internal committee to study the problem and recommend action, and he employed an independent consulting firm to make a similar study and recommendations. Dr. Dayton (Lee) Alverson from the Montlake laboratory was a member of the internal committee.

The recommendations of the two study teams were basically the same. Two groups were established to conduct research. One group conducting primarily oceanic research would report to the appropriate Associate Director of the National Marine Fisheries Service in Washington, D.C., while another group conducting shore research, local in nature, would report to the Regional Director. Four fishery research centers concerned with marine studies were established, of which the Montlake laboratory was one; four inshore and estuarine laboratories were established, of which Auke Bay Laboratory near Juneau was one.

The Pollution Laboratory at Mukilteo, the Environmental Laboratories associated with the Columbia River programs, and Fisheries Engineering (Fish-Passage) program, the Aquaculture Station at Manchester, and a field station at Kodiak, Alaska, all remained with the newly established Northwest Fisheries Center (NWFC) at Montlake.[27/]

As a result of the studies, all vessels under the NOAA programs were placed into a vessel pool, available to all but beyond the control of any single unit.

In 1976 the National Marine Fisheries Service realigned its organization and functions in order to administer the

26/ Reorganization Plan No. 4 of 1970 (84 Stat 2094).

27/ Originally named the North Pacific Research Center but changed shortly afterwards to the Northwest Fisheries Center.

new and expanded responsibilities it assumed as a result of the 200-mile fisheries conservation zone legislated by the Magnuson Fishery Conservation and Management Act. The four regional fisheries centers were given full responsibility for both the biological/environmental and fisheries utilization research. The Auke Bay Laboratory had been a part of the NWFC since 1974 and continued under the administration of the newly named Northwest and Alaska Fisheries Center.[28/]

At the time of the establishment of the Northwest Fisheries Center at Montlake in 1971, Dr. Alverson, who had been with the Exploratory Fishing and Gear Development Unit at Montlake since 1958, was appointed Center Director. Dr. Brian Rothschild served as the Deputy Center Director for the first year and was then replaced by A. T. Pruter, a former associate of Dr. Alverson's in the Exploratory Fishing Unit who was working at the time at NMFS headquarters in Washington, D.C. Dr. Alverson remained Director of the Center and the Montlake laboratory until his retirement in October 1979. Dr. Francis Fukuhara then served as Acting Director until his retirement in February 1980, followed by Dr. Murray Hayes. The new Center Director, Dr. William Aron, was appointed in July 1980.[29/]

The biological research program during this last decade was strongly influenced by the passage of several laws: the National Environmental Policy Act of 1969, the Federal Water Pollution Control Act of 1972, the Marine Mammal Protection Act of 1973, the Endangered Species Act of 1973, and the Magnuson Fishery Conservation and Management Act of 1976. In addition, the laboratories at Montlake, and later, Auke Bay also participated in a number of cooperative programs, including the Outer Continental Shelf Environmental Assessment Program (OCSEAP) of NOAA and the Bureau of Land Management; the Processes and Resources of the Bering Sea Shelf (PROBES) Program of the National Science Foundation; and the Marine Resources, Monitoring, Assessment, and Prediction (MARMAP) Program of the National Marine Fisheries Service.

As a result of the reorganization, the biological programs of the joint staffs of the former Montlake laboratory and the Exploratory Fishing and Gear Development Unit related to resource management were placed into three major divisions: Resource Assessment and Conservation Engineering (RACE) Division, (formerly Fish, Shellfish and Oceanography Studies), Resource Ecology and Fisheries Mangagement (REFM) Division, and Coastal Zone and Estuarine Studies (CZES) Division. The Environmental Conservation (EC) Division (in part) and the Fisheries Data and Management Systems (FDMS)

28/ The history of the Auke Bay Laboratory is found in another section of this review.

29/ At the present time, the Center's Administrative Unit consists of Center Director Dr. William Aron (vice D. Alverson), Deputy Director Hiro Heyamoto (vice A. Pruter), and Senior Scientist and Scientific Consultant Maurice Stansby, with G. Tanonaka, Dr. L. Low, C. Gill, A. Wilson, M. Barrett, E. Zweifel, and assistants.

Division are described elsewhere in this review.[30/]

The first 2 or 3 years as part of the new NOAA organization were difficult for the biological programs of the Northwest Fisheries Center at Montlake and the other Centers. Funding was limited and staffs had to be markedly reduced. Because of the costs of vessel operation, the oceanographic studies, begun near the end of the previous decade, were among the hardest hit. The Miller Freeman could not be operated for the oceanographic studies in 1971, and the George B. Kelez was decommissioned and taken out of the fleet in 1974. The Center was unable to participate in the national multi-agency MARMAP Program involving the basic collection of oceanographic data on ocean currents, water properties, and food patterns in the North Pacific. Most research was limited to addressing the original research requirements of the International North Pacific Fisheries Commission program and to finishing existing field studies.

The marine biological program at Montlake began to recover about 1975-76 with the new responsibilities and funding made available from OCSEAP and the enactment of the Magnuson Fishery Conservation and Management Act of 1976.

The Resource Ecology and Fisheries Management Division was given an especially important role in the development of the management plans and policies for the U.S. and foreign fisheries operating in the northeastern Pacific Ocean and the Bering Sea. The immediate demands were great: the scientists at the Seattle and Auke Bay laboratories had to assemble the available information on the life histories and fisheries of the various species of fish and to define the optimum harvesting schemes for each species for use by the Pacific and North Pacific Fishery Management Councils. Especially difficult were the Fishery Management Plans for the groundfish fisheries involving mixed catches of the various species. The preliminary plans were developed within a very short period, reviewed, and became a part of the Councils' management program in 1977.

In the years that followed, the direction of the program shifted toward the problems and information necessary for the prediction of the abundance of fish and the optimum level of harvest in the near future as a base for the management plans that must be prepared for each coming year.

30/ When the Center was first established, there was no change in project leaders from the previous organization of the laboratory: Dr. Francis Fukuhara (Marine Fish, Shellfish and Oceanography), Dr. Gerald Collins (Coastal Zone and Estuarine), and Reynold Fredin (Fisheries Data and Management).

Resource Assessment and Conservation Engineering (RACE) Division is under the direction of Dr. Murray Hayes with R. Wolotira [Shellfish Assessment and Ecology, Kodiak, (MARMAP II)], Miles Alton [Multispecies Assessment (MARMAPII)] including R. Mintel (Survey Strategy) and W. High (Foreign Cooperative Research), B. F. Jones (Conservation Engineering) and M. Nelson [Hydroacoustic Assessment (MARMAP II)], and assistants.

Resource Ecology and Fisheries Management Division (REFM) is under the direction of R. Marasco and includes Dr. L. Low (Division Data Management), J. Ingraham (Descriptive Oceanography), Dr. T. Laevastu (Ecosystem Model Development), Dr. A. Kendall (Ichthyoplankton Investigations), R. French (Foreign Observer Program), Dr. R. Marasco (Socio-economic Models), G. Hirschhorn and J. LaLanne (Age and Growth Studies), Dr. J. Balsiger, R. Francis, Dr. K. Henry, J. Reeves, R. Major and others mentioned above (Status of Stock Models and Evaluation), and assistants.

The age and growth studies became an essential part of the forecast since results indicated the relative abundance of young fish entering the fishery in each successive year. It began as a modest program and a carry-over from the early days at Montlake, but in 1980, ages were determined for some 92,000 walleye (Alaska) pollock, Pacific whiting, Pacific cod, rockfish, sablefish, and yellowfin sole.

Of similar importance and use is the study of the abundance of eggs and larval fish collected by fine-mesh nets from the spawning-nursery areas in the North Pacific and the Bering Sea. The information gained from these studies provides a direct link to the effect of the ocean environment on the survival of commercially important fish at the very young and critical stage of life.

During 1975-76, the oceanographic studies took on new meaning and purpose, and over the next several years, an eight-component ecosystem model (DYNUMES) and a prognostic (or predictive) bulk biomass model (PROBUB) were developed. These models have proven most useful in evaluating the complex interactions between the marine biological and oceanographic conditions. For example, by the use of these computer models, it is now possible to predict with some accuracy the size and fluctuations in abundance and distribution of the various species of fish, and the effect of varying intensities of fishing on the different stocks of fish as well as the environment. These analyses provide a most valuable tool for fishery management and rank as one of the outstanding accomplishments of the fifth decade at Montlake.

This unit is also responsible for placing observers aboard foreign fishing vessels to collect information on the size and composition of the catches and other information on the operation of the fisheries within the U.S. 200-mile fisheries conservation zone. This is a large program, involving about 90 observers in 1980, with volumes of narrative and data reports which are valuable not only for the management of the foreign fisheries but also for the U.S. fishermen in their efforts to develop fisheries in this offshore area.

The Resource Assessment and Conservation Engineering Division focuses on the other objective of the Magnuson Fishery Management and Conservation Act, that is, assisting in the development of U.S. fisheries both within the coastal area, and more important, in the 200-mile zone. In developing a fishery, the fisherman usually asks three questions: How many fish are there, where are the greatest concentrations of fish, and what is the most efficient gear for catching them? This very succinctly defines the work of this division. At the present time, most of the effort is devoted to surveys of the important fishing areas to determine the relative abundance of the fish in the different areas. The studies continually involve new techniques that can be used to more accurately census the abundance of the fish in the ocean. For example, a great deal of attention is being given to the use of very modern sonic or acoustical equipment that will detect and continuously identify major concentrations of fish as the vessel moves from one area to another. The unit is also developing new shrimp and herring "samplers."

In connection with ocean surveys, this unit conducts most of the basic biological studies on the populations of various fish. They have undertaken innumerable tagging studies on the

North Pacific stocks of fish (rockfish, Pacific cod, sablefish) and many of these have been undertaken cooperatively with state and university research groups of several states and with the scientists and agencies of Canada, Japan, Republic of South Korea, and the Soviet Union.

The Division of Coastal Zone and Environmental Studies operates the fish-passage program developed by Dr. Gerald Collins in the early 1950s. Expanded considerably in scope during the 1960s, it has been under the direction of Dr. Wesley Ebel since the establishment of the Center in 1970. The Division has three major sections: aquaculture, ecological effects of dams, and habitat investigations.[31/]

Since the beginning of the fish passage program, the results have provided important criteria for the design and preparation of the dams on the Columbia River. A substantial part of its present funding still comes from other agencies. The deleterious effect of dams on the runs of salmon and steelhead ascending the Columbia River has become even more pronounced in the past 2 or 3 years. Many of the runs of chinook and coho salmon ascending the rivers are now declining markedly, causing much concern to the fishery agencies of Washington, Oregon, and Idaho. One of the principal causes of this decline is the loss of migrants as they pass over or through the dams on the Columbia River or the lower Snake River.

In 1970 CZES estimated that the effect of the two dams on the lower Snake River at that time reduced the survival of migrants by 50%. The major causes of this loss are the passage of downstream migrants through the turbine, the heavy predation on the weakened fish just below the dams, and the association of the fish with the supersaturation of nitrogen or other gases in the water below the dams. Methods have been devised to collect and transport young salmon and steelhead around these dams and avoid these sources of high mortality. CZES also conducts work on the survival of hatchery and wild fish in the estuarine areas, and studies the behavior of adult salmon near the dams by use of a radio tracking system, to determine the effect of dam operation on the migrating salmonids.

Studies have also been made of other causes of mortality in the lower Columbia River estuary. Three areas of work have now been completed: the effect of dredging in the lower Columbia River, the toxicity of the discharge from the cooling towers of the Trojan nuclear power plant, and the effect of chemical fire retardants on salmonids. The results of these studies have had immediate impact on decisions made by a number of federal and state agencies.

Fisheries enhancement studies conducted at Manchester, Puget Sound, Washington, demonstrated in the first years that rapid growth can be obtained by rearing coho salmon in salt water. Subsequent work has focused on ways in which the present methods used can be made more economical. A vibrio disease has been identified and a method of mass vaccine developed. A number of studies have been made that will increase the

---

31/ Dr. Snyder and the personnel from the Oregon field stations were transferred in 1978 back to the Coastal Zone and Estuarine Studies (CZES) Division, where they had been until 1972, because their work on salmon in the Columbia River then was more closely associated with the program of CZES Division than with EC Division.

returns from aquaculture, including the development of rearing strategies of salmon from freshwater through saltwater stages, broodstocks of salmon kept for their entire life in saltwater pens, and perhaps most interesting, methods of rearing spot prawn successfully in pens with salmon at a more rapid growth than those found in natural conditions. For instance, harvestable shrimp (40/lb) can be grown in 12 months and "prawn-size" shrimp (16/lb) in 24 months.

In summary, the biological research program at Montlake over the fifth and last decade can best be characterized by two words--change and success. There has been the vast reorganization of commercial fisheries within NOAA in the Department of Commerce followed by a period of austerity, reduced staffs and the elimination of a number of the programs and activities. There has been the centralization of all research activities into four major Centers and the introduction of multi-disciplinary approach to our fishery problems. There has been the effect of legislation which placed new and primary responsibilities upon Montlake and its research staff for criteria needed in the maintenance and management of the fisheries in the North Pacific and Bering Seas. The research programs that were aimed during the third and fourth decades toward the more basic research are now more applied and are considered by many to be "management biology." And, at last, use is being made of the vast amount of data that the Montlake laboratory has accumulated over the years.

It is perhaps a fitting conclusion that the end of this decade and the first 50 years of the Montlake laboratory, was marked by the retirement of Dr. Alverson and the appointment in 1980 of Dr. William Aron as the new Director. Dr. Aron is no stranger to Seattle nor to the Pacific Northwest. Although born on the east coast, he did his graduate work at the University of Washington, receiving his Master's Degree in 1956 and his Doctorate in 1960. He took part, indirectly, in the activities at Montlake at that time and often relates that it was the money received through a contract between the laboratory and the Department of Oceanography at the University of Washington that helped him survive during those lean student years. The work that he did under that contract provided Dr. Aron with material for his first publication.

We end the fifth decade and begin the next 50 years at Montlake with no great change in program nor organization but a heritage of accomplishment and dedication of the many scientists who worked at the laboratory over the years, setting standards for others to follow.

In addition, there are other assets characterizing the Montlake laboratory that Dr. Aron recognizes and is intent on following. There has been the spirit of growing cooperation between the Northwest and Alaska Fisheries Center, the universities and other agencies, the industry, and the community as a whole; these ties will be strengthened even further to solve the fishery problems that each year are becoming more and more complex. Dr. Aron is also very much aware of and plans to retain as far as possible the depth of scientific expertise that has been characteristic of the Montlake laboratory over these 50 years, and the ability of the scientists to be able to respond to new challenges that will certainly arise in the future development and management of the fisheries and the maintainence of the

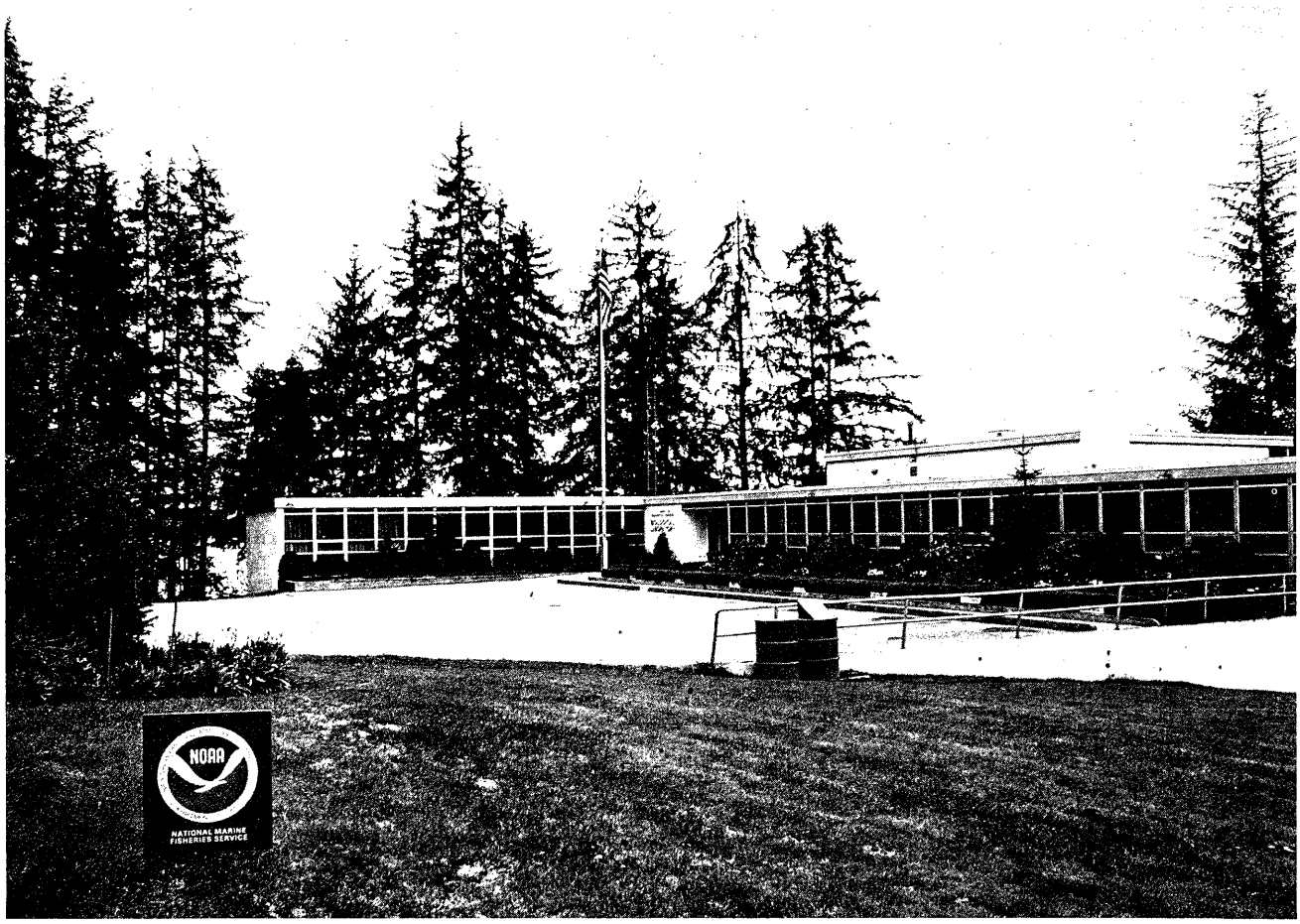
resource. These are the thoughts that have been so well expressed in the theme of this 50th anniversary - "Fifty Years of Cooperation and Commitment" - and this remains Dr. Aron's goal for the future.

Acknowledgements

This history of the biological programs and research would not have been possible without the help of a number of "old timers" who, individually and collectively, have recounted and documented the events that occurred at the Montlake laboratory during the first ten years or so. We are especially grateful for the assistance given us by the following: Thomas J. Barnaby, Heward Bell, Clifford J. Burner, Dr. Lauren Donaldson, Samuel J. Hutchinson, Edward A. Power, Dr. Robert R. Rucker, and Arnie Suomela. We also wish to give special recognition to William Markham Morton, who until his recent death, had undertaken a compilation of the biographies of a number of his colleagues at the Montlake laboratory. The material, which he presented in the first two volumes, has provided innumerable references to dates and events reported in this text.

Biological Research at Auke Bay Laboratory

Robert R. Simpson[1]



ACTIVITIES

Fisheries in the Territory of Alaska were managed by the federal government until the advent of statehood in 1959. In 1955 Secretary of the Interior Douglas McKay transferred Donald McKernan to Alaska to fill the newly established post of Alaska Fishery Administrator. Research on Alaska's commercial fisheries, which had been based at the Seattle Laboratory, was then transferred north so that "all functions concerned with the management of the commercial fisheries to the territory will be handled by a single field organization." Only two of the Seattle residents chose to move to Alaska, so a new staff of biologists had to be recruited. Dr. William Royce was appointed as the Assistant Administrator in charge of research, and in 1957 he established a new Alaska commercial fisheries group that was initially based in the Alaska-Juneau Mine Building.

1/ Alaska Regional Office, National Marine Fisheries Service, NOAA, P.O. Box 1668, Juneau, AK 99802

Dr. Royce organized the salmon research into geographically separate investigations--southeastern, central, and western Alaska. Each team was responsible for studies on migration and population dynamics of the salmon stocks in its particular region. Dr. Royce also established salmon survival investigations in southeastern Alaska, Bristol Bay, and Kodiak. Marine fish investigations were established for herring and king crab studies and a biometrics unit to serve the other research activities. Other individuals involved in the new research organization included Harry Rietze, Dr. Charles DiCostanzo, Theodore Merrell, Dr. Richard Myron, Dr. Richard Straty, Chester Mattson, Fred Thorsteinson, Dr. Norman Wilimovsky, and Dr. Howard Tait. When Dr. Royce resigned in 1958 Dr. George Harry became Director of the Fisheries Research Institute (FRI) of the University of Washington, which was extensively involved with Alaska salmon research.

In 1958 and 1959, Congress appropriated $430,000 for construction of the Auke Bay Laboratory, and the new facility was occupied in 1960 under the directorship of Dr. Harry. In 1967, Dr. Harry transferred out of Alaska and Dr. William Smoker became the Auke Bay Laboratory Director and served in that capacity for 14 years. Dr. George Snyder was appointed Director of the Auke Bay Laboratory in September 1981. The Laboratory is situated on a picturesque site overlooking Auke Bay, 12 miles north of Juneau. Nearby, Auke Lake and Auke Creek supply freshwater and serve as natural experimental areas.

Auke Bay is used for estuarine studies and supplies saltwater to laboratory aquaria. The building consists of 14,000 ft^2 of office/laboratory space for 50 persons. When the Laboratory was established, its activities were geographically extended by permanent outlying field stations at King Salmon and Brooks Lake at Bristol Bay, Karluk Lake on Kodiak Island, Kasitsna Bay in lower Cook Inlet, Olsen Bay in Prince William Sound, and Traitors Cove and Little Port Walter in southeastern Alaska.

The Little Port Walter station is the longest continuously operating fisheries facility in Alaska. This station was completed in 1940 with Civilian Conservation Corps labor under the management of Sam Hutchinson and research focused on Sashin Creek pink salmon. A weir on the creek has enabled counts of adult pink salmon to be made since 1934 and fry since 1940. Pink salmon research at Little Port Walter, until 1971, had been concerned primarily with natural factors that affect production and survival of pink salmon in fresh water. In the 1970s, the station became Alaska's principal salmon ocean ranching research facility for jointly shared state and NMFS programs.

The King Salmon facility served principally as the Bristol Bay Fishery Management Center and as the logistics and maintenance base for outlying field camps where research activities were undertaken. This facility was most active during the latter period of federal management of Alaska's fisheries, and during 1956-60, it supported the seasonal activities of nearly 100 full time permanent and temporary personnel. For several years the King Salmon base had been in caretaker status but, since 1978, the U.S. Fish and Wildlife Service has been using the base as a logistics center and headquarters for the Bechanof National Wildlife Reserve.

The Brooks Lake field station at Bristol Bay was established in 1940, enlarged in 1958 and 1960, and abandoned in 1973 because of severe bear predation and budget constraints. The station was used for intensive ecological studies of spawning grounds and nursery areas of the Naknek River system from 1957 through 1968. These studies culminated in numerous scientific publications on the population dynamics of sockeye salmon in the Naknek system. In 1978, the Brooks Lake Field Station was turned over to the Katmai National Park and Preserve of the National Park Service as a logistical-maintenance center.

The Olsen Bay field station, located at Prince William Sound, was operational between 1960 and 1969 for studies on the intertidal spawning and survival of pink and chum salmon. In the Sound's streams, from 50% to 75% of salmon spawning occurs in the intertidal areas. This station's usefulness was given considerable re-emphasis during the latter part of the 1960s for determining the effects of the Alaska earthquake on production of pink salmon in Prince William Sound. In 1981, the Alaska Pacific University began using the station for an environmental studies program and for teaching and training students.

Although Karluk Lake on Kodiak Island has been a site for intermittent federal sockeye salmon research since 1921, the program was expanded in 1956, and the main field laboratory and living facilities were constructed in 1960. Research objectives were to estimate the reproductive potential and optimum numbers of spawners occupying Karluk River and the separate tributaries of the lake. Budgetary restrictions forced abandonment of Karluk Lake studies in 1968. Some small programs involving monitoring of adult escapements and smolt migrations have been continued by the Alaska Department of Fish and Game. In 1978, the facilities at Karluk were transferred to the Kodiak National Wildlife Refuge of the U.S. Fish and Wildlife Service.

The Kasitsna Bay Station, located at lower Cook Inlet across Kachemak Bay from Homer, was constructed in 1957 and has been operational since then as a year-round field facility for shellfish research. Studies at this station have been concerned with the life history of Alaska shrimp and crab species, population dynamics leading to derivation of regulated annual harvest levels of Kachemak Bay shrimp as well as description of Alaska shrimp and crab larvae and of oceanic properties in Kachemak Bay affecting their distribution and abundance. In September 1977 the station was transferred to the Northwest and Alaska Fisheries Center's Kodiak facility. In 1981 the University of Alaska began using the station for shellfish research.

In contrast to the typical high seas activities by NMFS laboratories studying fish populations, the activities at the Auke Bay Laboratory for the most part have been landbased. Exceptions to this were the following short-lived, vessel-based studies: 1) Bering Sea king crab population studies 1965-72; 2) foreign fishery observer program and Pacific ocean perch study 1964-69; and 3) study of survival of juvenile salmon transiting from Bristol Bay, 1969-72.

During the more recent history of the Auke Bay Laboratory, the trend has been for a general shift from studies within watershed environments to studies in estuarine environments and from the field into the laboratory.

Fresh and saltwater systems and wet laboratory facilities were installed in the laboratory, and a chemistry and physiology laboratory was converted from office space. Experimental hatchery facilities were installed at Auke Creek, and a massive freshwater pipeline serving the new hatchery and rearing facilities at Little Port Walter were all installed with substantial assistance and funding from the State of Alaska.

By the 1970s the activities of the Auke Bay Laboratory focused on research and development of salmon ocean ranching, studies of the impacts of petroleum development and other disturbances on fish populations and habitats, and on assessment of shrimp and herring populations.

All federal biological research in the North Pacific areas under the National Marine Fisheries Service, except for that at Auke Bay, became a part of the Northwest Fisheries Center when it was formed in 1971. The Auke Bay Laboratory became a part of what was then renamed the Northwest and Alaska Fisheries Center in 1976.

Beginning in 1978 as a result of intensive planning, a major part of the Laboratory's activities was reoriented. Increased effort was placed in the Center's MARMAP program, which had national emphasis in NMFS. The collective activities of the laboratory focused on causes underlying recruitment variability in marine ecosystems. Research efforts were directed primarily at the egg-through-early-juvenile life of commercially important species that included pink and coho salmon, herring, walleye pollock, and rockfish. Also in 1978, the Auke Bay Laboratory was assigned responsibility for all biostatistical support for salmon research within NMFS for the U.S. Section to the INPFC. Coupled with this assignment was the responsibility for monitoring the Japanese high-seas salmon fishery, instituting the foreign salmon fishery observer program, and for the analyses to estimate the numbers of North American salmon being intercepted by the Japanese fishery. New program changes are being considered to bring other aspects of ABL research into closer alignment with fishery management issues of the Magnuson Fishery Conservation and Management Act of 1976.

ACCOMPLISHMENTS

A number of notable accomplishments have brought regional recognition and credit to the Auke Bay Laboratory. This recognition is indicated by a multitude of close alliances that have been evolving between the laboratory and agencies of the Alaskan and the federal government and with industry and community groups. In some cases, state and federal agencies have sought assistance and formally sponsored laboratory research. In the Alaska and ABL salmon restoration programs, where objectives are parallel, memoranda of agreement have been issued for sharing facilities, personnel, logistics, and other program costs. Members of the laboratory serve on the Governor's Fishery Council, constituted to develop legislation and attune state institutional mechanisms to the state-of-the-art of salmon ocean ranching. The petroleum industry financed laboratory bioassay studies concerned with the effects of crude oil on Alaskan fish. The U.S. Fish and Wildlife Service sponsored and repeatedly renewed a contract with ABL between 1969 and 1979 to monitor the

chronic effects of petroleum at the trans-Alaska pipeline terminal at Port Valdez. Research at Auke Bay to support management of salmon, herring, shrimp, and crab resources has been accomplished in harmony with efforts of the Alaska Department of Fish and Game (ADFG).

Following is a list of some of the laboratory's research accomplishments and actions that provide bases and support for dealing with fisheries management, protection of fish habitat, and restoration of salmon resources.

FISHERIES MANAGEMENT

Salmon

1. Described ranges of optimum escapements for sockeye salmon in major Bristol Bay river systems.
2. Correlated migration routes of adult Bristol Bay sockeye salmon from major river systems with oceanic currents and water masses.
3. Developed a new model that allocates salmon catches taken in a multistock common estuary Bristol Bay fishery to their appropriate rivers of origin.
4. Studied the oceanic nature of the routes of seaward migrating juvenile sockeye salmon in broad Bristol Bay estuaries and their growth and food habits to obtain measures of survival and to explain some hitherto unknown causes of fluctuating magnitude of returning sockeye salmon runs.
5. Determined the rivers of origin and the migration routes of pink, chum, and sockeye salmon taken in the Alaska Peninsula purse seine fishery.
6. Established boundaries of subdistricts for managing the Bristol Bay salmon fishery through information from a tagging study in the late 1950s.
7. Surveyed chum salmon resources in rivers of the subarctic and arctic regions of Alaska.
8. Surveyed abundance of Yukon River salmon and their use for subsistence.
9. Developed methodologies for measuring the timing and escapement of sockeye salmon in the Copper River.
10. Determined optimum pink salmon spawning densities under different stream conditions of southeastern Alaska and determined the survival rate of eggs and alevins over the winter.
11. Derived basic knowledge about the success, intensity, and extent of intertidal spawning by pink salmon in Prince William Sound where more than 50% of all spawning is intertidal.
12. Developed a technique, refined and used by the ADFG, to successfully predict the magnitude of pink and chum salmon runs in Prince William Sound.
13. Contracted with the University of Washington to catalog information on salmon streams in southeastern Alaska and for research in Bristol Bay to determine impacts of predation and lake fertilization on sockeye salmon smolts to: 1) develop a description of lake environment supporting sockeye salmon and 2) derive indices of smolt migrations.
14. Developed statistical estimators and measures of their precision to evaluate composition of stock mixtures. This technique is now used by ADFG for in-season management of Cook Inlet and Bristol Bay salmon, by the Fisheries Research Institute in ascertaining continent of origin of salmon taken on the high seas, and by the International Pacific Halibut Commission in estimating the sex composition of historical halibut landings from otolith collections.
15. Improved predictions of abundance of chum salmon runs by

quantifying the influence of marine environment on age and size at maturity and growth.

16. Derived new basic knowledge useful to fishery management and treaty negotiations on oceanic migration and distribution of different chinook salmon stocks in southeastern Alaska and their contributions to different fisheries.

Shellfish

1. Developed methodology used by the state of Alaska to forecast the annual productive capacity of shrimp stocks and to establish stable harvest levels in Kachemak Bay.

2. Conducted large-scale tagging of Gulf of Alaska king crab stocks to study biology, migration, and stock boundaries. For a number of years, annually assessed the status of Bering Sea king and snow (Tanner) crab stocks being harvested in the multinational fisheries. Developed a yield-per-recruit model used for establishing annual harvest levels of Bering Sea king crab.

3. Developed and published keys and complete descriptions of larval stages of major pandalid shrimp species and crab species in the North Pacific Ocean.

Marine Fishes

1. Analyzed impact of foreign fishing on Alaska Pacific ocean perch stocks and correctly forecast their decline.

2. Operated a groundfish observer program, for a number of years, by placing U.S. specialists aboard Japanese trawlers to estimate the levels of incidental halibut catches taken off Alaska.

3. Documented precise homing behavior of some rockfishes and the presence of juvenile Pacific ocean perch in fjords of southeastern Alaska.

4. Described dynamics of herring populations, schooling ecology, seasonal distribution; determined rates of growth and mortality; estimated sizes of spring spawning populations; in recent years, allied with the state to assess wintering stocks harvested in new food herring fisheries; and perfected a method of tagging herring.

5. Described the movements and feeding of walleye pollock during their first year of life in southeastern Alaska.

6. Defined coastal nursery grounds of Pacific rockfish of southeastern Alaska.

7. Described the food habits of Pacific cod, flathead and yellowfin sole, and of juvenile and young adult pollock in southeastern Alaska.

8. Collaborated with scientists at the Center's Seattle Laboratory in determining the effect of temperature on the rate of development of walleye pollock embryos and developing predictive equations for estimating spawning and hatching time of the embryos.

9. Determined the peak spawning period of walleye pollock in northern southeastern Alaska.

10. Described the stomach contents of two beached humpback whales and determined the major fish items in their diets.

General

Assisted in the creation of a comprehensive State of Alaska Fisheries Management Policy--that lays out the Department of Fish and Game posture on several controversial issues--by detailing an ABL member to that organization under the provisions of the Intergovernmental Personnel Act.

Protection of Fish Habitat

1. Developed SCUBA capability to study shallow-water marine ecology and built perhaps the best-trained team of diver-ecologists in cold-water areas.

2. Assisted the Atomic Energy Commission in evaluating effects of nuclear testing on marine organisms near Amchitka Island.

3. Surveyed estuarine bottom at a site used for log dumping and raft storing and found that dumping logs caused the substrate to be buried under masses of woody debris, making it nearly devoid of bottom organisms. Criteria for recommending permitting of sites for log dumping to minimize effects of fishery resources are based on these surveys.

4. Tested effects of aerial spraying of DDT on fish and aquatic insects in forest streams and achieved a local moratorium before use of DDT was forbidden by federal laws. Determined critical toxicity levels of various concentrations of a herbicide (2-4-D) on salmonids in Alaskan watersheds. Pinpointed residual DDT accumulations in freshwater fishes throughout Alaska.

5. Provided key information on the Kachemak Bay shrimp and crab nursery area used as an important basis for the state to buy back a $25-million oil lease from an oil company.

6. Published extensively quoted argument on the statistical difficulty of measuring the effects of logging on salmon through use of catch and escapement data.

7. Provided a comprehensive analysis of forest management practices and needs of the Alaska Department of Environmental Conservation.

8. Responded to major petroleum developments and corresponding national needs for information on potential impact on fisheries and habitat through expanded field studies of marine community dynamics coupled with laboratory bioassay and physiology studies. Oil effects research by ABL has extended over a 10-year period and has resulted in 22 papers published in national or international journals. Some notable conclusions have been included

a. The relative sensitivity of Alaskan marine species to petroleum hydrocarbon.

b. Some early life stages of shrimp and crab are more sensitive to oil than others.

c. Early life stages of marine species are generally more sensitive to oil than older stages, and adults are generally less affected by oil than juveniles.

d. Pelagic marine species of fish and invertebrates are generally more sensitive to oil than intertidal species.

e. Salmon eggs are tolerant of petroleum hydrocarbons in short-term exposures, but long-term exposures result in high mortality at hatching.

f. Some fry are much more sensitive to petroleum hydrocarbon during the transition from freshwater to the marine environment than at other life stages.

g. Pioneered use of the macoma clam as an indicator of environmental stresses used to ascertain measures of oil pollution in Prince William Sound.

9. Surveyed the entire Alaska coastline from Yakutat to the Bering Strait and published an atlas that provides qualitative physical descriptions of this stretch of beach line.

10. Determined the effects of the 1964 Alaska earthquake and resultant land elevation changes on the

production of pink and chum salmon in Prince William Sound.

11. Provided testimony as expert witnesses before the state legislature on such matters as tanker, logging, and hatchery legislation.

12. Assessed the fishery resources encountered by the 800-mile trans-Alaskan pipeline and recommended procedures to minimize damage at stream crossings.

13. Defined oceanic conditions in several areas that were considered for development for transport of timber, pulp, or oil.

14. Made numerous recommendations on water-use construction projects to protect or enhance salmon runs. For example, laboratory experiments were performed to simulate the cold-water conditions at the Grace Creek dam site on salmon egg development.

Restoration of Salmon Resources

In recent years the Auke Bay Laboratory developed a regionally recognized leadership role in ocean ranching research as well as technology and development of Alaska salmon species together with a concomitant alliance with the ADFG and with the Governor's Council for restoration of salmon resources. Among the Laboratory's accomplishments are

1. Published the very popular Salmon Ranchers Manual that translated findings in salmon hatchery and rearing research into a practical format.

2. Established a viable run of pink salmon in a natural stream by transporting and transplanting adults to replace an extinct run in southeastern Alaska. This technique was adapted as a management tool in Prince William Sound.

3. Developed a technology for producing high-quality fry in naturalized artificial environments with use of incubation boxes in wild streams and rearing pens in estuaries.

4. Worked with fishery managers to arrange management of a special open fishery on surplus coho salmon returning to the NMFS research station at Little Port Walter.

5. Developed and tested methodology of planting coho salmon fry in unutilized lakes, as minimal cost nurseries, for producing high quality smolts and increase in adult returns.

6. Coordinated development of a statewide plankton watch concept that strategically correlates release timing of hatchery fry with estuarine conditions to maximize adult returns.

7. Developed a comprehensive historic summary and analysis of early-day hatcheries in Alaska from 1891 to statehood in 1959.

8. Developed a rearing program utilizing a unique system of floating raceways that permit precisely controlled fresh water, intermediate saline, and saltwater culture to optimize salmonid growth and survival.

9. Tested new criteria for chinook salmon brood stock development and enhancement technology in Alaska for use in developing hatchery programs and rehabilitating depressed natural runs.

Research on Effects of Chemical Contaminants

Neva L. Karrick[1] and Sin-Lam Chan[2]

PRIOR TO 1970

Only a limited amount of research on the effects of chemical contaminants on marine animals was carried out at the Seattle and Alaska laboratories prior to 1970. A few investigations were started in the 1960s, including work to determine what effects water which had been supersaturated with gases had on salmon as they passed over Columbia River dams. Robert Clark began a project in 1969 to monitor the accumulation of petroleum hydrocarbons by intertidal organisms in Puget Sound. Ray Anas investigated accumulation of DDT in fur seals in the Pribilof Islands. The Technology Laboratory was able to measure the amounts of DDT and mercury in the edible flesh of commercial fish and shellfish of the Pacific Coast and Alaska. However, none of this early work definitively

1/ Former Deputy Director, Environmental Conservation Division, Northwest and Alaska Fisheries Center, present address: 4926 52nd S., Seattle, WA 98118.

2/ Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

answered the question of whether the presence of man-introduced contaminants affected marine animals or the ecological systems.

Organization of EC Division

Research at Seattle on the effects of pollution was first conducted by the Food Science Pioneer Research Laboratory (FSPRL) under Maurice Stansby. Research planning began in the spring of 1970. After the Northwest Fisheries Center (later Northwest and Alaska Fisheries Center) began operations in October 1970, members of the FSPRL started exploring the effects of chlorinated hydrocarbons on salmon. This work was soon extended to include the effects of petroleum hydrocarbons. Much of this early work was carried out by Dr. Edward Gruger, Neva Karrick, and Dr. T. Roubal.

On 18 January 1972, the FSPRL was disbanded and the Environmental Conservation (EC) Division was established. This division absorbed the FSPRL staff of Stansby, Dr. Gruger, Karrick, Dr. Roubal, Dr. Donald Malins, Nell Nickels, and Paul Robisch. Maurice Stansby was named Director. In July 1972 a number of other Center scientists with pertinent backgrounds or experience were transferred to the new EC Division. These included: Leonard Fulton; Robert Clark and John Finley, who had worked previously on petroleum hydrocarbons in the environment; Ray Anas, who had worked on contaminants in seals; Dr. Harold Hodgins, Dr. Fred Utter, William Gronlund, Douglas Weber, and Ethel Blood, all of whom had been doing physiological, behavioral, and genetic research on salmon; Dr. George Snyder and employees from the field stations at Mukilteo, Washington, and Prescott and Hammond, Oregon. Fulltime permanent employees in these groups included Warren Ames, Donovan Craddock, Richard Hughes, Benjamin Patten, and George Slusser (from Mukilteo); Dr. Theodore Blahm, Larry Davis, Maurice Laird, and Robert McConnell (from Prescott); and Joseph Durkin, Roy Pettit, and Carl Sims (from Hammond).

In addition to these permanent positions there were 17 fulltime temporary positions, a total of 46 fulltime positions in the new EC Division. Of these positions, 15 were in the Pioneer Research Unit at Seattle, 12 were in the physiological unit under Dr. Harold Hodgins at Seattle, and 19 were under Dr. George Snyder (15 in field stations and 4 in Seattle).

The functions of the new division were to study the nature and extent of chemical pollution in marine environments and to relate these findings to possible alterations in the health of marine organisms. The EC Division adopted an interdisciplinary approach to these complex issues, and utilized specialists in the fields of analytical chemistry, biochemistry, vertebrate and invertebrate pathology, electron microscopy, immunology, and behavioral marine biology.

RESEARCH 1970 THROUGH 1974

From 1970 through 1974, in addition to organization of the EC Division, other efforts were carried out.

Research was carried out by the chemists who had been transferred from the discontinued Food Science Pioneer Laboratory. This research actually began as a portion of the program of that laboratory even before it became a

part of the EC Division. Techniques were devised starting in 1970 to adapt some of the methodology, formerly used for the research on oxidation of fish oils, to problems of effects of environmental contaminants on fish. For example, Dr. Roubal devised ways of utilizing spin labeling, a technique using electron paramagnetic resonance, on which Dr. Roubal had done pioneering research relating to the oxidation program. He used this technique so that it could be used to study the fate of fat soluble contaminants assimilated into fat depots of salmon. This spin labeling procedure proved to be a valuable tool, and the basis for several papers describing its application to fish.

Using more conventional approaches, Dr. Gruger and others within the group began with an investigation of pickup and release by fish of chlorinated hydrocarbon compounds, such as PCBs, from the water in which they lived. By 1973, attention began to be concentrated more on the pickup and release of hydrocarbons from petroleum discharged into waters inhabited by fish.

In some cases biologists and physiologists within the division worked on problems they had become engaged in before the Northwest Fisheries Center was organized. Some groups under Dr. Snyder at Prescott, Oregon, continued work on problems concerning water which, in passing over dams, had become supersaturated with nitrogen and caused gas-bubble disease in fish. At Dr. Snyder's station at Hammond, Oregon, work was carried out on pickup by fish of spray contaminants used for controlling forest fires. Later, problems at the mouth of the Columbia River in connection with dredging were undertaken. At Mukilteo, work was continued on effects of elevated water temperatures that might occur when nuclear power plants used water for cooling and then returned it to areas inhabited by fish. Also considerable effort was aimed at improving conditions for holding fish to bioassay various effects brought about by water pollution. Thus the Mukilteo station was transformed into a facility available to all of the EC programs where testing adverse effects upon fish could be studied.

In the group under Dr. Hodgins, various programs involved determining causes of skin tumors in fish and of other fish diseases, application of electrophysiology to possible disorientation of fish interfering with spawning migrations as a possible effect of pollution, and studies involving genetics. These were all areas in which Dr. Hodgins' staff had formerly been engaged, and research was undertaken which made use of the knowledge and skills of these staff members in pollution and other studies of importance to the goals of the EC Division.

In the late 1960s Robert Clark began surveying the levels of petroleum hydrocarbons at selected sampling stations around Puget Sound and in the Strait of Juan de Fuca. This work was continued and a new study was begun on the continuing pollution caused by oil escaping from tanks of a vessel wrecked on the northwestern coast of Washington.

RESEARCH FROM 1975 TO 1981

On 1 November 1974, Dr. Donald Malins was appointed Director of the EC Division following the retirement of Stansby. At that time the major effort

of the Division was directed toward investigations on the effects of petroleum in the environment on marine organisms. Other important investigations dealt with the effects environmental changes in the Columbia River had on salmon (carried out at the two Oregon field stations), and the effect of altered temperature on fish (carried out at Mukilteo).

The EC Divison presently consists of four major task units: Sublethal Biochemical Effects (Dr. U. Varanasi, Task Leader), Contaminant Effects of Life Processes (Dr. H. Hodgins, Task Leader), Invertebrate Pathology (Dr. A. Sparks, Task Leader),the National Analytical Facility (Dr. W. MacLeod, Task Leader).

An interdisciplinary approach, coupled with a staff able to conduct both field and laboratory research, led to cooperative research with other organizations also concerned with the effects of pollutants on marine animals. As a result of its collaborative efforts with other NOAA programs--specifically, the Marine Ecosystems Analysis (MESA) Program, Outer Continental Shelf Environmental Assessment Program (OCSEAP), and the Energy Resources Project III--and with the Environmental Protection Agency (EPA), the EC Division was able to broaden its scope of research to address more effectively the problems of environmental pollution. These efforts made possible biological and chemical field studies in such widespread geographical areas as Puget Sound, Washington; Prince William Sound, Alaska; the New York Bight; the Bering Sea; the Gulf of Alaska; and the Brittany coast of France.

Contaminants

An important issue in the last half of the 1970s was the possible effects of drilling and oil spills in cold, northern waters. Chemical, physical, and biological reactions with almost infinite number of petroleum compounds create a dynamic environment. The EC Division planning broke the complex picture into workable segments of research. Initial laboratory impact studies were done on the water-soluble fraction of aromatic hydrocarbons and selected metals. Early studies provided basic information on uptake and discharge of the contaminants by marine organisms. As techniques were refined, both for chemical analyses and for exposure of fish and shellfish to components of oil, research progressed to include a determination of metabolites formed and the effects of these metabolites and of oxidized compounds. While laboratory and field studies that assess the impact of single contaminants are continuing, emphasis has been directed toward studies of the effects of multiple contaminants. Tasks on Sublethal Biochemical Effects and on Contaminant Effects of Life Processes are evaluating the potential for interactions among representative petroleum hydrocarbons, chlorinated hydrocarbons, and heavy metals.

Sublethal Biochemical Effects (SBE)

In studying the effects of petroleum hydrocarbons, Dr. Varanasi and her colleagues have shown that these are potentially toxic metabolites in marine organisms. Several aromatic hydrocarbons were studied in depth. Their conversion products were isolated from a variety of marine species and specific tissues, and were chemically identified. These conversion products

tend to remain in tissues and body fluids of marine organisms long after the parent hydrocarbons have disappeared.

Further work by the SBE group has shown that the liver enzymes of flatfish extensively metabolize the carcinogenic hydrocarbon, benzo[a]pyrene, to intermediates that interact with DNA. Such interactions are believed to be the starting point for tumor formation. Both parent aromatic hydrocarbon and metabolites have been shown to enter the reproductive system of flatfish. The presence of such pollutants in eggs and milt may interfere with the fertilization of eggs and the subsequent development of embryos. Studies are in progress to examine these issues.

Contaminant Effects on Life Processes (CELP)

Dr. Hodgins and his colleagues have undertaken a variety of laboratory and field studies designed to improve understanding of the effects of pollutants on physiological, pathological, and behavioral processes of marine biota. For example, laboratory studies have shown that flatfish exposed to sediments contaminated by crude oil take up a variety of petroleum hydrocarbons. Light- and electron-microscopic examination of exposed fish showed an enhanced accumulation of lipids in the liver, and clinical tests revealed altered hematocrit values and hemoglobin levels. Other laboratory studies have shown that exposure to the water-soluble fraction of crude oils can cause significant changes in predator-prey relationships resulting in decreased predation by adult coho salmon. Still other studies have revealed little or no effect of crude oil exposure on resistance to infectious disease by various salmonid and flatfish species.

Field studies undertaken by the CELP Task have addressed a number of critical questions including the possible relationship between enhanced incidence of disease (particularly those of noninfectious etiology) and high levels of environmental contaminants. In a continuing survey undertaken in collaboration with MESA, Dr. Bruce McCain and his coworkers have documented an increased incidence of certain liver tumors and hepatic lesions among fish collected in urban estuaries containing high levels of pollutants. The manifestations of these lesions in terms of organ dysfunction and fish health are presently under investigation in laboratory studies.

Additional field research was undertaken in collaboration with OCSEAP following the grounding of the tanker Amoco Cadiz off the coast of France. The research was aimed at gaining a better understanding of the impact of a major oil spill; Dr. Joyce Hawkes evaluated the effects of the petroleum hydrocarbons on mussels within the spill zone. Electron microscopic examination of exposed organisms revealed increased areas of lipid and increased numbers of lysosomal granules in cells of the digestive glands. In other OCSEAP-oriented field studies, Douglas Weber demonstrated that petroleum hydrocarbons can disrupt the normal migratory behavior of adult salmonids.

While the laboratory and field studies assessing the impact of single contaminants are continuing in both the SBE and CELP tasks, recently emphasis has been directed toward the study of the effects of multiple contaminants.

The EC Division scientists are presently evaluating the potential interactions among representative petroleum hydrocarbons, chlorinated hydrocarbons, and heavy metals.

Auke Bay Laboratory

In addition to the work on effects of chemical pollutants on marine organisms being carried out by the Environmental Conservation Division at Seattle, an effort within the Environmental Program is being carried out by the Center's Auke Bay Laboratory. This program emphasizes problems specific to Alaska. Considerable work has been conducted on problems caused by the wood products industry where substances toxic to fish have leached from trees into streams. Considerable emphasis, especially in recent years, has been placed on problems connected with the petroleum industry in Alaska. Long-term monitoring studies have been made both in marine waters near oil pipelines where oil is transferred to ships and at oil-drilling sites. A recent study at Port Valdez investigated effects of dumping billions of gallons of ballast water used by tankers on their northern runs.

In addition to this field study, laboratory investigations are also conducted at Auke Bay. Many of these studies relate to aspects such as pick-up and discharge of petroleum and petroleum compounds by fish and shellfish, and the effects of these contaminants. Both short-term acute-toxicity studies and long-term sublethal-effects studies are being made, but most emphasis is on the former. Unlike the EC Division at Seattle, a majority of the staff with the Auke Bay program has a background in biology or fisheries, although most have had experience or other training in physiology or other disciplines.

This physiological project is headed by John Karinen. Other scientists in the program include: Patricia Arasmith, Malin Babcock, Sidney Korn, Stephen Lindsay, and Dr. Stanley Rice. Theodore Merrell has overall charge of the Environmental Program, including the physiology-bioassay project, and of the watershed and estuarine ecosystems projects which include work in effects of the trans-Alaskan pipeline. In these latter two projects, workers include: Dr. K. Koski, L. Barr, R. Walters, and R. Myren.

Electron Microscope Unit

The research on early biological effects of pollutants required definition of the early structural changes in tissues and organs. Consequently an electron microscope unit was formed in 1976 when the Northwest and Alaska Fisheries Center and the Environmental Protection Agency purchased transmission and scanning electron microscopes. Dr. Joyce Hawkes is in charge of the studies performed on the scopes; other personnel in the unit are Carla Stehr, Paul Olson, and William Paine.

Invertebrate Pathology (IP)

The capabilities of the EC Division were expanded in 1977 when Dr. Albert Sparks transferred from Washington, D.C., to set up a Task on Invertebrate Pathology. The IP task focuses on research to better define and characterize the diseases of marine invertebrates. To date, Dr. Sparks and Jolly Hibbits have identified a number of previously unrecognized disease syndromes and are studying their pathological manifestations. In

particular, they have demonstrated the highly invasive nature of the fungus causing black mat disease which previously was believed to colonize only on the external surfaces of the snow (Tanner) crab. This observation, along with the documentation of a high incidence of black mat disease in Alaskan waters, suggests a possible relationship between this disease and the recent decline of this commercially important species.

National Analytical Facility

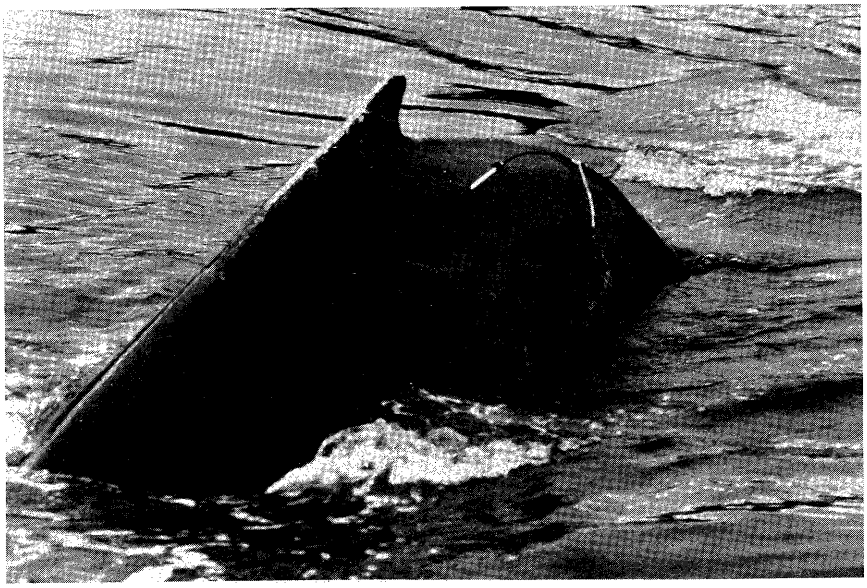
The NOAA National Analytical Facility (NAF) provides NOAAs environmental programs with detailed information on the types and amounts of trace chemical contaminants in the marine environment. Many of NOAAs environmental programs must contend with extremely complex mixtures of chemical compounds which are challenging to isolate, identify, and measure. To deal effectively with such mixtures, highly trained analytical chemists and technicians are needed to operate the modern, sophisticated instrumentation required for these trace chemical analyses. This need presents difficulties for many research projects which have neither the resources nor the volume of analyses to justify the undertaking. Chemists on the staff of the facility include: Task Leader Dr. William MacLeod, Donald Brown, Douglas Burrows, Victor Henry, Dr. Margaret Krahn, and Patty Prohaska.

The NAF operates with state-of-the-art equipment, such as glass-capillary gas chromatography coupled with mass spectrometry, and high-performance liquid chromatography using ultraviolet and ultra-violet-fluorescence on-line detection systems. In addition to providing analytical services for laboratory studies, the staff is studying new ways to analyze marine pollutants and their toxic conversion products. Their research has provided new procedures for analyses of environmental samples.

Using the combined expertise of many different disciplines, scientists in the EC Division are providing important information to state and federal agencies and other groups, on the possible impact of man-made chemicals and other stresses on marine life.

Marine Mammal Research

George Y. Harry, Jr. [1]



First successfully tagged and tracted humpback whale.

Northern fur seals.

The Pribilof Islands, home of some 2 million fur seals, were discovered in 1786 by the Russian navigator Gerassim Pribilof, and Russia began exploitation of the seals almost immediately. During the latter part of the Russian regime, the fur seal management program allowed the herd to increase and when the United States purchased Alaska in 1867, the population was probably near maximum abundance.

The U.S. government soon recognized that efficient management of fur seals required knowledge about the size and biological characteristics of the herd. An agent of the Treasury Department, Henry Elliott, was dispatched to the

1/ Former Director, National Marine Mammal Laboratory, Northwest and Alaska Fisheries Center, present address: 4259 133rd S.E., Bellevue, WA 98006.

islands in 1872. Elliott spent several summers in the Pribilofs, estimating the size of the herd, mapping rookeries and hauling grounds, and drawing fur seals and their surroundings. His reports and conclusions, although sometimes controversial, for the first time directed public attention to the fur seals of the Pribilof Islands and their environment. Elliott continued his intense efforts on behalf of the fur seals until his death in 1930, giving his last testimony on the species at the age of 80.

In 1893 the U.S. Commissioner of Fisheries became responsible for fur seal research. This responsibility has remained with the federal fishery agency, through several name changes and up to the present, except for the period 1903-08. During the first 2 years, research was directed by C. H. Townsend, who made an important contribution toward understanding the distribution of fur seals by plotting the location of pelagic catches in the North Pacific Ocean and Bering Sea. Controversy about the effects of pelagic sealing led to agreement between Great Britain and the United States to institute independent scientific investigations. The results of these studies, published in four volumes in 1898, summarized the knowledge of fur seal biology and populations at that time.

During the last two decades of the 19th century and to a limited extent during the first decade of the 20th century, uncontrolled sealing at sea decimated northern fur seal populations. In 1911 a treaty prohibiting pelagic sealing was signed by representatives of the United States, Great Britain (for Canada), Russia, and Japan. In 1914, the Secretary of Commerce appointed George Parker of Harvard University, Wilfred Osgood of the field Museum of Natural History, and Edward Preble of the Department of the Interior's Bureau of Biological Survey to census the Pribilof herd, to evaluate past influences and current sealing practices on the herd, and to recommend future practices which would lead to its restoration. The report of their scientific findings, published in 1915, emphasized the importance of pup counts as a basis for estimating the rate of increase in the herd. The Bureau of Fisheries largely accepted the recommendations of Osgood, Preble, and Parker, and techniques for gathering routine population data were gradually developed. All data, however, were collected by island administrative personnel. No biologists were assigned to the Pribilof Islands between 1915 and 1939, and almost no biological research was carried out.

Although little formal fur seal research took place before 1939, many important contributions to the natural history of the Pribilofs were made by a schoolteacher, Dr. G. Dallas Hanna, who arrived on St. Paul Island in July 1913 at the age of 26. Dr. Hanna remained on St. Paul Island almost continuously until September 1918 and returned in the summers of 1919 and 1920. Although his principal duties were those of schoolteacher and storekeeper, he also collected specimens, made photographs and assisted with fur seal research. Between 1914 and 1951, he authored 41 publications on the natural history of the Pribilof Islands. After leaving the islands, Dr. Hanna continued his scientific career as geologist, paleontologist, naturalist, and inventor; at the time of his death in 1970, he was curator of geology at the California Academy of Sciences.

In 1940 the Commerce Department's Bureau of Fisheries and the Interior Department's Bureau of Biological

Survey were merged to form the U.S. Fish and Wildlife Service under the Department of the Interior. For the first time, mammalogists and fur seal managers were brought together within one agency. Since 1940 (except for 1942), biologists have been continuously assigned to fur seal studies. As the first Director of the Fish and Wildlife Service, Dr. Ira Gabrielson assumed responsibility for the Pribilof Islands fur seal herd. Gabrielson and others had become skeptical of the "bookkeeping system" developed for estimating the size of the fur seal population, which resulted on paper in a herd size of about 3.5 million animals. This census was not based on biological research because almost none had been carried out since 1915. Gabrielson asked Frank Ashbrook, who was in charge of fur seal investigations for the service, to develop a research plan. Such a plan required firsthand information about the herd; therefore, in June 1940, Ashbrook and Dr. Victor Scheffer of the Bureau of Biological Survey were dispatched to the Pribilof Islands. The 1940 studies marked the beginning of the modern period of fur seal research. Scheffer previously had taken part in the Aleutian expedition aboard the vessel Brown Bear (1936-38), directed by Olaus Murie, and in 1938 had established an office in Seattle at the University of Washington Forestry Building, Anderson Hall. Seattle thus became the headquarters for fur seal research.

The Fur Seal Treaty of 1911 was scheduled for renewal in 1941, but unexpectedly in October 1940, Japan gave notice of its intent to withdraw from the treaty the following year. Japan claimed that the Pribilof Islands fur seal herd migrated annually into Japanese waters and consumed vast quantities of food fish. In response to this claim, staff members of the Fish and Wildlife Service in Washington, D.C., developed a 2-year research plan which would assess damage to the commercial fishery caused by seals, calculate the rate of intermingling of the Asian and the Pribilof Islands fur seals, and determine the food species of fur seals. On 30 June 1941, Congress appropriated $290,000 for the investigation. Scheffer was made project leader and the following five biologists were assigned to the study: Wilbert M. Chapman, Henry Banner, Kelshaw Bonham, Ford Wilke, and Donald Shipley. Headquarters for this expanded research program remained in Seattle at the University of Washington Forestry Building, Anderson Hall. The Black Douglas was selected as the research vessel, but before research began, Pearl Harbor was attacked and the vessel was taken over by the U.S. Navy.

In the spring of 1942, the Aleutian Islands became an active war theater and all fur seal research came to a halt. Scheffer was able to return to the Pribilof Islands in the summer of 1944 and resume his fur seal research, continued until his retirement in 1969. Scheffer collected specimen material from marked animals of known age, obtained additional information on the age-length relationship, studied the parasites of fur seals, and collected testes as evidence of the age at which spermatogenesis begins.

Research continued at a low level during the war years, but in 1947 plans were made to reactivate the Black Douglas and to undertake pelagic fur seal research. Congress appropriated $62,500 for this study and biologists William Sholes, Karl Kenyon, and Robert Brown were hired. Headquarters for the expanded fur seal research was in the

Montlake Laboratory, now the Northwest and Alaska Fisheries Center. The Black Douglas made two trips out of Seattle in 1947, the first one was to the Pribilof Islands and back with side trips to Unalaska and Bogoslov Island, and the second was to Attu Island. However, the vessel proved much too large for efficient pelagic seal hunting. In 1948 the Black Douglas left Seattle on her third and last fur seal research cruise. The vessel went to the Pribilof Islands and back to Unalaska, across the North Pacific Ocean to San Francisco, to San Pedro, and finally to Seattle.

Following World War II, land-based research was also increased. In 1947 and subsequent years the pup tagging which was initiated in 1941, was greatly expanded. In 1948, Scheffer and Kenyon took aerial photographs of all rookeries as an experimental censusing technique. An important breakthrough in fur seal research took place in 1948 when Scheffer extracted 36 teeth from a freshly killed animal to photograph dentition. During the process, he noticed faint ridges circling the root of each tooth and hypothesized that each ridge might indicate one year of life. His theory proved to be correct and, as a result, a routine part of the field operations on the Pribilof Islands each year has been a collection of teeth for age determination.

In 1948 a plan was being developed in Tokyo for pelagic research in waters off Japan. The Natural Resources section of the General Headquarters, Supreme Commander for the Allied Powers, undertook to study the natural resources of Japan and to assist in their restoration. A Wildlife Branch was established and Wilke was sent by the U.S. Fish and Wildlife Service to study the migration and feeding habits of fur seals wintering off Japan. Field operations started in December 1948 on a small Japanese vessel and were resumed with two Japanese biologists in 1950.

Another important event took place in 1949 when it became evident that assistance was needed in statistical design of experiments and population dynamics work. Dr. William Birnbaum, Director of the Laboratory of Statistical Research at the University of Washington and his assistant, Dr. Douglas Chapman, agreed to help work with statistical problems. Chapman became a consultant to the fur seal program in 1950 and has continued in this capacity. With Scheffer and Kenyon, he was instrumental in the 1954 revision of the estimated fur seal population--recalculated to be 1.8 million animals, based on biological observations, instead of 3.6 million.

After U.S. involvement in pelagic research off Japan ended in 1950, Wilke returned to the Seattle office. A major international fur seal study took place in 1952; Wilke and Kenyon, representing the United States, and Fred Taylor and James Manzer, representing Canada, went to Japan joining Fukuzo Nagasaki in studies off Japan. (The Soviet Government was invited to take part in the research operation but declined, although expressing an interest in re-establishing international arrangements for the conservation of fur seals.) Six vessels operated in Japanese waters; Scheffer headed the research team in the waters off the western coast of North America using two vessels. Major results included data on intermingling of fur seals at sea from U.S. and Soviet Islands, pregnancy rates, food of seals, and lengths and weights of 400 fetuses.

In 1953 Scheffer was detailed to Denver, Colorado, for 2 years, followed by 1 year in England. That same year Wilke was placed in charge of fur seal research, remaining in Seattle in charge of marine mammal research until his retirement in 1970.

The period 1953 to 1956 was one of austerity for fur seal research. Wilke, Kenyon, and an administrative assistant were the only staff members during this period. By October 1954 the Montlake Laboratory had become crowded and, as a result, the fur seal investigation was moved to rooms in a converted house in Edmonds, Washington. The house also contained a barber shop and a plumbing shop.

Although fur seal research between 1953 and 1956 was at an ebb, international events were taking place which would lead to greatly expanded research programs. The United States, Soviet Union, Japan, and Canada agreed that a North Pacific Fur Seal Conference should be convened to draft a new treaty. Discussions took place intermittently from 20 November 1955 to 9 February 1957 when the Interim Convention on Conservation of North Pacific Fur Seals was signed in Washington, D.C., on behalf of the four governments. The convention continued the ban on pelagic sealing and called for a cooperative research program to collect and share field data. The interim convention, with some modifications, continues in effect to the present and relies on scientific research to determine the measures necessary to maintain the maximum sustainable productivity of the fur seal resources and to understand the relationship between fur seals and other living marine resources. Since the signing of the convention, the objective of the fur seal research program has been to fulfill the research requirements stated in the convention.

Carl Abegglen and Alton Roppel joined the permanent research staff in 1956, and during the same year, a new laboratory was occupied on St. Paul Island. The following winter, research headquarters was moved from Edmonds, Washington, to Navy buildings on the Sand Point Naval Air Station, Seattle, and remained there until part of the Navy property was transferred to the National Oceanic and Atmospheric Administration (NOAA) in 1976. After NOAA took possession of the property, the south end of hangar 32 was converted for marine mammal research headquarters. Now under construction at the NOAA Sand Point facility is a new building which will include the National Marine Mammal Laboratory.

In the early 1950s, biologists concerned with the Pribilof Islands fur seals were aware that the herd had ceased to grow and came to the conclusion that the herd should be reduced in size, by killing female fur seals, in order to increase productivity. The commercial harvest of female fur seals began in 1956 and continued through 1968 although, from 1963 to 1968, only females in excess of those needed to maintain herd size were harvested.

In 1957, Karl Niggol joined the staff and was involved in pelagic research until he left the laboratory in 1962. Clifford Fiscus joined the pelagic research team in 1958 and became its leader after Niggol left. In 1958 staff biologists chartered two halibut schooners and one purse seiner for studies of the abundance, distribution, and feeding habits of seals off the western coast of North America. Pelagic studies from chartered vessels, in cooperation with Canadian

scientists, continued each year through 1974. At that time, the decision was made to interrupt sea work and analyze the vast amount of data which had been collected. The analysis and publication of pelagic data continues in cooperation with Canadian scientists. Ocean research was resumed in the fall of 1980; the objectives included monitoring the arrival of the various year classes of seals in southbound migration in southeastern Alaskan waters.

In 1956 the U.S. Fish and Wildlife Service was divided into two parts; the Bureaus of Commercial Fisheries (BCF) and Sport Fisheries and Wildlife (BSFW). The federal responsibility for pinnipeds and cetaceans was given to BCF while the responsibility for sea otters, manatees, and walrus was assigned to the BSFW. This artificial division of responsibility had little effect on BCF's marine mammal research because almost no research had been done on those species which became BSFW's responsibility.

At about the same time that BCF was established as part of the Fish and Wildlife Service, a sea otter research program was started under Karl Kenyon. Since this species became the responsibility of the Bureau of Sport Fisheries and Wildlife, Kenyon transferred to that Bureau. His office remained with the fur seal group in Edmonds and he transferred to Sand Point when the Marine Mammal Biological Laboratory moved there in 1957. Kenyon's program contributed to administrative funds of the marine mammal laboratory until he retired in 1973. At that time, the Seattle program of the Fish and Wildlife Service was transferred to Alaska and Ancel Johnson replaced Kenyon as project leader.

When Kenyon transferred to BSFW in 1956, Alton Roppel replaced him in BCF, and the entire scientific fur seal staff consisted of Wilke and Roppel. Later that year, Carl Abegglen was hired as project leader for investigations on the Pribilof Islands and held this position until his transfer to Washington, D.C., in 1962. Roppel replaced Abegglen as project leader and did field research on the Pribilof Islands every year from 1956 through 1980 when he announced his retirement effective in January 1982.

An important provision of the Fur Seal Convention allowed for cooperative research and exchange of scientists. As a result, in 1958 Gordon Pike and Fukuzo Nagasaki visited St. Paul Island as official observers for Canada and Japan, respectively. Many similar exchanges have occurred to the present, often involving active, cooperative research among scientists of the various countries. For example, the first Soviet observers visited the Pribilof Islands in 1960. That same year Scheffer visited the Soviet fur seal rookery on Robben Island off the southern coast of Sakhalin Island; in 1963 Wilke, and in 1975 Harry, visited the same island. Wilke, Roppel, Niggol, and Kenyon observed fur seal research on the Commander Islands in 1961 and Fiscus and Johnson visited there in 1968. In 1958 George Tanonaka (on loan from High Seas Salmon Studies) participated in Japanese ocean research off Hokkaido, and in 1965 and 1967 Hiroshi Kajimura, who had joined the staff in 1963, participated in the Japanese research program off Honshu and Hokkaido.

Chapman continued his fur seal population studies in the 1950s and based on 8 years of tag returns from 1950 to 1957, in 1958 he reported on population estimates of Pribilof

Islands fur seal pups. He found unresolved discrepancies in his data and concluded that new studies of the estimation procedure were needed. He felt that factors such as tag-induced mortality may have been causing bias in the annual estimates of abundance. Chapman's analysis led to the development of a new method for making population estimates. Pups are now marked by shearing fur from the top of the head and population estimates are made in August, rather than marking pups with metal tags and making population estimates from recoveries in the harvest several years later.

By the summer of 1960 Chapman had been providing advice to the laboratory regarding statistical procedures and population analyses for almost a decade. That year he visited the Pribilofs to familiarize himself with the research operations. It also had become apparent that the laboratory needed a fulltime biometrician, and in 1961 Ancel Johnson was added to the staff in this capacity. Chapman and Johnson cooperated on fur seal statistical and population problems until Johnson transferred to the Bureau of Sport Fisheries and Wildlife, Department of the Interior, in 1973.

Dr. Mark Keyes joined the laboratory as a veterinarian in July 1962 and visited the Pribilofs that summer. He returned to the islands each summer until 1981 when limitations were placed on travel. Dr. Keyes' assignment was to discover the causes of fur seal mortality, determine the relative importance of the various factors causing death, assess the effects of metal tags on fur seals, and study hook worm and other parasites. A principal assignment for Dr. Keyes from 1967 to 1971 was to initiate and monitor, in conjunction with Northwest Regional Office personnel, contract studies to develop more humane harvesting and killing methods. The conclusion from these studies was that the killing method could not be improved with extant knowledge, although several changes in the procedure for herding fur seals to the harvest areas were recommended and put into effect.

In November 1963 Kajimura joined the laboratory to assist in pelagic research. Kajimura has remained with the pelagic investigation since that time and in 1973 became project leader when Fiscus transferred to other responsibilities at the laboratory.

From the late 1950s until 1970, pelagic and land research continued at a steady pace with a fairly constant number of personnel. Chapman continued his fur seal population studies and in 1964 published a critical study of population estimates. Wilke was Laboratory Director during this period and also the U.S. member of the Standing Scientific Committee of the North Pacific Fur Seal Commission. Richard Bauer entered on duty in 1962 to assist Roppel in studies on the islands after Abegglen transferred to Washington, D.C. Bauer spent one field season on St. Paul Island before transferring to the U.S. Forest Service. He was replaced by Raymond Anas, who was on the staff from 1964 to 1971. Thomas O'Brien and Gary Baines worked with pelagic investigation for a short time. Patrick Kozloff started as a temporary employee in the summer of 1964 and upon his graduation from the University of Alaska in 1969, became a permanent member of the staff under Roppel.

Until 1968 the only known breeding area of the northern fur seal in the eastern Pacific region was the Pribilof Islands. That year a small, breeding colony of this species was discovered

on San Miguel Island off the coast of southern California, the island is also home for five other pinniped species. This discovery presented the opportunity to examine population structure as the colony increased in size. A University of California graduate student, Robert DeLong, was assigned to the project and became a permanent member of the biological staff in 1974. At that time, another graduate student, George Antonelis, became DeLong's assistant at San Miguel Island and in 1980 he was appointed to the permanent staff. This fur seal colony continues to increase in numbers, studies of the competition between northern fur seals and the California sea lion which use the same breeding sites and pupping areas continue, as do studies of reproductive success and of food and feeding habits. Interrelationships among pinniped species utilizing San Miguel Island shores and waters is also a continuing study.

CETACEAN STUDIES BEFORE 1970

Although much of the early federal marine mammal research was on fur seals, there was also some interest in cetaceans, especially the large whales. Dr. Remington Kellogg, who was associated with the Smithsonian Institution's National Museum for nearly 50 years and was Director from 1948 to 1962, attended the First International Conference on Whales and Whaling in 1930, sponsored by the League of Nations. In 1949 the International Whaling Commission was established, and for its first 18 years, Kellogg was the U.S. representative to the Commission. He resigned in 1966 at the age of 73.

In 1946 Dr. Raymond Gilmore joined the Fish and Wildlife Service with headquarters at the National Museum, Washington, D.C. One of his first duties was to prepare background information for the meeting the same year which resulted in the International Convention for the Regulation of Whaling. He also carried out field studies at the maritime industries whaling station on Humboldt Bay in northern California from 1947 until the operation closed in 1951, and visited the whaling station at Coal Harbor, Vancouver Island, B.C. Headquarters for Gilmore remained at the National Museum until 1952 when he moved to the Fish and Wildlife Service Laboratory at Stanford University.

While stationed on the west coast, Gilmore concentrated his research on gray whales, but he also collected biological data from whales landed at the Del Monte Fishing Company's whaling station on San Francisco Bay. In 1954 the laboratory at Stanford University was transferred to Scripps Institution of Oceanography at La Jolla, California, where Gilmore continued his studies of gray whale biology and numbers. In 1958 the Fish and Wildlife Service decided to concentrate marine mammal research at the Seattle laboratory, and during that summer Gilmore was stationed in Seattle where he completed a manuscript on his gray whale research. In September 1958 Gilmore resigned from the Fish and Wildlife Service and returned to San Diego, where he still works with gray whales and other marine mammals at the San Diego Natural History Museum as Research Associate in Marine Mammals.

Gilmore was replaced by Dale Rice, who transferred from the Denver Wildlife Research Laboratory, Bureau of Sport Fisheries and Wildlife, in November 1958. Allen Wolman joined the staff in

1965 to assist with cetacean studies. At the time Rice began whale studies, two whaling stations were in operation on San Francisco Bay at Richmond, California--one by the Del Monte Fishing Company and the other by Golden Gate Fishing Company. Much of Rice's program involved examination of whales brought into these shore stations, and this whale research continued until 1971 when the large commercial species were declared endangered and the last remaining U.S. whaling station, Del Monte's, was closed. Other parts of the whale research program involved tagging animals from chartered catcher boats, observing living whales from vessels and from shore, and analyzing catch statistics. In addition to the commercial species taken at these whaling stations, gray whales were taken under special permit. An annual census of the southward migration of the gray whales was conducted near Monterey, California, beginning in 1967-68. A monograph on the life history and ecology of the gray whale was published by Rice and Wolman in 1971. Rice also spent April and May of 1961 and 1962 in Eskimo whaling camps near Point Hope and Barrow, Alaska, studying bowhead whales.

Because of the inclusion of whale research, the marine mammal program in Seattle in 1960 was designated as the Marine Mammal Biological Laboratory. At about the same time, responsibility for marine mammal research was delegated to the regional office in Seattle from headquarters in Washington, D.C.

Scientists from the Marine Mammal Biological Laboratory began active participation in meetings of the International Whaling Commission (IWC) in 1960. At the suggestion of U.S. Commissioner Kellogg, the North Pacific Working Group was formed, consisting of one biologist from each of the four nations concerned: Canada, Japan, United States, and USSR. The working group was instructed to coordinate and review past and future research efforts in the North Pacific Ocean and to advise the Commission on necessary management plans. Rice was the U.S. member of this working group and attended annual meetings of the Commission. The IWC North Pacific Working Group identified the need for an expanded whale marking effort and, as a result, every year from the winter of 1962-63 to 1968-69, laboratory personnel tagged whales off the North Pacific Coast. The objective was to determine which breeding stocks contributed to the populations that were exploited on the various summer grounds.

The laboratory program and staff remained stable until 1969, when the decision was made in Washington, D.C., headquarters to transfer whale research to the Fishery-Oceanography Center at La Jolla, California. Rice was tranferred with the program in January 1970. Wolman stayed in Seattle and became a member of the fur seal pelagic research program.

PERIOD OF AUSTERITY

From 1970 to 1973, the only research funded at the Marine Mammal Biological Laboratory was for fur seals. The total laboratory budget for this period was less than $300,000 which allowed only routine monitoring of the herd at sea and on the islands. In the spring of 1970 Wilke retired as Laboratory Director and Roppel became Acting Director. In addition to Roppel six permanent biologists were on the staff during the summer field season, down

from nine in 1969. They were Patrick Kozloff, Dr. Mark Keyes, Ancel Johnson, Clifford Fiscus, Hiroshi Kajimura, and Allen Wolman. In the fall of 1970 Dr. George Harry transferred from his position as Director of the federal Great Lakes Fisheries Laboratory (at Ann Arbor, Michigan) to become Director of the Marine Mammal Biological Laboratory; concurrently, he became the U.S. member of the North Pacific Fur Seal Commission's Standing Scientific Committee.

When in 1970 the Bureau of Commercial Fisheries became the National Marine Fisheries Service under a new agency, the National Oceanic and Atmospheric Administration, the Marine Mammal Biological Laboratory became a division of the Northwest Fisheries Center, with Dr. Harry as Division Director. Headquarters remained at Sand Point.

Although 1970 to 1973 was a period of austerity for marine mammal research, events were taking place in Washington, D.C., which would lead to a greatly accelerated program. In 1971 and 1972, hearings were held before the U.S. Congress with the objective of enacting federal legislation for the conservation of marine mammals. Congress passed the Marine Mammal Protection Act in 1972, making the conservation of marine mammals a federal responsibility. The Act declared a moratorium on the taking and importing of marine mammals and marine mammal products with certain exceptions. The Act further states that marine mammals should not be permitted to diminish beyond the point at which they cease to be a significant functioning element in the ecosystem; the primary objective of their management should be to maintain the health and stability of the marine ecosystem.

EXPANDED RESEARCH

Because it seemed likely that federal funding would become available for marine mammal research, the Marine Mammal Division staff in 1971 prepared research plans to develop information needed for conservation of those marine mammals of U.S. concern and prepared status reports on these species.

Additional money for marine mammal research first became available in the summer of 1973; about $87,000 was appropriated for whale research. As a result, in August 1973, Rice was transferred back to the Marine Mammal Division from the Southwest Fisheries Center and Wolman again was assigned to cetacean research. Another $38,000 was made available for pinnipeds other than fur seals and $116,000 for expanded fur seal research. The total research budget almost doubled from approximately $300,000 in 1972 to about $550,000. To provide scientists for these new programs, Willman Marquette, James Johnson, Robert Lander, and Gerald Sanger were transferred from other divisions of the Northwest and Alaska Fisheries Center; Dr. Roger Gentry came aboard as a new federal employee.

Because of rapid expansion of the Marine Mammal Division, Dr. W. Bruce McAlister was appointed Deputy Director in 1974, transferring from his position as Deputy Director of the Marine Fish and Shellfish Division. In addition to his duties as Deputy Director, Dr. McAlister initiated a study of the interaction of marine mammals and fish of commercial importance in the eastern Bering Sea and Aleutian Island area. In 1976 Michael Perez joined the staff to assist Dr. McAlister with these studies. Dr. McAlister resigned as Deputy Director in 1978 but remained at

the Laboratory as a part-time employee until 1981 when Dr. Thomas Loughlin transferred from NMFS headquarters to take over the research Dr. McAlister had been carrying out.

The increase in funds for fur seal research was prompted by the finding that the herd had not responded with the expected increase in productivity after the reduction in herd numbers between 1956 and 1963. In 1972 laboratory scientists proposed a major field experiment involving suspension of the commercial harvest for pelts at St. George Island. By eliminating harvest, the herd would be expected to change in age/sex composition and size, to approximate as closely as possible the "pristine" condition that had existed before 200 years of harvesting began. Direct comparison of this herd against the continuously harvested St. Paul Island herd, only 40 miles away, would reveal man's effects on the processes that control herd size. Intensive research on behavior, physiology, and pathology were intended to show the mechanisms by which the herd changed toward a non-harvest equilibrium.

Despite some reluctance on the part of Japan, the research plan was approved at the 1972 meeting of the Fur Seal Commission with the understanding that the ban on the St. George Island commercial harvest would not be permanent. Ancel Johnson was named supervisor of intensified land studies, except for disease work, but soon after, he left the laboratory; Dr. Roger Gentry became project leader in 1974, a position he still holds.

The results of this experiment to date are as unexpected as were the results of the 1956-63 herd reduction program. The number of male fur seals has increased as a result of not being harvested but females and pups have decreased. The mechanism by which male and female population levels may be interrelated is still unknown. Biologists are attempting to acquire knowledge about this relationship by increasing their efforts to measure feeding behavior of males and females at sea and by estimating the energetic requirements of seals of all ages and both sexes.

The Alaska Native Claims Settlement Act gave title to most of the land and buildings on St. Paul Island to the Tanagusix Corporation, an Aleut group. As a result, and because of a need for more facilities, new quarters for NMFS management and research staff were constructed on the lagoon about 1/2 mile from town. These quarters were occupied in 1975, although several staff houses on St. Paul were retained for school teachers and, during the summer, NMFS cooperative researchers. The main research laboratory remained in the basement of the community store until the new, combination NMFS office and research laboratory was occupied in 1977.

With the transfer of Johnson to the Bureau of Sport Fisheries and Wildlife, it became apparent that a replacement was needed to provide statistical and biometric assistance to the fur seal project; Robert Lander assumed these responsibilities. One of Lander's major accomplishments was to tabulate and publish the vast amount of fur seal population data which had been collected on land, with the exception of the tagging data and, in cooperation with Canadian scientists, the pelagic data of the United States and Canada. Lander was also active in preparing U.S. position papers for the annual meetings of the Fur Seal Commission. He retired in January 1981.

Because of Lander's pending retirement, Dr. Charles Fowler, from Utah State University, was hired in 1979 to assume responsibility for fur seal population studies. In 1980, Dr. Fowler was placed in charge of all fur seal research.

KILLER WHALE STUDIES

In the early 1970s there was considerable public objection to the capture of live killer whales in Puget Sound for public display in oceanaria. After passage of the Marine Mammal Protection Act in 1972, a permit from the National Marine Fisheries Service was needed to capture killer whales. Before such a permit could be issued, it was necessary to know how many killer whales could be taken, if any, without adversely affecting the stock. The Marine Mammal Division began a cooperative program with the Washington Department of Game and with Canadian scientists to determine the number of killer whales in the coastal waters of the United States and Canada and to determine migration routes of the whales. Canadian scientists developed a system of identifying individual whales from physical characteristics such as scars and marks on the dorsal fin, and most individuals in whale pods resident to waters of the United States and Canada can now be identified. Although the National Marine Fisheries Service issued a permit for the capture of several killer whales, none was ever taken and no attempts have been made to capture killer whales in U.S. waters since 1975.

BOWHEAD WHALE RESEARCH

Another cetacean problem surfacing in the early 1970s involved the killing of bowhead whales by Alaskan Eskimos for subsistence purposes. This take had greatly increased over previous years and there were also indications of a rise in the number of whales wounded but not landed. The Marine Mammal Division had been aware of this problem, but until 1974 no research funds were available to study bowhead whales. Fortunately, Dr. Floyd Durham of the University of Southern California had been gathering biological and statistical information from Eskimos and Eskimo whaling camps during the preceding decade. In spring 1973, the Marine Mammal Division let a contract of a few thousand dollars to the University of Southern California for Dr. Durham to conduct field studies at Point Hope whaling camps. The Naval Arctic Research Laboratory in Barrow provided support for this study and allowed use of a small cabin at Point Hope. In April 1973 Dr. Durham and Dr. Harry arrived at Point Hope in subzero weather, tunneled through the snow into the cabin which was to be research headquarters, and in the dark of night, and with the help of the local schoolteacher, succeeded in starting the oil heating stove. Thus began a bowhead research program which greatly expanded over the next 5 years.

For the 1974 whaling season, $14,000 was allocated to bowhead whale field research and Marquette at Point Hope, and Fiscus at Barrow, gathered information during the spring whaling season. Fiscus returned to Barrow in the fall of 1974 to participate in an aerial survey of bowheads during the fall migration. Marquette subsequently returned to arctic Alaska each year through 1980 on bowhead research. The

bowhead research project remained at a low level in 1975, but the U.S. Bureau of Land Management's OCSEAP provided additional funds for the 1976 and 1977 seasons.

Fiscus was made OCSEAP project leader in 1975, and in the fall of that year, Dr. Howard Braham joined this program. After approximately 1 year, Braham became leader of the project when Fiscus was designated supervisor of all pinniped research including fur seals, a position he held until his retirement in 1980. In 1976 and 1977, Bruce Krogman and David Rugh, respectively, were added to the OCSEAP project and they became permanent staff members in 1978. Aerial surveys were started in 1976 primarily to determine the numbers and distribution of bowhead whales in offshore waters. Camps were established on the ice at the edge of open-water leads near Barrow to census whales as they migrated to summer feeding areas. Very few whales were sighted from the air that could not be counted from camps on the shore ice. Additional National Marine Fisheries Service funding became available for the 1978 spring season and the bowhead whale program was further expanded. For example, one experiment conducted by James Johnson involved recording bowhead whale vocalizations to determine if whales were passing the ice camps undetected. Bowhead sounds were identified, but the technique was not successful in enumerating whales.

In 1981, a considerable portion of the bowhead whale field program was contracted to the Alaska Eskimo Whaling Commission. The 1982 bowhead field work of the National Marine Mammal Laboratory will be much reduced because of a decline in funding.

OCSEAP contracted with the Marine Mammal Division not only for bowhead whale research but also for information on distribution and abundance of marine mammals in the Gulf of Alaska and in the Bering and southern Chukchi Seas. The desired information was obtained from 1975 to 1977 through a combination of aerial and ship surveys and observations on land.

Additional OCSEAP funding was made available to the National Marine Mammal Laboratory in 1980 to investigate gray whale feeding locations in the northern Bering Sea, to make a survey of the abundance and distribution of endangered species in the Gulf of Alaska, and to compile and analyze data obtained from NOAA vessels and other ships in areas of OCSEAP concern. These were one-year contracts which have been completed.

HUMPBACK WHALE RESEARCH

In the early 1970s the regional office of the U.S. Forest Service in Juneau agreed to record sightings of marine mammals made by naturalists aboard the Alaska ferry system in southeastern Alaska and Prince William Sound. Forest Service naturalists recorded concentrations of humpback whales in the Frederick Sound area. The first aerial survey for humpback whales from Juneau, south into Frederick Sound, was made by Dr. Harry and Dr. Tadayoshi Ichihara of the Japanese Far Seas Fisheries Research Laboratory in August 1973. Humpback whales were sighted in Stephens Passage and were abundant in Frederick Sound.

The first cruise to obtain information on distribution and abundance of humpback whales in southeastern Alaska took place in August 1975 aboard the Murre II, a vessel attached to the Auke

Bay Laboratory. This and subsequent vessel trips were made in cooperation with Charles Jurasz aboard his vessel, the Ginjur.

Humpback whales are found in southeastern Alaska waters primarily in summer; during winter, the species is found in the Hawaiian Islands waters and off the west coast of Mexico. In an attempt to find the migration route of the southeastern Alaska humpback whales, marine mammal scientists implanted experimental radio tags in their blubber. These tags were developed under the supervision of Dr. Carleton Ray of the Johns Hopkins University, and William Schevill and William Watkins of the Woods Hole Oceanographic Institution. The radio-transmitting tags were fired from a modified 12-gauge shotgun. Under the direction of Dr. Michael Tillman, humpback whales were tagged from chartered vessels in Frederick Sound and vicinity in 1976 and 1977. A cooperative radio-tagging effort under the direction of James Johnson, Marine Mammal Division; William Watkins, Woods Hole Oceanographic Institution; and Douglas Wartzok, the Johns Hopkins University, was also undertaken in Prince William Sound in 1978. However, these tags did not remain in the whale blubber long enough to provide information on migration routes, and no further radio-tagging was carried out by Marine Mammal Division scientists until 1980. At that time, the Marine Mammal Tagging Office, under the direction of Larry Hobbs, was transferred to Seattle from Washington, D.C. During 1980 under an OCSEAP contract, further radio-tagging experiments were undertaken with bowhead whales.

The humpback whales, which winter in the Hawaiian Islands and give birth to their young, became a great public attraction in the early 1970s, and some biologists feared that harassment might cause a decrease in the number of surviving calves. Little information was available on the number and distribution of humpback whales in the Hawaiian Islands. In order to estimate population size and obtain information on distribution, the Marine Mammal Division chartered vessels to count humpback whales around the main Hawaiian Islands during the winters of 1976 to 1979. The greatest concentration of whales was found on Penguin Bank southwest of Molokai, and the total number of whales was estimated to be about 650. This project was carried out by Dale Rice and Allen Wolman.

The cooperative program with the U.S. Forest Service for collecting information on marine mammal sightings from naturalists aboard Alaska State ferries led to a similar program with other vessels operating in waters of the North Pacific Ocean. Paul Sund, stationed at the NMFS Tiburon, California Laboratory, was assigned to establish a system to obtain oceanographic and biological information from vessels of opportunity. Sund set up a system by which vessels, especially NOAA research vessels, reported marine mammal sightings to the Marine Mammal Division for computer storage. In 1975, a NOAA Corps officer, Lt.jg Roger Mercer, was assigned to the Marine Mammal Division and supervised this project. Lt. Mercer was replaced in 1978 by Lt. Lewis Consiglieri. The sighting data have been of great value in providing information about the distribution of marine mammals. For example, the data have been useful in determining which marine mammals might be affected by development of petroleum resources in the waters off Alaska.

WHALE POPULATION DYNAMICS

The major concern of the International Whaling Commission (IWC) is to make certain that the stocks of commercially exploited whales remain in healthy condition. Management of whale stocks requires an adequate knowledge of the population dynamics of the various stocks; however, the Marine Mammal Division did not have an expert on whale population dynamics. Therefore, in 1974 Dr. Tillman of the Northwest and Alaska Fisheries Center's Division of Marine Fish and Shellfish was assigned half-time to the Marine Mammal Division to carry out whale stock assessment studies. Dr. Tillman attended the IWC meeting in 1974 for the first time and has been a U.S. member of the Scientific Committee every year since then. He became a full-time member of the Marine Mammal Division staff in 1975 and was assigned as program leader for all cetacean studies. In 1978 Jeffrey Breiwick joined Dr. Tillman in whale stock assessment research. Following the resignation of Dr. McAlister as Deputy Director in 1978, Dr. Tillman was appointed to this position while continuing his whale population studies; he is currently vice chairman of the IWC Scientific Committee.

In 1976 responsibility for U.S. participation in the IWC observer program was transferred from NMFS headquarters in Washington, D.C., and Larry Tsunoda and Eugene Nitta, observers at Japanese land-based whaling stations, joined the permanent staff. In 1978 Merrill Gosho replaced Nitta, who transferred to the NMFS Southwest Regional Office.

U.S.-MEXICO COOPERATIVE GRAY WHALE DYNAMICS

A research agreement was signed in 1978 between representatives from the Instituto Nacional de Pesca, Departmento de Pesca, Mexico City, and the Marine Mammal Division to conduct a 5-year research program on gray whales in their winter grounds in Baja California. Breeding ecology in the calving lagoons, as well as spatial and temporal distribution inside and outside the lagoons was emphasized.

In 1979 and 1980 research teams from PESCA and the NMFS joined to study gray whales in Laguna Ojo de Liebre and adjacent waters. In 1980 an aerial survey was also made to determine the distribution and relative abundance of gray whales along the west coast of Baja California. In 1981, scientists from PESCA continued the research in Laguna Ojo de Liebre, documenting the movements of whales into and out of the lagoon and making a population estimate of those whales using the lagoon. Concurrently, scientists were conducting coastal and offshore systematic surveys using a boat and an aircraft simultaneously to estimate the size of the population which occurs outside the lagoons and throughout Baja California. These studies are expected to provide the kind of information needed to make sound management decisions.

OTHER PINNIPED SPECIES

The northern elephant seal, once abundant along the Pacific coast from Cape Lazaro, Baja California, to central California, was nearly wiped out by excessive commercial harvesting

in the 19th century. At the turn of the century, the population of this species was about 100 animals; however, the elephant seal has made a remarkable recovery. By the mid-1970s, it was once again abundant and had reoccupied much of its breeding range as far north as the Farallon Islands, California. In 1977 the Marine Mammal Division, through a contract with the University of California, summarized information about the status of this species. The elephant seal report was important in reaching the decision that the species should not be classified under provisions of the Endangered Species Act of 1973. The principal California breeding area is on San Miguel Island, where laboratory biologists have been carrying out population studies since 1972.

The Guadalupe fur seal was believed to be extinct as a result of commercial exploitation in the 19th century. In 1926, however, a few animals were discovered by fishermen on Guadalupe Island. Since that time, recovery of the species has been very slow and the breeding range has not spread to other areas. Little information was available about these fur seals in the mid-1970s so the Marine Mammal Division contracted with the University of Washington for a 2-year study. In cooperation with Mexican authorities, a graduate student from Mexico, Luis Fleischer, carried out field studies on Guadalupe Island for two seasons. Fleischer concluded in his 1978 master's thesis that the Guadalupe fur seal population numbered about 1,000 animals.

Enroute to Japan in 1972 for a meeting of the Fur Seal Commission, Dr. Harry stopped in Honolulu to confer with Palmer Sekora, Superintendent of the Fish and Wildlife Service's Hawaiian Island National Wildlife Refuge, about the status of Hawaiian monk seals which reside in the northwestern Hawaiian Islands. Both biologists were concerned that the small population of monk seals was threatened by increasing human activity especially since the species was not protected by an endangered species designation. Following these discussions, action was started to add the Hawaiian monk seal to the endangered species list, and in 1976 it was so designated.

In 1975 the Marine Mammal Division, in cooperation with the Fish and Wildlife Service, initiated planning on a research program to obtain information about the number, biology, and critical habitat of Hawaiian monk seals. Fiscus and DeLong took part in cruises to the northwestern Hawaiian Islands in 1976, 1977, and 1978 to census monk seals. In 1978 an additional trip was made to Laysan Island in an attempt to determine the cause of a sudden die-off of monk seals. In 1980 the feeding behavior of monk seals was investigated at Lisianski Island. This study included personnel from the National Marine Mammal Laboratory, Southwest Fisheries Center of the National Marine Fisheries Service, and Scripps Institution of Oceanography. The information obtained is being used to formulate a plan with the objective of increasing the number of Hawaiian monk seals. In 1979, the monk seal research program was transferred from the National Marine Mammal Laboratory to the Southwest Fisheries Center.

U.S.-SOVIET COOPERATION

In the Bering and Chukchi seas, U.S. and Soviet nationals harvest what may be intermingling stocks of ice seals and walrus. On the U.S. side, the

harvest is principally by Alaskan Eskimos for subsistence uses. Exchange of research information about these species benefits both countries. For this reason, informal meetings of scientists from the United States and the USSR took place in conjunction with annual meetings of the Fur Seal Commission in the early 1970s. Cooperation in marine mammal research was formalized when the presidents of the United States and the Soviet Union on 23 May 1972, signed an agreement for cooperation in the field of environmental conservation. In January 1973, a subgroup of experts on marine mammals met in Moscow to discuss problems of conservation management and research of marine mammal populations. Dr. R. V. Miller, research specialist on marine mammals in the NMFS Washington, D.C., office, was designated coordinator for the U.S delegation and Dr. Harry became a member of the U.S. Steering Committee. The first meeting of the marine mammal subgroup in the United States was held in Washington, D.C., in December 1973; representatives from the Marine Mammal Division included Dr. Harry, Fiscus, and Ancel Johnson. No U.S. funding has been allocated specifically for cooperative USA/USSR research, but nevertheless the program has been very successful in developing cooperative marine mammal research projects of interest to both countries. Meetings to develop research plans are held at approximately 18-month intervals, alternating between the two countries. Harvest data on marine mammals of the Bering and Chukchi seas and titles of marine mammal publications with copies of important publications from each country are exchanged. Soviet scientists have taken part in research activities of the National Marine Mammal Laboratory in the North Pacific Ocean and Arctic waters. Scientists from the National Marine Mammal Laboratory have joined Soviet scientists for bowhead whale research aboard Soviet vessels.

DALL'S PORPOISE

The Marine Mammal Protection Act of 1972 requires that permits be issued to any foreign vessels which incidentally take marine mammals during commercial fishing operations within the U.S. 200-mile zone. Japanese salmon gillnet fishermen operating within this zone incidentally take Dall's porpoises and therefore are subject to provisions of the Act. The Marine Mammal Division began a 3-year study involving Japanese and U.S. scientists in 1978; Dr. Linda Jones, formerly on the staff of the Marine Mammal Commission, was selected as project leader. The objective of the program was to assess the impact of the Japanese gillnet fishery on Dall's porpoise stocks and to determine methods of reducing the mortality of porpoises captured in the nets. The program has been carried out aboard Japanese research and commercial fishing vessels, and in 1981 the period of research was extended. Information has been obtained on Dall's porpoise population size, life history, and food. Studies are now under way to develop methods of preventing porpoises from becoming entangled in the gillnets.

COLUMBIA RIVER ESTUARINE MARINE MAMMALS-FISHERIES INTERACTIONS

At a workshop sponsored by the Marine Mammal Commission in 1977, the Columbia River and adjacent waters were recommended as an area for study of

marine mammal-fisheries interactions. A research program was developed by the states of Oregon and Washington and funds were provided by the National Marine Mammal Laboratory and the Columbia River Estuary Data Development Program. The research was contracted to the Washington Department of Game. The first report has been completed. It provides information on the numbers of harbor seals taken in the Columbia River gillnet fishery and detected by aerial surveys, as well as information from tagging and sampling of harbor seals for biological data. The program is planned to continue through 1982. DeLong has responsibility for this program.

NATIONAL MARINE MAMMAL LABORATORY

In recognition of the expanded research role of the Marine Mammal Division, in 1979 the Division was designated as the National Marine Mammal Laboratory, remaining as a part of the Northwest and Alaska Fisheries Center. In the same year Dr. Harry announced his retirement effective January 1980, and Dr. Tillman was appointd Laboratory Director. Dr. R. V. Miller was transferred from the Washington office to replace Dr. Tillman as Deputy Director. The Laboratory is now divided into three major research areas: Cetacean Program under Dr. Braham, Fur Seal Program under Dr. Fowler, and Marine Mammal Fishery Interactions Program under DeLong.

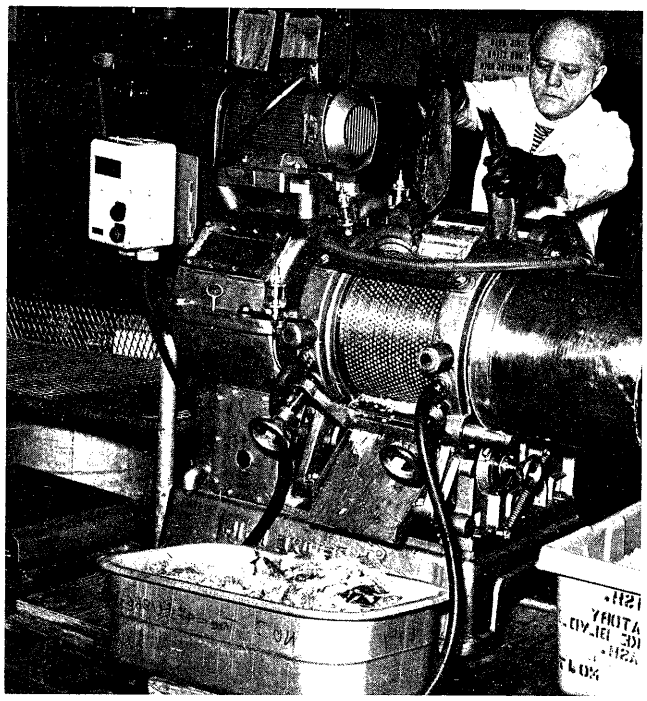
The Laboratory is now well established as an important component in the study of ocean ecosystems.

ACKNOWLEDGEMENTS

Much of the information on fur seal research before the mid-1960s came from an unpublished manuscript by Dr. Victor Scheffer and Ethel Todd, entitled History of Scientific Study of the Alaskan Fur Seal, 1786-1964, and from Victor Scheffer, 1980, Adventures of a Zoologist. Former staff members of the Laboratory who contributed information are: Karl Kenyon, Clifford Fiscus, and Victor Scheffer. Present staff members who gave assistance include: Dr. Michael Tillman, Dr. Howard Braham, Dr. Linda Jones, Dr. Mark Keyes, Robert DeLong, Alton Roppel, Hiroshi Kajimura, Dale Rice, and Allen Wolman. Walter Kirkness, Director, and Joe Scordino biologist, Northwest Regional Office, Pribilof Islands Program, also reviewed parts of this history.

Technological Research

Maurice E. Stansby[1] and John A. Dassow[2]



Top left
Dr. W.T. Roubal, chemist at the Pioneer Research Laboratory, explains the use of equipment for following oxidation of fish oils to an interested group of open house visitors in 1970.

Bottom left
Charles Butler, chemist at the Seattle Technological Laboratory, demonstrates in 1948 the use of the fish liver sampler devised by F. Bruce Sanford.

Right
Max Patashnik, chemical engineer, is shown operating a device that is separating the flesh of rockfish from the skin an bones. Photo taken at the Utilization Research Division in 1974.

PACIFIC COAST PRIOR TO 1933

Biological research on fisheries in the Pacific Northwest had an early beginning in the 1880s under the pioneering efforts of Gilbert and others. What was happening in fishery technology at these early stages? When the U.S. Commission on Fish and

1/ Former Director, Environmental Conservation Division, Northwest and Alaska Fisheries Center; present address: 5105 N.E. 75th Street, Seattle, WA 98115.

2/ Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

Fisheries was set up in 1871, its first Commissioner, Spencer Fullerton Baird, had an appreciation of the need for technological investigations. Under contract from the Commission, research was undertaken in New England to explore the nutritive value of fish. Baird also initiated efforts to adapt technological discoveries from Europe to fisheries in the United States. Unfortunately, Baird died before this type of work had been extended to the Pacific Coast. Baird's successors had no interest in fishery technology and decreed that all such work in the agency should cease. It was felt that if the U.S. Department of Agriculture was interested, it could carry out research on fish or fishery products along with its investigations on other foods. The Department of Agriculture was interested and began in a limited way some work on fishery products.

At first such work was limited to small field operations on the Atlantic coast, mostly from Washington, D.C. In 1913, the Bureau of Chemistry in the Department of Agriculture made fish studies an additional function of their egg and poultry laboratory at Philadelphia, which was under the direction of Mary Pennington. The task was assigned to Ernest D. Clark and L. H. Almy, who worked on fish in their Philadelphia laboratory while carrying out summer field studies, some in the Pacific Northwest. In 1916 Clark established a small laboratory in Seattle where research was conducted on storage of frozen and iced fish and on problems encountered in the transportation of fish. In 1921 the Philadelphia laboratory was closed and the Department of Agriculture's work on fish was discontinued.

Meanwhile, in 1917 Lewis Radcliffe became Chief of the Division of Statistics and Methods of the Bureau of Fisheries, succeeding Alvin Alexander, who had been in charge since 1903. Unlike Alexander, Radcliffe felt strongly that technological research should be conducted by the Bureau. As a result, in 1918 the first Bureau of Fisheries laboratory was established in temporary quarters in San Pedro, California, under the direction of Leslie Lingle. After Lingle resigned in 1921, Harry Beard became laboratory director, assisted by Arthur Wells and one or two temporary assistants. However, budgetary problems became acute, forcing closure of the laboratory in 1924.

Other technological activities were performed on the Atlantic coast by the Bureau of Fisheries, starting in 1919 when a temporary field station was opened in Gloucester, Massachusetts. Later a small permanent laboratory was opened in Washington, D.C., which operated during the 1920s but was closed about 1930. In the late 1920s, the principal technological station of the Bureau of Fisheries was in Reedville, Virginia, and the work there was concerned with menhaden fish meal and oil. In 1931, the personnel of this station, most of whom worked in Washington, D.C., were transferred to Gloucester, Massachusetts, and from 1931 to 1935 the Gloucester Laboratory was the principal technological laboratory of the Bureau of Fisheries. In 1935 it was closed, and all personnel transferred to a new laboratory at College Park, Maryland.

1933 THROUGH 1941

When plans were being formulated in the late 1920s for a new building in Seattle to house Pacific coast Bureau of Fisheries activities, space was

included for technological investigations. It was hoped that after completion of the building funds would be available to employ a staff for the technological operation in Seattle. Because the budget did not include special funds for such work, two employees, Roger Harrison and A. Anderson, were transferred in May 1933 from the Gloucester Laboratory to begin technological research at the new Montlake laboratory.

Harrison, who was in charge of the new Seattle Technological Laboratory, was a graduate of Washington State University and had worked as a chemical engineer at the U.S. Department of Agriculture in 1926-28 before transferring to the Bureau of Fisheries in 1928. He worked on improvements in the manufacture of fish meal in Washington and at the Bureau's field station in Reedville, Virginia, until 1931 when the laboratory was established at Gloucester. There he worked with Anderson on scientific experiments to investigate factors, such as drying temperature, in the manufacture of fish meal.

Anderson, a graduate of the College of Fisheries, University of Washington, was a fishery technologist, had worked in industry for a fish meal equipment manufacturer and had participated in the design and installation of fish reduction plants in California, Norway, Iceland, Hawaii, and British Columbia from 1922 to 1930. After a year in Washington, D.C., he went to Gloucester in 1931 to work with Harrison on the fish meal manufacturing project. He also worked on extraction procedures for obtaining oil from low-oil-content fish livers.

Upon their arrival in Seattle in 1933, it was not surprising that Harrison and Anderson gave first attention to problems connected with by-products of the fishing industry. Not only was there prior interest and experience in this field, but several urgent problems along these lines were awaiting solution in the Pacific Northwest and Alaska. Waste from salmon cannery operations was not being fully utilized, and there was growing interest in utilizing what had only then been recognized as a valuable source of vitamin A--low-fat-content fish livers, such as those from halibut.

One of the researchers' first projects concerned utilization of salmon trimmings; the result was the development of a method for extracting oil from edible portions of salmon, such as tail and collar trimmings, which could be added to subsequent lots of canned salmon when the oil content of the raw fish was below average. This practice soon became widespread and is still used today by the salmon canning industry.

Other projects conducted on by-products during the first few years of operation included: 1) working out, in collaboration with the Food and Drug Administration, standards of quality for halibut liver oil, 2) developing improved procedures for extracting oil from low-oil-content fish livers, 3) in collaboration with the Poultry Department of Washington State University, investigating the nutritional properties of dogfish shark meal for poultry, 4) designing a small-scale fish reduction unit for use at a Bureau of Fisheries salmon hatchery at Quilcene, Washington for rendering spent carcasses of salmon, 5) investigating the problem of overheating and oxidation of oil in stored fish meal and developing methods to reduce such changes.

In 1936 the first step was taken toward expanding the research into fields involving preservation of fish for human consumption. This consisted of initiation of an industry-supported fellowship for exploring the use of a product derived from oat flour (Avenex made by Musher Co.) to extend the cold storage life of frozen fish. This work continued for several years. Although the Avenex treatment failed to work successfully for fish, this study on preservation ultimately led to a broadening of the scope of research at the laboratory.

In 1937 the laboratory acquired the services of several Works Progress Administration (WPA) supported chemists on temporary assignments that continued for five years. Employed under this program at various times were: Jacob Ash, Charles Butler, Robert Carlson, William Clegg, and Louis Simonson. Several subprofessional positions, both full- and part-time, were also established under the WPA program. These temporary additions to the staff greatly increased the amount of productive work that was accomplished.

In 1937 Anderson was transferred to Washington, D.C., and in February 1938 the vacancy he left was filled by Maurice Stansby, a chemist transferred from the College Park laboratory to Seattle. During 1940 two additional full-time, permanent positions were acquired, one for a chemical engineer, filled by William Hamm, and one for a chemist, filled by Harris Magnuson. Stansby was transferred in 1940 to be laboratory director of the newly constructed Fishery Products Laboratory at Ketchikan, Alaska, and the vacancy he left was filled by F. Bruce Sanford, a chemist who had been employed at an oil company which processed fish and other oils. Stansby started several programs at the Seattle laboratory concerned with rancidity development in frozen fish, before his departure to Ketchikan. Sanford began studies on the chemistry and stability of vitamin A in fish liver oils, a project that continued for about 10 years.

In 1937-38 a pilot plant was constructed at the Seattle laboratory which permitted large-scale experiments, particularly in the by-products field. The cost of this facility was provided by the Public Works Administration (PWA), and it illustrates how, in the past, minimal funding could still result in significant accomplishments. Only $2,000 was granted for the pilot plant construction, but after the 25 x 40 ft wood frame building had been erected, it was found that remaining funds were sufficient to install plumbing, a steam boiler, and several other small pieces of equipment. Salaries of two full-time professional employees, one half-time typist, and one quarter-time scientific aide, plus all operational expenses in 1937, amounted to only about $9,000. During 1938 another $1,600 from PWA and WPA permitted further work and additions to the plant, including construction of a tunnel dryer and a brine freezer.

The fishery by-products program, which was continued by Harrison and Hamm, included work on spontaneous combustion of fish meal and on improvement of analytical methods for determining oil in fish meal. The WPA-sponsored employees worked on proximate composition determinations of Pacific Northwest fish (much of this was done over a 10-year period by William Clegg) and on development of freshness tests for salmon. Work was performed by Magnuson on solubility of fish protein.

A very large program, developing information needed for U.S. utilization

of Alaska king crab, was performed under Harrison in 1940 and 1941 (see discussion under Exploratory Fishing).

Considerable work was conducted to improve methods for the chemical analysis of fish and fishery products. Harrison was appointed referee by the Association of Official Agricultural Chemists to develop new analytical methods for the determination of the oil content of fish meal. Stansby developed new methods for both the determination of rancidity of the oil in fish and for the determination of volatile bases as a freshness test for fish.

Personnel.--During this initial period of technological investigations at the Montlake laboratory from 1933 to 1941, it is interesting to note how many individuals worked on the program in some capacity and later went on to long and productive careers in fishery work, either within this agency or with other institutions.

Andrew W. Anderson progressed through positions in the Washington office, as founder and head of the Market News Service, Chief of the Branch of Commercial Fisheries (1943-56), and then as Assistant Director, Bureau of Commercial Fisheries (1956-61). After his retirement from the Bureau, he worked for a few years as fisheries attache in Copenhagen for the U.S. Foreign Service. He lived near Poulsbo, Washington. (Died in April 1982)

Lyle Anderson worked at the Technological Laboratory at Montlake as a Musher Foundation Fellowship Student from 1935 to 1936. He later worked at the Fishery Products Laboratory starting in 1940 and was Director of the Seattle laboratory from 1942 to 1945. He then became a fishery technologist in private industry, and for many years he has been in charge of technological work at Bioproducts Company in Warrenton, Oregon.

Charles Butler worked as a WPA chemist at the Seattle Technological Laboratory from 1937 to 1938 and then as Musher Foundation Fellow in 1938. From 1939 to 1943 he worked in the fishing industry (Columbia River Packers Association, Astoria, Oregon, and Alaska Fish Oil Extraction Company at Ketchikan). He was employed in the Bureau of Commercial Fisheries from 1943 to 1967, rising from chemist to Director of Technological work at Honolulu (1948) to Chief, Technological Section (1954-59); he served as Assistant Director of the Industrial Research Division in Washington from 1962 to 1966. He retired in 1967, living first in Florida, then in Hendersonville, North Carolina, and finally in Alexandria, Virginia, where he died in January 1979.

John Dassow worked at the Seattle Technological Laboratory as a WPA chemist in 1940. He then was employed at the Fishery Products Laboratory at Ketchikan, Alaska (1940-45) and as chemist at the Alaska Fish Oil Extraction Company at Ketchikan (1945-46). He returned to the Seattle laboratory as a part-time chemist in 1946 where he also pursued academic studies at the University of Washington. He was employed at the Seattle Technological Laboratory part-time as a NDGA Fellowship student. He was appointed chemist at the Seattle laboratory in 1948 and served as Laboratory Director at the Ketchikan laboratory from 1950 to 1955. He has been working since as Deputy Director of the Technological Laboratory (now called Utilization Research Division) of the Northwest and Alaska Fisheries Center in Seattle. He retired

in April 1982.

Lauren Donaldson worked on a part-time temporary appointment under Roger Harrison from 1934 to 1936. Dr. Donaldson has gone on in his field of fishery biology to become a world-famous authority on the biology of salmon. He recently retired as professor at the College of Fisheries, University of Washington, but continues to live in Seattle.

William Hamm worked as a chemical engineer at the Seattle Technology Laboratory from 1940 to 1944. He left to become Director of the Bureau's technological laboratory in Puerto Rico. He died in the early 1950s while working as a chemist at Van Camp Seafood Company at Terminal Island, California.

Roger Harrison served as the first director of the Seattle Technological Laboratory and then transferred to the Washington office as Chief of the Technological Section in 1942. He left the Bureau of Fisheries in 1944 and went on to a series of positions in industry and other governmental agencies as follows: in charge of research at Halibut Liver Oil Producers, Seattle 1944-58; Agency for International Development, Korea, 1958-62; and Chief Technologist for Fisheries Department, U.N. Food and Agriculture Organization of the United Nations, Rome, 1962-69. Since his retirement he resides in La Mesa, California.

Robert Rucker was a National Youth Administration student assistant at the Seattle Technological Laboratory in 1936. He was at Western Fish Disease Laboratory, Seattle, 1945-75, where he was Laboratory Director for part of this time. He retired in 1975 and resides in Seattle.

Bruce Sanford began work as a chemist at the Seattle Technological Laboratory in 1940. Beginning in 1952 he served as a scientific editor for Seattle scientific publications, eventually becoming editor for scientific papers for all of the technological laboratories. Sanford retired in 1971 and still lives in Seattle.

Maurice Stansby worked as a chemist at the Seattle Technological Laboratory from 1938 to 1940 and then was Laboratory Director at the Ketchikan Fishery Products Laboratory, 1940-42; at the Seattle Technological Laboratory, 1942-66; at the Food Science Pioneer Research Laboratory, 1966-72; and Director of Environmental Conservation Division, Northwest and Alaska Fisheries Center, 1972 to November 1974. Since November 1974 he has been working in the Center Director's Office, Northwest and Alaska Fisheries Center.

Summary of 1933-41 Accomplishments.--During this 9-year period, 1933-41, under Roger W. Harrison as laboratory director, much effort went into developing the laboratory, its facilities, and personnel to a point where efficient operations were possible. The construction and outfitting of the pilot plant building was a major accomplishment. Although the budget for regular funds during this period only permitted an expansion of two to three full-time permanent staff, Harrison overcame the problem of inadequate staffing by arranging for WPA temporary employees and cooperative and fellowship people. By the end of 1941 and counting such individuals, the staff numbered nine persons. The work conducted during this period resulted in 13 research papers. The principal fields of research and accomplishments

included the by-products work, in which salmon oils and halibut liver oils were characterized as to chemical composition and vitamin content; fish liver oil extraction methods were improved; properties of dogfish meal were determined and manufacturing methods improved; and methods of utilizing salmon trimmings to make oil for adding to canned salmon were devised. In food fish studies, knowledge of location and handling methods of king crab was developed so that a new industry was established; long-term studies on characterization of chemical composition of fishes of the Pacific Northwest were initiated; and new chemical methods were developed for analysis of fish and fishery products.

1942 THROUGH 1954

In 1942 Roger Harrison was transferred to Washington, D.C., to serve as chief technologist for the Bureau of Fisheries. Maurice Stansby returned from Ketchikan to replace Harrison as director of the Seattle Technological Laboratory. The work programming changed drastically to cover important wartime activities, and the budget and staff size increased considerably to accomplish the expanded objectives. Although the WPA project, which had provided a major part of the personnel, was phased out in 1942, by the end of that year the new programs had raised the number of full-time personnel to 14; by the end of 1943, when the wartime projects reached full implementation, there were 20 individuals on the staff and 16 of them were full-time professionals. New projects included the investigation of feasibility of substitute containers, including such aspects as whether using fiber cases instead of tin, for iced fillets, would substantially reduce cooling time in ice, and how much the thickness of tin plate on cans could be reduced without causing major corrosion problems with different species of canned fish. Areas where U.S. exports had been cut off by the war were especially critical. In addition to potential tin shortages, a shortage of agar, obtained from Japanese seaweed, was feared. Investigations on substitutes for agar from other seaweeds showed that a product considerably inferior to agar could be extracted from Gracilaria seaweed. Fortunately, the war ended before either the stock-piled tin or agar were exhausted. Another project was conducted to investigate preparation of dehydrated fish. A process was developed and the product test-marketed.

The Laboratory's vitamin A project was expanded. Meetings were held with representatives of the vitamin A industry and standardized analytical methods were adopted for stockpiling vitamin A from fish livers. To augment this process, Bruce Sanford developed a rapid, portable, fish liver sampler which was adopted by the fish liver industry.

As an offshoot of the earlier king crab investigations, some of the fishery engineers, notably Carl Carlson, worked with laboratory technologists, principally Charles Butler, and represented the government in design and operation of the Pacific Explorer. This vessel was a government-financed factory ship modified from a World War I 8,800-ton vessel, the Mormacrey. It was converted to a factory ship, capable of freezing fish or shellfish, cutting fillets, and reducing waste to fish meal and oil. Although the vessel performed satisfactorily, it was not

completed until after the end of World War II. At that time, however, there was no longer the urgent need for additional protein food that would justify operation of the vessel, especially when considering the adverse economic aspects which made a profitable venture impossible.

Several employees of the Seattle laboratory were detailed to other government agencies in connection with wartime activities. Frank Piskur spent a long detail and Maurice Stansby a much shorter one at the Chicago Quartermaster Corps Laboratory in connection with use of fish by the armed forces. R. Paul Elliott was detailed to work with the Army Veterinary Corp in New England in connection with development of specifications for fish.

In 1946 and 1947 an addition was made to the pilot plant, doubling its size. In the new addition, cold storage and quick freezing facilities were installed, increasing research on freezing and storage of fish. Expanded facilities for dressing and handling fresh fish were also provided.

Between 1947 and 1954, after phasing out the wartime activities, the programs changed again. In 1947, wartime budgets were eliminated, resulting in a 50% reduction in the staff at the Seattle Technological Laboratory. Fortunately, a $48,000 grant allowed the rehire of some displaced personnel to work on a project involving utilization of Alaskan cannery waste. Methods were developed whereby substantial portions of the waste, formerly discarded in Alaska, were frozen and shipped to hatcheries in the Pacific Northwest for use as fish feed. The laboratory also worked in collaboration with the Bureau of Fisheries' Hatchery Division to improve the nutritive value of fish feed.

A new program evaluated the composition, especially the vitamin content, of fish meal. This work, conducted by Neva Karrick and others, provided information that enabled poultry feeders to realize the full value of fish meals when applying newly introduced computerized formulation of feeds.

In 1948 with funds of the Fishery Education Section of the Bureau of Fisheries, a new periodical began publication, Commercial Fisheries Abstracts (CFA). Maurice Stansby was editor and the staff of the Seattle Technological Laboratory prepared abstracts on commercial fishery topics from important scientific journals. This publication continued to be prepared at Seattle and mailed to users throughout the world for more than 25 years.

Starting in 1951 the laboratory began conducting technological work on fishes from fresh water such as the Great Lakes. This work first involved evaluation of the cold storage life of freshwater species. Work also started on determining the chemical composition of freshwater species of fish.

In 1953 research was begun, in a small way, on chemical derivatives to be made from fish oils and on methods for fractionation of fish oils. This work was greatly expanded in 1955.

Personnel.--From 1942 to 1954 in addition to staff continuing from the preceding period (Butler; Dassow, for part of the period; Sanford; and Stansby), many new employees participated in the program. These included William Clegg, chemist, who had previously worked on temporary

appointments and who carried out much work on proximate composition of fish. Mabel Edwards, a laboratory aide, began a career assisting Neva Karrick on vitamin B complex assays. R. Paul Elliott worked both as a microbiologist and on Commercial Fisheries Abstracts. Martin Heerdt, employed as a fishery technologist, carried out research on fish preservation, but after spending considerable time in a sanitarium recovering from tuberculosis, Heerdt discontinued his active laboratory work and spent most of his working hours preparing abstracts. In 1954 he prepared 150 abstracts, over 50% more than any other staff member.

Dr. G. Ivor Jones, a chemist, worked on problems involving utilization of salmon cannery waste. Neva Karrick began a long career as chemist with the Laboratory in 1947. She worked first on utilizing salmon cannery waste, then on vitamin content of fish hatchery feed.

Lynne McKee, with long experience in the salmon canning industry, carried out work during World War II on lowering the tin content of cans used for fish. He later worked on other problems in canning fish. David Miyauchi, a chemist, was employed during this period and worked on many chemical aspects of preservation of fish. Katheryn Osterhaug, a home economist, was employed to develop new recipes for fish. George Pigott, a chemical engineer, worked on the problems of utilizing salmon cannery waste and on corrosion of cans containing fish. Frank Piskur, a chemist, was on the staff for a short time during this period but then went on to assignments elsewhere in the agency including Director of the Bureau's College Park Laboratory, and Associate Regional Director in Alaska.

Bruce Sanford continued his chemical investigations on vitamin A, which he had begun in 1940. With chemical synthesis of vitamin A achieved in the late 1940s, however, the production of this vitamin from fish livers ceased. Sanford then turned to other endeavors, becoming increasingly active in editing scientific papers, which occupied most of his time for the remainder of his career. In 1954 he published his first paper in this field, "Planning Your Fishery Research Paper." He also founded and edited a new government journal, Fisheries Industrial Research.

In 1942 Victor Scheffer, on loan from the Alaska Fur Seal Investigation (suspended because of the war) began a 2-year project on American sources of agar. He was assisted by Vincent Senn, a newly appointed chemist. The field work was conducted at Scripps Institute of Oceanography at La Jolla, California.

Roy Stevens was employed to carry out many of the duties connected with the publishing of Commercial Fisheries Abstracts, and he served as assistant editor during this period.

David Wieg was employed in 1949 as a laboratory aide, and since that time he has assisted with a wide variety of laboratory investigations. He continues in this capacity.

In 1954 the staff of the Technological Laboratory included the following full-time employees: Maurice Stansby, chemist and Laboratory Director; Bruce Sanford, chemist; Neva Karrick, chemist; William Sumerwell, biochemist; David Miyauchi, fishery products technologist; Kathryn Osterhaug, home economist; Roy Stevens, fishery products technologist; Patricia Terao, chief clerk; David Wieg and Mabel Edwards, laboratory aides; Mildred

Martin, procurement clerk; Margaret Brown, secretary; Marjorie Zachow and Marjorie Pearse, clerk typists.

Part-time employees included: Martin Heerdt, William Clegg, Robert Doll, Edward Gruger, and Murray Andrews, all chemists; Rosemary Schairer, clerk-stenographer; Lois Elgin, home economist; and Harriet Starr and Marian MacFarlane, laboratory aides.

In 1942, the budget for the Laboratory was about $29,000, with five full-time employees. By 1945, when wartime activities had peaked the budget had reached about $64,000. Seventeen full-time employees were on the staff. In 1947 massive reductions of wartime positions and budgets took place, and the Seattle laboratory lost one-half of its personnel. This resulted in an annual budget of $34,000 and eight full-time staff members. The impact of the sudden drop in the budget and personnel was softened by the previously mentioned grant of $47,600 for a 2- to 3-year research project on utilization of salmon cannery waste. Although quite a few staff members had to be terminated, several were retained for the special projects. In the meantime, other contributed funds were obtained from the Refrigeration Research Foundation, from the fish hatchery section of the Bureau of Fisheries, and from the Continental Can Company. By 1954 the annual budget had risen to about $61,000 and there were 14 full-time staff members.

Summary of 1942-54 Accomplishments.--Under Maurice Stansby as Director, the Laboratory spent about 5 years with major emphasis on special wartime projects and 8 years on peacetime projects. This was a period of great expansion in the size and scope of the work. It also resulted in a tremendously increased output of research and other publications. During this period, 140 papers were published, an average of more than 10 per year. Facilities were improved by expanding the size of the pilot plant building and providing freezer and cold storage equipment. Accomplishments related to wartime activities included providing information, services, and in some cases personnel details, to numerous wartime agencies such as the War Production Board, the Office of Price Administration, and the Army Quartermaster Corp; developing a successful method of producing dehydrated fish; and developing equipment for sampling fish livers.

During peacetime, the laboratory staff devised a method for getting current literature to the fishing industry by publishing the monthly Commercial Fisheries Abstracts; devised a successful means for utilizing Alaskan salmon cannery waste which was adopted by industry; established the vitamin B content of fish meals; conducted research on cold storage properties and chemical composition of fresh water species of fish in the absence of facilities in the Great Lakes area; and conducted the first research on fractionization of fish oils and preparation of chemical derivatives from them.

1955 THROUGH 1965

Beginning in 1955 the Seattle Technological Laboratory received supplementary funding from import revenues under the Saltonstall-Kennedy (SK) Act. This provided up to $200,000 per year in addition to regular funding. After 1960, as the value of the research from the special SK funding became apparent, a portion of

the SK funds were replaced each year by additional regular funding so that by 1965 the SK funds were reduced to $70,000, but regular funding had increased to $316,000, making a total budget of nearly $400,000. A considerable portion of the supplementary SK funds was used for contract research at universities. This brought new ideas into the overall research programs and provided additional research findings.

The principal research areas covered by the new funding were in fish meal; in fish oil research, especially at Seattle; and in developing standards of quality for using the newly inaugurated inspection of fishery products program.

Much of the work carried out on contract at universities was carried out at the universities of Minnesota and California. The University of Minnesota was chosen for a major part of the fish oil research because the largest and best qualified oil research laboratory in the country was Hormel Institute, a part of the University of Minnesota located at Austin, Minnesota. Additionally, since the most immediate new use for fish oil was apt to be for iron ore concentration and 60% of all iron ore was mined in Minnesota, the School of Mines and Metallurgy of the University of Minnesota was the most experienced in this field.

The University of California was selected for another major portion of the work because the Institute of Marine Resources and the Department of Food Science and Technology, parts of the University, were best qualified for work on research on oil in fish meal and oil in fish flesh. Major aspects of the program required experienced laboratory work which the University of California was able to provide. Other universities and research laboratories where smaller portions of the work were carried out included the University of Washington's College of Fisheries; Oregon State University's Department of Food Technology; the Phillip R. Park Research Foundation at Terminal Island, California; the University of Wisconsin's Department of Poultry Science and Wisconsin Alumni Research Foundation; and the Mayo Clinic.

Fish Oil Research.--A major research thrust during the decade beginning in 1955 was to obtain background information on the chemistry of fish oils and to develop new uses for them. Fish oil work proceeded along industrial and nutritional lines. In the industrial area many new uses were investigated, including use of fish oil derivatives for ore flotation, for insecticides, for chemical intermediates to be used in making a variety of other products, and for other purposes. A considerable part of the industrial oil application program concerned the use of fish oil compounds for concentrating low grade iron ore. Work was conducted cooperatively with the University of Minnesota College of Mines and Metallurgy. A practical procedure was developed and has been used in some foreign countries. This procedure will be available for future use in this country after the higher-grade taconite ores, which use the cheaper magnetic process, have been depleted.

A number of chemical firms used the program's findings to produce new industrial products from chemically synthesized fish oil derivatives. Most of these uses are proprietary applications for which no information is available.

The nutritional investigations primarily examined the potential of polyunsaturated fish oils and fish oil

fatty acids for use as cholesterol depressants. Based upon rat feeding tests performed under contract by the University of Minnesota's Hormel Institute, it was found that fish oils and fish oil fatty acids are several times more effective, weight for weight, than vegetable oils, such as corn oil, in lowering serum cholesterol. Furthermore, in a 15- to 20-year study by a Seattle heart physician, Dr. Averly Nelson (1972), the animal tests were confirmed as applying to human subjects. Of those patients who followed the prescribed diet high in seafoods, nearly three times as many survived longer than heart patients on the ordinary (control) diet.

Other tests in the Seattle program on medical applications of fish oils suggested that they are valueless in curing wounds and burns. This study was performed at the Mayo Clinic to determine whether the use of fish oil in ointments facilitated healing, as had been believed for many years.

Perhaps the main benefit of the fish oil program was the accumulation of basic information on the chemistry and nutritive value of fish oils, about which very little was known before these studies were made. Much of the general information has been summarized in a book by Stansby (1967), and much of the nutritional and pharmaceutical information is given in a review by Stansby (1969).

Standards Program.--Under the standards program, detailed specifications were established for most of the commercially important species of fish which are handled in the fresh or frozen state in the Pacific Northwest. These standards provided the means for inauguration of a federal voluntary inspection service in the Pacific Northwest. Research on the quality of fresh and frozen fish, and on the development of standards was coordinated by John Dassow and included freezing and preservation studies by Richard Nelson and development of quality criteria and methodology for grade standards by Max Patashnik, Wayne Tretsven, and others.

Other Programs.--Studies on the chemistry and microbiology of fresh, chilled fish were expanded in 1961 with the initiation of a major research project on the feasibility of extending the storage life of chilled fish by low-dosage irradiation. This study was supported by the Atomic Energy Commission under its national food irradiation research program. Ten papers and several contract reports by the program leader, David Miyauchi, and co-workers John Spinelli and Dr. Melvin Eklund were published on the irradiation pasteurization studies. Other contributions included 12 papers on fresh fish quality determination and frozen fish inspection methodology, and six papers by George Pigott summarizing his comprehensive study of iron sulfide discoloration in canned tuna.

A program on the proximate composition, and sodium and potassium content, of saltwater fish of the Pacific Northwest and of the Great Lakes and other freshwater species was completed during the 1955-65 period. Much of this work was conducted by Claude Thurston at the Seattle Technological Laboratory. He published 15 scientific papers on this work.

Personnel.--During the decade ending in 1965, a considerable number of new personnel were added to the staff in connection with the SK and irradiation programs.

Harold Barnett carried out research on

preservation and processing, working particularly with hake.

John Dassow, in his capacity as supervisory fishery products technologist, was in charge of the work on the development of grade standards as well as all the work on the preservation of fish. The latter included the fish irradiation project which was being expanded. It also included the various programs on the preservation of fresh and frozen fish, and working with the fishing industry to assist them in problems in handling and processing fish.

John Dyer, a chemical engineer, worked to develop practical methods for fish oil fatty acid fractionization.

Dr. Melvin Eklund carried out microbiological research, especially studies of Clostridium botulinum problems in irradiation preservation of fish.

Erich Gauglitz, Jr., headed the project on preparation of chemical derivatives from fish oils.

Dr. Edward Gruger, until 1 July 1965, headed the organic chemistry program which dealt with fish oils. He then was detailed to the cooperative program with the Food Science and Technology Department, University of California at Davis, where he began thesis research on antioxidant mechanisms in fish oils.

Dr. Herman Groninger was project leader for biochemical research investigations concerned with spoilage of fish.

Alice Hall, a chemist, worked on characteristics and utilization of dogfish and other shark species of the Pacific and Atlantic coasts.

Patrick Hunter, an engineering technician, assisted in the refining of fish oil, especially in connection with molecular distillation to produce palatable fish oil.

Clifford Houle worked on fatty acid derivatives from fish oils.

Barbara Kemp worked on the fish irradiation project, particularly on chemical, and corresponding flavor changes that occurred in irradiation-pasteurized fresh fish. She also did research on the chemistry of shark and Pacific whiting (hake) proteins.

Neva Karrick, in her capacity as supervisory chemist, was in charge of the programs on fish oils and other chemical aspects classified as basic research.

George Kudo carried out research on sharks. He also was detailed to the biological laboratory to act as an observer on Japanese fishing vessels.

Lawrence Lehman, organic chemist, worked on the project to develop chemical derivatives of fish oil fatty acids.

Lynne McKee carried out work to assist the fishing industry with problems of freezing and canning crab. With John Dassow, she carried out the first technological work on the processing problems in the mechanized shrimp industry, following the introduction of the first mechanical peeler on the Pacific coast in 1956 in Westport, Washington. On several occasions, McKee was also detailed to assist with problems in east coast and Gulf of Mexico fisheries.

Dr. Donald Malins was detailed to Aberdeen, Scotland, where he worked at the University of Aberdeen and at Torrey Research Station, to carry out

work on biopathways in lipids.

David Miyauchi was the project leader for the expanding program on irradiation of fish being financed by the Atomic Energy Commission. He personally carried out research on the radiation process while supervising subprojects dealing with food chemistry, food microbiology, and Clostridium botulinum problems.

Richard Nelson, a chemical engineer, supervised several projects on food preservation and processing, including icing and refrigeration of fish at sea, objective measurement of quality changes in iced halibut, and development of quality standards for frozen fish.

Max Patashnik, a chemical engineer, carried out research on the measurement of quality changes in halibut, salmon, and bottomfish; and the application of this research to development of quality standards. Patashnik did the initial, and later, detailed research on the problems of mushy texture in Pacific whiting, the relationship to the protozoan parasites, and the effect of handling and icing practices aboard the vessels.

Gretchen Pelroy headed the subproject on food microbiology under the irradiation program.

Paul Robisch, a chemist, carried out miscellaneous chemical analyses for different programs. He also assisted Stansby in a program on odor and flavor.

Dr. William (Ted) Roubal returned from a 2-year detail at the University of California at Davis where he had been carrying out research on oxidation of fish oils. He received his doctorate while at Davis. After his return to Seattle he began research on fish oil oxidation employing the new technique that involved the use of an Electron Paramagnetic Radiation (EPR) instrument.

Dr. Virgina Stout, a chemist, carried out research on synthesis of organophosphorous fish oil derivatives as products which might be useful in a number of ways, such as fire-retardants, pesticides, and lubricants.

John Spinelli, a chemist, worked on the food chemistry portion of the irradiation project. This involved research on storage changes in iced fish which occur very early before actual spoilage has taken place. An important phase of this study was on the chemistry of the autolytic processes, the relation of early quality and flavor losses to nucleotide degradation, the decrease of inosine monophosphate, and the accumulation of hypoxanthine.

Patricia Terao continued her position as administrative officer for the laboratory. This involved such duties as budget planning and personnel appointments. Because of her long association with the laboratory, she took on other duties such as preparing many of the in-house annual reports. She also was in charge of answering general technological inquiries which did not require a detailed scientific reply.

Dr. Claude Thurston worked at the laboratory as a chemist from 1955 to 1961. He had been a professor of chemistry at Walla Walla University at College Place, Washington, and left to become the director of food research at Loma Linda University. During his 6 years with the Technological Laboratory at Seattle, he carried out a tremendous

amount of work on the proximate composition, and sodium and potassium content of fishes of the Pacific coast and also some work on freshwater species. He was assisted by several laboratory aides and organized the work to obtain a maximum amount of results. There is little that is not known about proximate composition of most Pacific Coast species as a result of the vast amount of data and published papers which were obtained during Thurston's relatively short tenure.

Wayne Tretsven conducted research on quality changes in fish with emphasis on the effects of handling, bleeding, icing, and washing fish aboard the vessel and in the plant. His early microbiological studies included problems of fillet contamination in the plant. Later work on halibut quality emphasized handling problems aboard the fishing vessel.

Dr. John Wekell, a chemist, worked on the chemistry and separation of glyceryl ethers from the flesh and livers of fish.

Dave Wieg, physical science aide, assisted John Spinelli in his food chemistry research.

Until 1961 Bruce Sanford worked as part of the Technological Laboratory staff. During this time he did editorial work almost exclusively, initially for the Seattle Technological Laboratory but later for all Bureau Technological Laboratories throughout the country. In 1961 this work was set up as a separate function from the Seattle Technological Laboratory, and it was designated as the Special Scientific Unit (SSU). It included both editoral activities and the preparation of the monthly publication, Commercial Fisheries Abstracts.

Summary of 1955-65 Accomplishments.--Under Maurice Stansby as Director, the Technological Laboratory activity expanded in budget and staff. The scope for the work was widened with a considerable portion of time spent on a crash program on chemistry and utilization of fish oils. During this period, 201 scientific papers and 23 books were published. In addition, a total of 80 papers resulting from contract and cooperative work financed by the Seattle laboratory were also published.

A major contribution from the research of this period was the compilation of information on the chemistry and nutritive value of fish oils. Much additional information was obtained on the proximate composition and mineral content of fish. The first research on irradiation as a means for preserving Pacific Northwest species of fish was conducted. Considerable research was also performed to obtain information required to establish standards for fish.

1966 THROUGH 1981

Organization and Objectives.--During 1966 the Technological Laboratory was reorganized. Under Maurice Stansby, formation of the Food Science Pioneer Research Laboratory became a separate research unit. The personnel and resources of the Technological Laboratory were assigned to either the Pioneer Research or the Technological Laboratory with a revised research program. Dr. Maynard A. Steinberg, formerly with the Gloucester Technological Laboratory, was appointed Director of the Seattle Technological Laboratory in August 1966.

At this time, it was obvious that factors other than reorganization made a complete review of the laboratory program essential. As the new Director, Dr. Steinberg had strong ideas about the importance of continuity in research objectives in relation to the scientific interests of the staff. The reorganized laboratory had retained, of course, the responsibility for applied research on the practical problems of preserving, processing, and utilizing fishery resources. The comprehensive research on the chemistry of fish oil from an analytical and industrial perspective was completed. New problems appeared: contaminants in fishery products, and the need to expand the horizons of fishery preservation. These problems included more than radiation preservation (supported by the Atomic Energy Commission) and emphasized the potential for research on other techniques for extending the keeping quality of traditional fresh fish species. Ideas for using fish species that were previously rejected by the Pacific coast trawl fishery needed more development to follow up the early work by Dassow and Patashnik with Pacific whiting. In 1968 the new objectives of the laboratory were defined at a program review as follows: (1) to develop scientific knowledge to improve the preservation, processing, and utilization of fishery resources; and (2) to apply and demonstrate to industry the improved process methods and concepts for efficient utilization of the total resource, with a primary emphasis on food production.

The laboratory was organized into six sections including four research programs, inspection, and administration: 1) Chemistry of Fishery Products--Erich Gauglitz, Jr., program leader, with Dr. Virginia Stout, Dr. Herman Groninger, John Dyer, Lawrence Lehman, Clifford Houle, Dr. John Wekell, and Barbara Kemp (later Koury) as research staff; 2) Preservation and Engineering--Richard Nelson, program leader, with Max Patashnik, Dr. Wayne Tretsven, Alice Hall, George Kudo, Harold Bennett, and Pat Hunter as research staff; 3) Radiation Preservation of Fishery Products--David Miyauchi, program leader, with John Spinelli, Gretchen Pelroy, Fuad Teeny, John Seman, Dave Wieg, and Laura Lewis as research staff; 4) Radiation Preservation Microbiology--Dr. Melvin Eklund, program leader, with Frank Poysky ; 5) Inspection--Morris Rafn, supervisor, and inspector George Berkompas, at Bellingham; 6) Administration--Laboratory Director Dr. Maynard Steinberg, Assistant Laboratory Director John Dassow, Administrative Officer Patricia Terao, and four secretaries--Margaret Hodgins, Gretchen Lindberg, Isabell Diamant, and Dolores DeWitt. Total staff was 33 and the budget was about $380,000, not including contract research funds for the radiation preservation research (funded by the Atomic Energy Commission from 1961 to 1969).

During the 1970s, the laboratory was designated the Pacific Utilization Research Center (PURC) with Dr. Steinberg as director. The technological research in Alaska, under Jefferson Collins, was relocated to Kodiak in 1971 and assigned to PURC after a somewhat confusing period of separate regional responsibility. Administratively this unification was very important in re-establishing Alaskan field research tackling problems of technological concern to the Northwest and Alaska fisheries. The budget increased to more than $900,000 by 1976; however, the staff remained at 35, including a scientific staff of three at the Kodiak Utilization Research Laboratory. In

October 1976, PURC became the Utilization Research (UR) Division of the Northwest and Alaska Fisheries Center, with continuing emphasis on increasing the utilization of fishery products. In August 1979 Dr. Steinberg retired and John Dassow was Acting Division Director until the new Director, John Spinelli, was appointed in February 1980. By early 1981, the total staff had decreased (with retirements in recent years of Dr. Tretsven, Dyer, Miyauchi, and Patashnik) to 29, including three at the Kodiak Utilization Research Unit--Jefferson Collins, Dr. Kermit Reppond, and Dennis Markey. In addition, two NOAA Corps officers, Lt. Jim Conrad and Lt. Cdr. Allan Kissam, were on detail to the Division's Preservation Research Program.

Chemistry of Fishery Products.--Increasing emphasis was devoted to the factors affecting the recovery, modification, and utilization of fish oils for food purposes. The recovery of oil derived from the isopropanol process for fish protein concentrate (FPC) production was studied as part of the national research program on FPC and, in 1971-72, in relation to the pilot production problems of FPC and oil at the experimental FPC plant in Aberdeen, Washington. Both species and process variables were examined; however, major emphasis was on the potential recovery of high-grade oil from menhaden and anchovy.

It turned out that the recovery and separation of isopropanol, oil, water, and soluble proteins was a much more difficult problem at the pilot production plant than at the laboratory. John Dyer was detailed to study this problem with fatty fish species at the Aberdeen plant, but because of related problems in the extraction of the oil from fatty fish as compared to the Pacific whiting, the engineering task became far too complex. For example, a major problem was eliminating the intractable and seemingly immovable emulsions that formed in the lines and heat exchangers, but this was essential to keep the process operating. Obviously a new engineering approach was needed to solve oil recovery problem with fatty species. The national FPC program and the Aberdeen FPC plant were terminated during 1972-73, ending the research on improved methods of extracting and refining the oil from menhaden and anchovy in the isopropanol FPC process.

The cooperative research and liaison of the Seattle staff with the FPC plant was remarkably unproductive in terms of finished results in relation to our plans and expectations. The effort and experience led to new directions and productive research in the 1970s on other processes for fish proteins, modified proteins, and protein derivatives. In addition, the process difficulties and lower yields that were encountered provided a broader technological understanding of the limitations of the FPC process.

Research on levels of organic contaminants in fish oil was initiated in 1966 with major emphasis on analyses for DDT in menhaden and other industrial fish oils and meals. The effort was broadened within a few years to include fish species of both the Atlantic and the northeast Pacific. Other chlorinated pesticides such as dieldrin were determined. The developing concern over polychlorinated biphenyls (PCBs) in the environment necessitated studies on its level in fish and shellfish of both the Atlantic and Pacific. With the continued cooperation of the menhaden industry,

the laboratory obtained seasonal samples of raw fish, meal, and oil for several years.

The long-range studies with the Atlantic menhaden industry presented numerous problems in obtaining the needed samples. The analyst, Dr. Virginia Stout, and the project supervisor, Erich Gauglitz, were concerned with the problem of obtaining cooperation with an industry which was sensitive both to the need for unbiased sampling and analysis of a most undesirable contaminant, and to the implications of the findings. When the results of the survey were finally published in 1981 they formed an historical note on the problem of environmental contaminants and the changing impact on a specific fishery. The decline in DDT usage was reflected in lower DDT levels in menhaden oil; however, data on PCB levels through 1976 showed a continuing moderate level in menhaden from most areas. Pacific species showed no problems with organic contaminant levels with the exception of fish from areas affected by agricultural runoff such as southern California coastal waters.

A major study of mercury levels in food fish was initiated following the 1970 reports of high mercury levels in tuna, swordfish, and freshwater fish from industrially contaminated waters. Major surveys were conducted on problem species such as halibut and sablefish in which high mercury levels (above the 0.5 ppm U.S. Food and Drug Administration guideline) appeared to be related primarily to age and size of the fish, and to a lesser extent, to the area.

In the history of the technological laboratory, it should be pointed out that this detailed study of mercury levels in fish and the accompanying health and economic implications represented an unprecedented high degree of industry and government cooperation. Fishermen, buyers, and processors were eager for the truth on mercury levels in the problem species but were concerned that premature release or confusing information could have dire effects in the marketplace. Looking back, the program worked quite well. An interesting sidelight is that in later years after the detailed analytical work was done, legal considerations dictated an increase in the FDA mercury guideline to 1.0 ppm, a level that would have ameliorated much of the short-term economic effects on industry in the few years of great concern. The work has gradually broadened in scope to include other trace metals of public health concern, e.g., lead, cadmium, and chromium.

Preservation and Engineering.--With the decreasing effort in development of product quality standards, a greater emphasis was given to the effects of handling, chilling, and preserving techniques on the quality of fish and shellfish.

The field studies on preserving and handling halibut at sea by Wayne Tretsven and Richard Nelson in the early 1960s and the detailed laboratory analyses on quality criteria by Max Patashnik had shown the real need for closely related vessel and laboratory experiments. A better understanding of the physical-chemical changes in the fish flesh during chilling and freezing was the result, and this affected the continuing preservation research on other species.

Studies were concerned with 1) live holding and shipping of Dungeness crab, 2) factors affecting water-holding capacity of fish tissue and methods of measurement, 3) quality of chilled and

frozen Dungeness and king crab meat, 4) quality of iced halibut and methods of determining and measuring quality differences for marketing, and 5) improved methods of chilling and holding fresh whole and dressed fish by use of modified atmosphere and modified refrigerated seawater (RSW) with carbon dioxide. The RSW research included several species of fish--salmon, rockfish, cod--in the early studies. In 1968, work on increasing the utilization of rockfish and Pacific whiting was initiated with new studies on the techniques and applications of mechanical flesh separation from skin and bone.

In 1968 Minoru Okada, a visiting biochemist with the Tokai Fisheries Regional Laboratory, Tokyo, Japan, arrived for a 10-month cooperative study of Japanese minced fish technology on Pacific coast species. Okada's pioneering research on minced fish, ("surimi") and fish cake ("kamaboko") had helped to increase the production of these processed products in Japan to astonishing levels--more than a billion pounds a year. His visit and the Seattle laboratory's interest in this new technology initially resulted from a brief visit by John Dassow to the Tokai Laboratory in 1966. The need to evaluate new processes for utilizing species like Pacific whiting and rockfish and, in later years, walleye pollock was the real incentive. From that year to the present, minced fish, and numerous ramifications of the concept of mechanically separated fish flesh, began to dominate much research at the Seattle laboratory and several other technological laboratories in the United States. Research on the properties and utilization of minced flesh in fishery products and processed meat products by David Miyauchi and George Kudo continued to the present, but with emphasis changing to species problems. A total of 89 papers and three patents were published on various preservation and engineering projects during 1966-76, a period of many new ideas for utilization as well as preservation.

With the passage of environmental protection and clean water legislation in 1969-72, a major study of the characterization, measurement, and treatment of fish and shellfish processing effluents was conducted during the early 1970s. A primary goal of this research was to provide objective data on the characteristics and physical-chemical treatment of the effluents. The efforts included cooperative industry studies at a number of processing plants in the Northwest and Alaska and provided a base for liaison with the Environmental Protection Agency, as well as advisory services with industry, and local and state officials in environmental control. Active field research in effluent treatment was terminated in 1976.

Inevitably, the cooperative field studies on effluent characteristics, analysis, and treatment by Richard Nelson and Harold Barnett of Seattle and Jefferson Collins in Kodiak established a new field of expertise in the laboratory that has been in continual demand.

Resource Development of Fish Protein Derivatives.--The research on problems of FPC production in 1971-72 led to continuing protein studies under John Spinelli, culminating in the development of and a public patent to Spinelli for the aqueous phosphate process for fish proteins. Work on improving the functional characteristics of purified muscle proteins resulted in a series of

studies by Dr. Herman Groninger and Ruth Miller on the preparation and properties of chemically modified (acylated) fish proteins. The extension of this field to modified forms of protein by Spinelli and Koury also suggested the preparation of drum-dried proteins with optional pretreatment of the fish or use of cereals for co-drying with fish mixture. A major objective in this research, which continues to the present, is the development of aqueous pretreatments of minced flesh and drying techniques that minimize costs and eliminate solvent processes for protein production from lean species.

One aspect of these studies on the purified proteins was the recognition of the importance of the functional characteristics, such as the gel-forming and emulsification properties, not only to protein isolates but to the quality changes of fresh and frozen fish. This work in the 1970s on functional proteins, resulted in two additional patents and 18 scientific papers, and remains an active area in the laboratory.

Radiation Preservation of Fishery Products.--This major research program was supported by the Atomic Energy Commission's (AEC) Division of Isotopes Development from 1961 through 1969 and included a comprehensive study of the feasibility of radiation preservation of fresh fish and shellfish. With his background on the research in measuring quality changes in fresh and chilled fish, David Miyauchi, the project leader, established a strong emphasis on the relationship of the sensory changes in the irradiated fish to the early chemical changes, as shown in Spinelli's research on correlation of flavor loss to the decrease in level of inosine monophosphate. Research included chemistry and microbiology of the early and late changes related to the freshness and spoilage of fresh fish, the measurements of acceptability by both subjective and objective criteria, the effects of prehandling and radiation at sea, the importance of packaging and quality control in extended storage and shipment tests, and the determination of preference at the consumption level. One of the final studies was the testing and experimental installation of a shipboard irradiator aboard the fisheries research vessel Miller Freeman. This research was conducted by Fuad Teeny, who irradiated five species at sea in various stages of rigor. Teeny and Miyauchi demonstrated in the later quality and storage tests that the shelf life of irradiated pasteurized fish was significantly longer for the pre-rigor fish than for the post-rigor fish. In addition to accomplishing the contract objectives, the studies provided numerous spinoff benefits for other research in basic quality determination, flavor changes, effects of additives, control of drip and water-binding characteristics, and variables of preference determination.

The data and reports proved to be particularly valuable because of the excellent documentation on changes in the control of untreated fish and shellfish along with the irradiated products. At the time the contract study was terminated, the approval of the radiation pasteurization process for fresh fish and shellfish by the Food and Drug Administration was in abeyance. It is useful to record that it now appears, in 1981, that FDA approval is imminent--almost 10 years later. A total of 29 reports and scientific papers were published on the specific phases of the contract research up to 1972.

Radiation Preservation Microbiology.--Early studies on the radiation pasteurization of fresh fish and shellfish and the profound effect on the survival and subsequent growth of the microflora led to a major investigation, supported initially by the AEC and currently by the U.S. Army Research Office, under Dr. Melvin Eklund, on the survival, outgrowth, toxigenesis, and possible control of *Clostridium botulinum* in radiation pasteurized fishery products. Following completion of the technological and chemical studies on radiation pasteurization, the research on *C. botulinum* was expanded to include any perishable fishery product, such as heat-pasteurized and smoked products.

The definitive research by Dr. Eklund and his small project staff on *C. botulinum* in relation to radiation pasteurization was applied in a most practical way to the problems of the hot-smoked fish industry. Of greatest importance was the need to show the specific limitations of temperature, moisture, salt, and sodium nitrite in establishing safe processing guidelines for hot-smoked fish. Active support by the smoked fish industry of this phase of Eklund's research has assured the continuation of this project, complementing the continuing support by the Army Research Office on the basic factors in growth and toxigenicity of the various types of *C. botulinum*. The research staff for these various projects in 1981 included: Dr. Melvin Eklund, program leader; microbiologists, Gretchen Pelroy and Mark Peterson; food technologist, Frank Poysky; and scientific aides, Lamia Mseitif, Rohinee Paranjpye, and Eric Rolseth.

The research on toxigenicity of *C. botulinum* includes the various forms of botulism of concern to public health, and effects of the environmental factors in the products and processes such as time-temperature, moisture content, salt level, and chemical additives. The continuing objective of the research is to understand the factors controlling *C. botulinum* outgrowth and toxin formation. This information should provide a firm basis for prevention of botulism by physical-chemical control of the organism whenever it is present in food. Through 1980, 35 reports and scientific papers were published on the microbiology of radiated pasteurized fish and the continuing studies of *C. botulinum* outgrowth in other partially processed and preserved fishery products, especially smoked and fresh fish stored in a CO_2-modified atmosphere.

The irradiation project offered a convenient means of studying autolytic changes in fish that occured in the absence of microbial growth. Under the direction of John Spinelli, it was shown that these changes produced a marked effect on the organoleptic characteristics of the fish. The rates of these changes and methodology for their detection were determined on several species of commercially important fish during the course of the irradiation research.

Fish Nutrition (Aquaculture).--The shortage and high price of fish meal during 1972-73 suggested the importance of technological research on alternative sources of feed proteins for use in developing aquaculture. To date, this study under John Spinelli has emphasized two aspects: 1) the problems and the potential of utilizing underutilized species (e.g., dogfish) and the unconventional protein sources (e.g., single-cell protein from petroleum), and 2) the improvement of the dietary components of salmonids in

relation to the nutritional requirements of the species and the desired qualities of the fish to be marketed. The utilization of pelagic red crab and krill as sources of carotenoid pigments for salmonids (rainbow trout and pen-reared salmon) and the effects on growth and quality of the harvested fish established a new research area in salmonid nutrition. Continuing carotenoid research in 1980-81 included evaluation of crayfish waste from Louisiana, a valuable carotenoid resource, and simple methods of extraction and concentration for feed using soy oil. Dr. John Wekell was named project leader in 1980 and with Karl Shearer, fish nutritionist, and Dave Wieg has continued research on problems of essential trace elements, particularly zinc, available in relation to alternative feed proteins (soy and cottonseed meal) in which natural chelators occur. Ten scientific papers have been published on these studies since 1975.

FOOD SCIENCE PIONEER RESEARCH LABORATORY 1966-81

Organization and Programs.--In 1965 Maurice Stansby, who had been director of the Seattle Technological Laboratory since 1942, received a PL 313 appointment. A group of scientists was transferred from the Technological Laboratory to work under Stansby in a new laboratory for long-term, fundamental research. These other scientists included: Neva Karrick, Dr. Edward Gruger, Dr. W. T. Roubal, Dr. Donald Malins, Anthony Barone, and Paul Robisch. The major field of research of the new Food Science Pioneer Research Laboratory was the mechanism of oxidative deterioration in fish oils, especially while fish oils were present within the flesh of fish. A secondary project was concerned with the role of unusual lipids in sharks and porpoises, the latter in connection with sonar reception and transmission. The sonar work under Dr. Malins was conducted primarily by Dr. Usha Varanasi, who was funded by the Office of Naval Research. A third project, undertaken several years later, was concerned with nitrosamines and smoked fish.

The Food Science Pioneer Research Laboratory was located on the same floor of the research buildings as the Technological Laboratory and had about five laboratories and several offices for its exclusive use. Instruments and certain o}her facilities were shared by the two laboratories.

Much of fiscal year 1966, the first year of the new laboratory's operation, was spent in completing research tasks that were underway before the Pioneer Research Laboratory was established. The laboratory started with its new programs in full operation by the summer of 1966 and terminated operations in 1971 when the Northwest Fisheries Center was established. At that time, the Pioneer Research Laboratory and its personnel became the first unit of the Division of Environmental Conservation of the Northwest Fisheries Center with Maurice Stansby as division director.

Research on Lipid Oxidation.--The research on oxidation of fish lipids within fish tissue was conducted partly at Seattle and partly by two of the Pioneer Research Laboratory personnel (Drs. Roubal and Gruger) stationed at the University of California at Davis' Food Science Department. In the latter investigations, Dr. Roubal determined the effects of oxidizing lipids in fish on proteins and established that

polymerization of protein occurred. Dr. Gruger investigated the role of natural biological antioxidants, principally alpha-tocopherol, and reduced co-enzymes on the oxidation of fish oil polyunsaturated fatty acids in model systems. At Seattle, Dr. Roubal applied electron paramagnetic resonance spectrometry to study effects of trapped radicals in dry products such as fish meal, fish protein concentrate, and freeze-dried fish. It was shown that the free radicals, rather than oxidation products of the oil such as aldehydes, are primary agents responsible for deterioration of protein quality. Such oxidative activity was shown to take place slowly over extended periods of time when the dry products were stored.

Also at Seattle, Karrick studied the effect of microbial action on oxidative deterioration of lipids in fish. Evidence was obtained to indicate that, when bacterial action occurred, the extent of lipid oxidation declined. Another phase of the work compared cold storage life of frozen coho salmon based upon lipid oxidation and flavor change. Comparisons were made between samples frozen in hermetically sealed tins and samples protected by other packaging means. The flavor of the samples stored in tin remained at an acceptable level for at least 10 times longer than for any other packaging method.

Research on Other Projects.--The work by Drs. Malins and Varanasi on unusual lipids concerned two quite different aspects. The nature and function of alkoxydiglycerides in dogfish and several other sharks was one aspect that was investigated. It was shown that in these species there is a varying ratio of such compounds to triglycerides. When this ratio changes, the buoyancy of the fish is altered and it is possible that lipid transformations between the two types of glycerides are employed by the sharks to assist in maintaining desired buoyancy levels when the fish move to different water depths.

In other aspects of the work, which was supported by the Office of Naval Research, the sonar communication sense organ of porpoises was investigated from a biochemical standpoint. The types of lipids present in the portions of the porpoise head through which the sonar waves are propagated and through which the reflected portions are received were found to vary. A hypothesis was investigated, namely, that the structure of these tissues is comprised of layers of lipids having different physical properties with respect to speed of transmission of sonar waves. Some evidence was found to suggest that the layers of lipids may be arranged in the form of a sort of lens which can focus the sonar waves and function as a sensing organ.

Because of published articles in the food science literature which suggested that nitrosamines having carcinogenic properties may form during processing smoked foods including fish, the U.S. Food and Drug Administration proposed limiting severely the amount of nitrates and nitrites that could be employed by the food industry. In the case of fish, the presence of considerable quantities of amines occurring naturally or as a result of early traces of spoilage indicated that on a theoretical basis fish might be more vulnerable to nitrosamine formation than other foods. Research conducted at the Food Science Pioneer Research Laboratory by Malins et al. (1970) showed that at the storage temperatures used for smoked fish and at nitrate and nitrite levels and other conditions used by fish processors, no

nitrosamines could form. In addition, Gruger showed that potential precursors for nitrosamine formation in fish flesh stored for long periods of time were either present at parts per million levels or were absent from the flesh. This work was also extended to possibilities that Alaskan salmon roe, which was preserved by nitrite and exported to Japan, might develop carcinogenic nitrosamines. The Japanese government had already tentatively banned importation of U.S. salmon roe preserved with nitrates for the subsequent season. Work performed by Dr. Roubal in the Washington, D.C., laboratories of the U.S. Food and Drug Administration showed decisively that nitrosamine formation did not occur. This work saved the multimillion dollar Alaskan salmon roe industry.

Accomplishments.--During the 5 years of active work of the Food Science Pioneer Laboratory in the field of food science, 74 scientific papers were published by its staff. Much of the work, which had been planned as a long-term basic research attack on the acute problems caused by lipid oxidation in fish, had concerned mechanisms of oxidation of fish lipids. Considerable basic information along these lines was accumulated. The Laboratory also became involved with the urgent practical problem concerning the possibility of carcinogenic compounds being formed in preserved fish, both from the Great Lakes area and from Alaska. The resulting crash program brought forth the needed information which prevented regulatory action that would have closed down the large and valuable Alaska salmon roe industry. It also bolstered the case against drastically and adversely requiring complete alteration in methods of manufacture for smoked Great Lakes chub which could have wiped out this industry.

It had been intended to follow up the initial basic findings concerning mechanism of fish lipid oxidation with work to suggest how oxidation in frozen salmon might be minimized. Because of reorganization and termination of the work of the Laboratory, this follow-up work had to be abandoned.

Finally, some basic research on the role of unusual lipids in both sharks and porpoises showed how these lipids are involved with functions of these species.

ALASKA, 1940-81

The Fishery Products Laboratory--later called Ketchikan Technological Laboratory--was built in 1940 and began operation in November of that year. When it opened, it had a staff and budget similar in size to the Seattle Technological Laboratory, including five full-time permanent professional employees. It did not change much in size over the years and is today, in fact, relocated at Kodiak, Alaska, somewhat smaller than it was in 1940.

Research in Alaska, 1940-65.--The Alaska laboratory, funded initially by both the Federal Government and the Territory of Alaska, was established primarily for the purpose of helping the Alaskan fishing industry utilize more species than were then being caught and processed. In 1940 salmon, halibut, and herring comprised 99.8% of the Alaskan fish catch. For all these species, stocks were either dwindling or were inadequate to supply a constant catch.

Initial research sought to develop crabs and clams as major new fisheries

in Alaska. The early efforts to develop king crab, which were directed from Seattle, have already been discussed. Today the Alaskan crab fishery comprises about 25% of the total fish harvest in Alaska. Efforts at the Ketchikan Laboratory in 1940 included as one of the major projects investigating the possibility of harvesting butter clams for marketing on the Pacific coast. At that time, supplies of clams harvested in Washington were diminishing. Preliminary work in 1941 and 1942 showed that there were abundant supplies of butter clams in southeastern Alaska which could be harvested. Later work, however, revealed that the presence of Gonyaulax at seasonal intervals made the clams toxic and inedible. Several years' work was spent trying to overcome this handicap to marketing these clams, such as by instituting a quality control inspection procedure to eliminate toxic clams, but without success.

Later work was conducted over a period of years on investigating preservation and handling procedures for Alaskan shrimp. These investigations have contributed to the success in building up a large Alaskan shrimp industry which currently amounts to more than 20% of the Alaskan fishery harvest.

By the mid-1950s, it was fairly obvious that the best possibilities for expansion of Alaska fisheries lay in developing shellfish resources. More and more of the effort of the laboratory went into work concerning such species. By the early 1960s practically the entire program of the laboratory was centered around aspects of shellfish utilization.

In 1962, when Dr. Murray Hayes became laboratory Director at Ketchikan, he continued to emphasize work on shellfish, particularly king crab and shrimp. He held annual meetings with industry representatives; the laboratory, working closely with the king crab industry, developed standardized criteria for king crab which helped to stabilize this still quite new industry.

From 1940 to 1965, 75 publications were issued resulting from the research and other activities of the Ketchikan Laboratory. Up to 1959, when Alaska became a state, the territory of Alaska supported the Ketchikan laboratory through the Fisheries Experimental Commission and employed individuals on the research staff who in several instances were later employed by the federal government in technological research at Seattle or elsewhere. These staff members included: Howard Craven, John Dassow, John Iverson, and Frank Piskur. At various intervals to 1971, when the Ketchikan laboratory was relocated at Kodiak, the research staff of four to six people included: Alfred Baker, Russel Brown, Clarence Carlson, John Chambers, Donna Galerman, William Hagevig, Robert Kyte, Raymond Landgraf, Carolyn Kelley, Richard Krzeczkowski, Phillip Sautier, Roy Porter, Frederick Stone, Richard Tenney, and Stanley Waskiewicz. Considering that this list does not include temporaries, it is obvious that turnover was a problem in the 31 years of the Ketchikan Technology Laboratory.

Research in Alaska, 1966-81.--The major program change during the period was the closing of the Ketchikan laboratory and the August 1971 relocation of personnel and facilities to the NMFS laboratory in Kodiak. The change reflected the decreasing importance of fisheries in the southeastern Alaska area and the continuing expansion of the shrimp and crab fisheries in central and western

Alaska. During the latter part of this period, the Alaska industry began plans for the development of a large bottomfish potential--pollock, rockfish, flounder, and cod.

During the last 5 years of the Ketchikan Laboratory, under Dr. Hayes and later Jefferson Collins, the staff initiated a major study of pink shrimp processing, including the conditions for precooking and canning in relation to yield and product acceptability. The growing problem of shrimp and crab waste in Alaska was studied in contractual research on potential utilization of crustacean waste for chiotina and chissam production. Studies of the chemistry of king crab and pink shrimp included quality and moisture retentivity factors, composition, and nucleotide studies. Eleven scientific publications resulted from these research activities.

Initial research at the relocated Kodiak laboratory, under supervision of Jefferson Collins, emphasized the physical-chemical characterization of fishery waste effluents with special attention to problems of sampling and analytical methodology. With the completion and publication of reports of this work in 1976, a major research project was initiated on development of bottomfish processing and the specific problem of handling and preserving walleye pollock and other trawl species.

The Technology Laboratory facilites at the Kodiak Laboratory were inadequate for wet fish preservation studies and pilot plant research; therefore, Collins developed separate research facilities in a building constructed by NMFS for storage and enforcement activities at Gibson Cove. One study was also completed on the use of the modified refrigerated seawater system as a method of improving the keeping quality of pink shrimp aboard vessel. In recent years, systematic studies were conducted on quality changes of walleye pollock, black rockfish, and Pacific cod in the refrigerated seawater and ice systems. To date, 10 publications and several industry information reports have been issued on the Kodiak technological research. The current staff of the Kodiak Utilization Unit is Jefferson Collins, program leader; and Kermit Reppond and Dennis Markey, chemists.

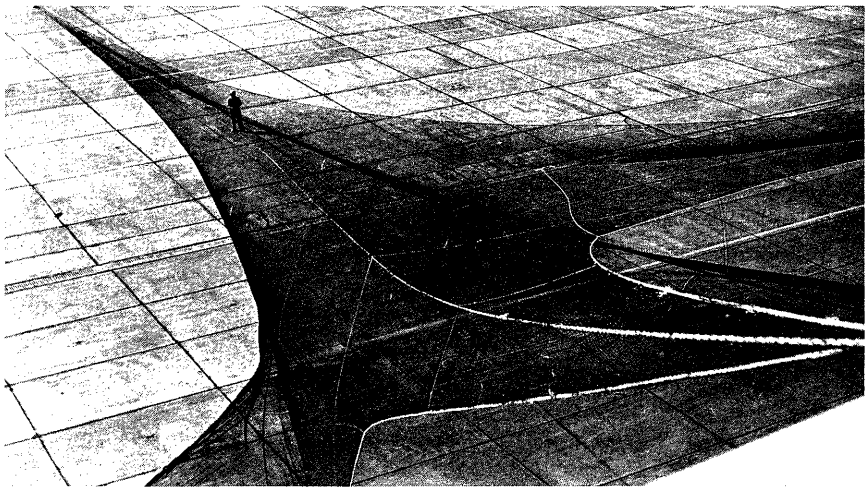
Ketchikan Laboratory Directors, 1940-81.

Name	Years
Maurice Stansby	1940-42
Lyle Anderson	1942-45
Harris Magnusson	1945-50
John Dassow	1950-55
Clarence Carlson	1955-57
Eyestein Einset	1957-60
Jefferson Collins (Acting)	1960-62
Murray Hayes	1962-70
Jefferson Collins	1970-71
Jefferson Collins	1971-present*

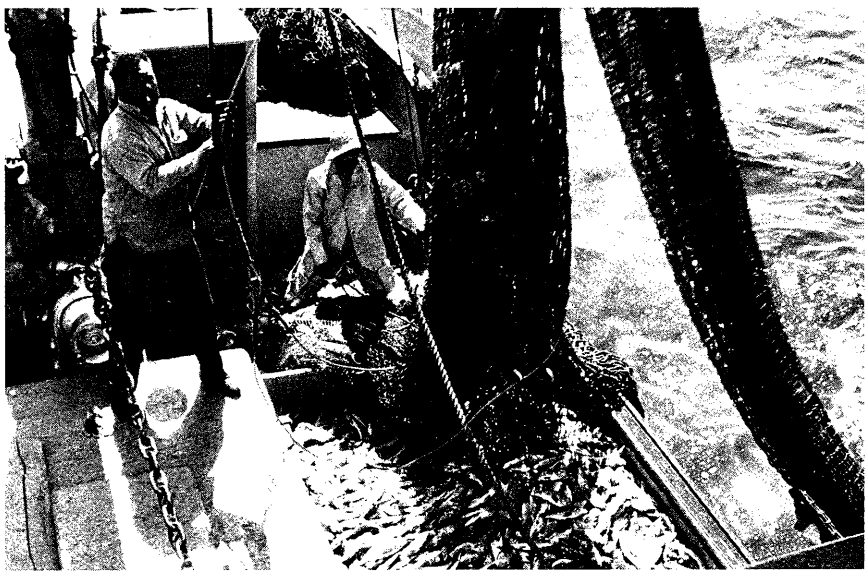
*After August 1971 the laboratory was relocated to Kodiak, Alaska

Exploratory Fishing and Gear Development

Melvin R. Greenwood [1]



Original Cobb pelagic trawl spread out on the parking apron at Sandpoint Naval Air Station, Seattle, about 1960.



Tordenskjold catch of Pacific ocean perch off southeastern Alaska in 1957. Captain Carl Serwold is standing on hatchcover.

Explorations to evaluate the commercial potential of latent fish stocks and/or fishing grounds, along with studies of fishing methods and equipment, were formally established as a separate activity of the Federal Government in 1949. With the objective to develop information needed by segments of the fishing industry interested in expanding or diversifying to new fishing areas and/or new stocks of fish, the special unit was designed to bridge an information gap inhibiting fishery development. To obtain practical (commercially significant) catch-rate and catch-composition data, commercial scale fishing systems were

1/ Former Deputy Director, Resource Assessment and Conservation Engineering Division, Northwest and Alaska Fisheries Center; present address: 8620 142nd N.E., Redmond, Wa 98052.

operated by experienced commercial fishermen on chartered commercial fishing vessels or research vessels built expecially for this unique purpose. Pre-1949 U.S. Fish and Wildlife Service (USFWS) exploratory fishing and gear research (EF&GR) activities in the northeastern Pacific Ocean and eastern Bering Sea were conducted by the Seattle Technological Laboratory as elements of processing and preservation studies or multi-disciplinary efforts designed to help industry utilize additional fisheries resources.

Information about potential commercial fish stocks not being utilized in this area began accumulating at least as far back as the 1888-90 surveys of the U.S. Fish Commission research vessel, Albatross, in waters off the territories of Oregon and Alaska. Although these early studies were basically for biological inventory and not intended to determine commercial production potential, the systematic coverage, which included documentation of habitat along with distribution and relative abundance by species, provided solid background for ensuing explorations. Additional information came from monitoring Japanese Bering Sea fisheries as well as from incidental catch data on observations of domestic commercial fisheries. The first major exploratory fishing expedition, the Alaskan king crab investigation of 1940-41, was an effort to study the resource and demonstrate feasibility for a domestic king crab fishery in the Bering Sea where Japanese floating canneries and fishing vessels had operated since about 1930. The following paragraph from the investigative report illustrates the level of concern at that time and sets forth initial reasoning for involving national government in such work:

"Increasing (exploitation) of a crab fishery by foreign nationals in water immediately adjacent to United States territory for subsequent export to the United States, raised serious question as to whether American interests were making adequate use of domestic fishery resources. Accordingly, early in 1940, the President requested the Secretary of the Interior to investigate the practicability of establishing an American king crab canning industry in Alaska. Initial inquiry indicated that lack of information regarding areas of abundance, methods for taking and canning king crab, and a general fear of not being able to compete with the imported product on a cost basis were the primary obstacles retarding domestic development. Since the cost of necessary exploratory work would be prohibitive for private enterprise under conditions then prevailing, the Congress authorized the Fish and Wildlife Service to make the study."

Roger Harrison, then in charge of the Seattle Technological Laboratory, USFWS, was overall supervisor of the investigation. Carl Carlson, Fishery Engineer, took leadership and documentatian roles in regard to vessels, on-board processing and fishing systems, and exploratory fishing. Carlson thus became the first USFWS exploratory fishing and gear specialist. He served in a similar capacity with several subsequent expeditions during the 1940s. Other investigative staff members included four fishery biologists--Arthur Hvatum, Camile Pertuit, Waldo Schmitt, and Marvin Wallace; a fishery economist--Leroy Christey; and a fishery technologist--Joseph Puncochar. Schmitt was on detail from the Smithsonian Institution where he was Curator of Marine Invertebrates. The expeditionary fleet included the cannery vessel, Tondeleyo (Capt. Arthur

Nelsen), the first year only; the fishing vessel, Dorothy (Capt. Ellsworth Trafton), both years; and the fishing vessels, Locks (Capt. Harry Guffey) and Champion (Capt. Anders Nilsen), the second year only.

The survey spanned thousands of miles, all the way from southeastern Alaska, around the perimeter of the Gulf of Alaska, through the Bering Sea, "to within sight of Siberia" (near St. Lawrence Island). A large king crab population was described in the Bering Sea near Alaska Peninsula, while smaller but substantial concentrations were noted in Pavlof Bay and Canoe Bay on the south side of the peninsula, around Kodiak Island, and in lower Cook Inlet. A comprehensive report was published as a Special Number Supplement to Fishery Market News in May 1942, just 8 months after completion of field work. The report was enhanced by four detailed appendices: 1) log of fishing operations, 2) fishing gear specifications, 3) description of canning operations, and 4) review of Japanese Bering Sea king crab fishery. The timeliness of publication plus the fishing log and fishing gear specifications became continuing features of EF&GR reporting. Since commercial type and scale otter trawls were the chief survey gear, a wealth of information on groundfish potential availability was collected. The report calls attention to "...an enormous reserve of edible fish--notably sole and pollock--which is at present wholly unutilized."

In 1945 with the above findings in mind, the War Food Administration recommended conversion of an ocean-going vessel into a factory ship and construction of five combination fishing vessels to supply it with otherwise unutilized raw materials needed to help overcome the wartime shortage of meat protein. At the end of World War II that same year, a decision was made by the Director, the War Mobilization and Reconversion Board, to complete conversion of the 410 ft. long cargo/factory/mother-ship, Pacific Explorer, and construction of four of the fishing vessels: Alaska, California, Oregon, and Washington. The work was funded under the Reconstruction Finance Corporation (RFC) which designated the Pacific Exploration Company (PEC) as its agent for construction and operation of the fleet. The vessels were leased to PEC at $50,000 per year plus 55% of the profits. To assure maximum economic, technical, and scientific benefits to the Government and the domestic fishing industry--provision was made for Government representatives to accompany the vessels and publish reports on their observations. The first of the PEC vessels to engage in a combination production/exploration/research operation in the northeast Pacific and Bering Sea was the Alaska in 1947 with Joseph King, Aquatic Biologist, Branch of Fishery Biology, USFWS, on board to observe and record operations. After a shakedown cruise as a tuna receiving ship off Costa Rica in 1947, the SS Pacific Explorer (along with 10 chartered catcher vessels: Bear, Borris, Dorothy, Foremost, Jeannette F., Kiska, Mars, Pearl Harbor, Sunbeam, and Tordenskjold) processed and packed king crab and groundfish in the spring of 1948. Norman Wigutoff, Fishery Marketing Specialist at the Ketchikan Fishery Products Laboratory, and Carlson, then Chief, Section of Exploratory Fishing, Pacific Ocean Fishery Investigations (POFI) at Honolulu, participated in and reported on operations. The Alaska and Oregon, respectively, rigged for purse-seine and live-bait fishing, prospected for western Pacific tuna in 1948 with O. R.

Smith and M. B. Schaefer of POFI on board as observers.

Studies relevant to the northeast Pacific Ocean and Bering Sea fisheries development, in addition to king crab-groundfish investigations occurring prior to initiation of Exploratory Fishing and Gear Development Section operations in 1948, included shrimp explorations sponsored by the Alaska Fisheries Experimental Commission (AFEC) in 1944 to determine "...commercial possibilities of shrimp resources in certain southeastern Alaska areas..." and in 1945 a shoreside survey to acquire input from local residents regarding possibilities for fisheries development in the Nome area. A similar shoreside survey in 1949 covered the rest of Seward Peninsula plus other areas around Kotzebue Sound as well as certain rivers and lakes in western Alaska. The AFEC was created by the Territory of Alaska "...to perform technological research and conduct studies to develop the fisheries of Alaska." The Ketchikan Fishery Products Laboratory was jointly supported and shared by AFEC and USFWS. Commission members in 1944 were Governor Ernest Gruening, Chairman; John Mendenhall, Secretary; and Lyle Anderson, Technologist in Charge, Fishery Products Laboratory. The 1944 shrimp survey was directed by Carlson, Fishery Engineer, on detail from the Seattle Fishery Technological Laboratory. Carlson and A. W. Anderson, Chief of the Branch of Commercial Fisheries at the time, did the 1945 personal-contact survey in the Nome area--while Wigutoff and Clarence Carlson, USFWS, Fishery Marketing Specialist, and AFEC Chemist, respectively, at the Ketchikan Fishery Products Laboratory, made the more extensive western Alaska shoreside-interview survey in 1949.

NORTH PACIFIC EF&GR, 1948-60

By 1947 it was apparent that an exploratory fishing and gear development unit was to be set up shortly. During 1948, exploratory fishing and gear development activities were initiated within the Seattle Technological Laboratory under Maurice Stansby. The aim was to organize a working group that would be ready to operate on the Pacific Coast as soon as the new activity could be developed. Funds totaling $92,680 were made available to the Laboratory for exploratory fishing operations on 1 July 1948.

The Washington, one of the PEC catcher vessels, was transferred to the Seattle Laboratory in July 1948 to be used in the new exploratory fishing project. The Washington made a 2-month trip to the Bering Sea, leaving Seattle on 23 August. Aboard on this trip--later designated as Exploratory Cruise (Expl. Cr.) No. 1, North Pacific Fisheries Exploration and Gear Research--were Joseph Ellson, fishery engineer, later named Project Leader for the new Exploratory Fishing Project at Seattle; Boris Knake, fishery engineer, temporarily detailed to Seattle from the Bureau's program in Boston; John Dassow, chemist, Seattle Technological Laboratory; and the vessel crew under Capt. Edwin Hansen. Late in 1948 it was decided that the Washington was not suitable for the kind of work needed and was sold for $150,000. This money was applied towards construction of a new research vessel, the John N. Cobb.

Although construction planning for the John N. Cobb consumed considerable staff time, two more exploratory fishing cruises were completed in 1949--Expl. Cr. No. 2, a Bering Sea king crab and groundfish survey, was

conducted aboard the 140-ft charter vessel, Deep Sea. The Deep Sea, designed especially for king crab fishing and processing, was built and operated under terms of the RFC. She was operated by Wakefield Fisheries, a pioneer large-scale king crab producer in western Gulf of Alaska and the Bering Sea. The vessel's crew included Capt. William Blackford and Mate-Fisherman Jose Franco. Franco also later served as Mate-Fisherman and Captain of the John N. Cobb. Ellson, Donald Powell (Seattle-based fishery engineer) and Henry Hildebrand (fishery research biologist, Branch of Fishery Biology) were aboard to direct and document operations. Expl. Cr. No. 3, with the former PEC vessel, Oregon, was designed to determine distribution of albacore tuna during its summer migration off Oregon, Washington, and British Columbia with Powell and Hildebrand aboard.

The Oregon later became the service's exploratory fishing and gear research vessel in the Gulf of Mexico and western Atlantic Ocean, operating out of Pascagoula, Mississippi. After being replaced by the new and larger Oregon II in the mid 1960s, the Oregon was returned to the Northwest in 1969 where she participated in Gulf of Alaska and Bering Sea explorations and resource assessment operations until finally being decommissioned in 1980.

During 1949, work was also underway in Seattle to develop an Exploratory Fishing Unit for a new laboratory in Honolulu, which was to conduct a program then known as the Pacific Oceanic Fishery Investigation (POFI). Carlson and another fishery engineer, Thomas Roseberry, were stationed in Seattle during 1948 making preparations for fishery engineering work in the POFI program as soon as the Honolulu laboratory building was completed. The exploratory fishing program operated there for only about 2 years, however, before being discontinued.

Late in 1949 the Seattle Exploratory Fishing Project was officially transferred from the Technological Laboratory to function as a separate entity. It remained under the local supervision of Ellson, who reported to the Section of Exploratory Fishing, under Richard Whiteleather, in the Washington, D.C., office.

Individuals serving as Chief, North Pacific Fisheries Exploration and Gear Research, 1949-71, were as follows:

1949 to 1950....Joseph Ellson
1950 to 1951....Donald Powell
1951 to 1955....Joseph Ellson
1955 to 1958....Donald Powell
1958 to 1968....Dayton Alverson
1969 to 1971....A. T. Pruter

Activities, 1948-60

Thanks to the anticipatory actions, the Seattle exploratory fishing program was in full swing with three cruises completed by its official starting date in 1949. The John N. Cobb, designed specifically for exploratory fishing and gear development, was under construction and nearly complete. After it was commissioned in February 1950, full operations were possible with the vessel's shakedown cruise to southeastern Alaska for shellfish explorations in March and April, designated Expl. Cr. No. 4.

The North Pacific Fisheries Exploration and Gear Research Program developed information on resource distribution, abundance, and catchability of latent fish stocks. Segments of the fishing industry considering expansion or diversification expressed need for such

information and their recommendations helped establish goals, priorities, and schedules. Significant contributions through the 1950s led directly to new or expanded fisheries on continental shelf-slope stocks of groundfish, crab, and shrimp from waters off Oregon and Washington, around the Gulf of Alaska, and into the Bering Sea.

Fishing methods and equipment were often designed, fabricated, modified, tested, and/or evaluated in conjunction with exploratory fishing operations. Significant improvements introduced in early years included a power roller to haul tangle nets; a tension block to dampen the shock of albacore hitting fast trolled lures; floating traps, gillnets, and longlines for high-seas salmon assessment; tags for tuna, salmon, and other fish; migration studies; and Gulf of Mexico-type shrimp trawls. Eleven of the John N. Cobb's first 41 cruises were devoted to studies of fishing methods and equipment--seven to midwater trawling, two to a fish pump device, and two to bottom and shrimp trawling.

Midwater trawling was emphasized because of the mounting evidence of large unused pelagic fish stocks such as northern anchovy, Pacific herring, Pacific saury, walleye pollock, Pacific whiting (hake), and various rockfish that were not available to conventional fishing systems. Aimed trawling was considered necessary to effectively assess and economically harvest such resources. The high-volume Pacific whiting and walleye pollock fisheries which have developed in the northeast Pacific and Bering Sea since the late 1950s proved these projections to be correct.

Groundfish Explorations

Explorations, led by Dayton Alverson along the continental shelf and slope off Oregon and Washington, located previously unknown trawling areas and concentrations of rockfish, "soles," and sablefish (black cod) during 1951-52. Other significant groundfish explorations took place in the 1950s on the continental shelf around the perimeter of the Gulf of Alaska from Dixon Entrance to Unimak Pass. Led alternately by Ellson, Edward Schaefers, Keith Smith, Melvin Greenwood, and Harold Johnson, about 10 cruises involving groundfish revealed extensive trawlable areas and latent stocks of fish--mainly rockfish and walleye pollock. At that time, domestic fisheries were not able to utilize these limited-value species from such remote grounds, but near the end of the decade large Soviet and Japanese trawl fleets appeared and fished them heavily for nearly 20 years. Only recently, thanks to the Magnuson Fishery Conservation and Management Act (FCMA) of 1976 and availability of the large combination crabber-trawler vessels, domestic fisherman have entered joint-venture operations to produce these fish in huge quantities for processing at sea aboard foreign factory ships.

Shrimp Explorations

Incidental-catch and stomach-content data consistently pointed to a bigger shrimp resource than was evidenced by production results through the mid 1950s. Researchers and fish producers agreed to the importance of shrimp explorations, and 11 of the John N. Cobb's first 23 cruises during 1950-56 included major efforts to locate commercially significant concentrations of shrimp. Most of these cruises,

including her first cruise, were headed by Schaefers with support from Ellson, Robert Livingston, Smith, Greenwood, and Johnson. A breakthrough which occurred in 1956 was the introduction of a Gulf of Mexico-type shrimp trawl which proved far more effective for taking the relatively small pandalid pink shrimp found in the northeastern Pacific Ocean and Bering Sea than were the beam trawls and small-mesh otter trawls used previously for research and commercial production. Catches of about 1,000 lb per 30-minute trawl off the Washington coast stimulated high interest in establishing a new industry in the Grays Harbor and Willapa Bay areas.

Following a successful experiment on processing shrimp from Washington at a Gulf of Mexico plant (arranged by the Seattle and Pascagoula, Mississippi, Technology Laboratories), shrimp peeling machines were introducted to the Pacific coast in 1956. These were capable of handling the very small shrimp (100 to 200 heads-on count) in profitable quantities. Unfortunately an economic boom-and-bust developed in the Grays Harbor-Willapa Bay area and ran its course over a 2 year period. With more than 20 peeling machines operating, fishermen quickly reduced the shrimp population until catch rates fell to unprofitable levels for both vessels and plants.

In the interim, however, shrimp surveyors with the Gulf trawls off the south shore of Alaska Peninsula and in the Cook Inlet-Kodiak Island area located even heavier and more extensive concentrations. In 1957, average catch rates by the charter trawler Tordenskjold in five separate areas around the Shumagin Islands ranged from 1,100 to 5,900 lb per hour. In 1958, catches of 900 to 3,500 lb per hour were taken by the John N. Cobb in the lower Cook Inlet and Kenai Peninsula areas; during the same cruise, catch rates frequently exceeded 2,000 lb per hour in the Kodiak Island-Shelikof Strait area. Shrimp processing facilities were soon set up in Seldovia, Kodiak, and Sand Point where some of the excess Grays Harbor machinery was used. Four cruises off Washington and Oregon in 1958 found new concentrations of shrimp which helped stabilize commercial endeavors based at Grays Harbor and Willapa Bay, Washington, and Warrington, Oregon. The 1957-58 Alaska and Washington-Oregon surveys were led alternately by Alverson, Greenwood, Johnson, and Fred Wathne.

Shrimp production in Washington and Oregon increased from nearly zero in 1956 to about 3 million lb in 1957 and more than 9 million lb in 1958. In Alaska production rose from a maximum of about 2 1/2 million lb per year through 1957 to 8 and 13 million lb in 1958 and 1959, respectively. Alaska shrimp production climbed steadily to about 48 million lb in 1969 and 128 million lb in 1976. Washington-Oregon production ranged from 2 to 35 million lb per year during the 1960s and 1970s.

Alaska Crab Explorations

Although no cruises were dedicated exclusively to crab explorations in the 1950s, king crab and snow (Tanner) crab were caught regularly in commercially significant quantities in the bottom trawls, shrimp trawls, and crab pots fished in 1954 and during 1956-59. Gulf of Alaska explorations were carried out from the John N. Cobb and the Tordenskjold. This information along with that obtained during the original king crab expeditions provided basic distribution data that helped the fishery develop. Prior to 1950,

domestic Alaska king crab production had never exceeded 1 1/2 million lb. The yield passed 5 million lb in 1957, 10 million in 1958, 25 million in 1960, and a peak of 159 million in 1966. Snow crab production, virtually non-existent through 1961, reached 61 million lb in 1973.

Albacore Tuna Explorations

The summertime abundance, distribution, and availability of albacore tuna from off Northern California to off southeastern Alaska was studied annually during 1949-52 and in 1956. The purpose was to find reasons for variations affecting year-to-year productivity of commercial fishing. Under Powell and/or Schaefers, an area up to 800 mi offshore was covered with various fishing and environmental monitoring systems. When conventional tags (used for migration studies) appeared unsuited to the fast swimming tuna, Alverson conducted tests in the University of Washington hydraulics laboratory where ribbon-like streamer tags were found to last longer at selected rates of flow. Specific reasons for year-to-year changes in abundance and distribution were not pinpointed. The only consistent environmental factor was that no albacore were found in waters colder than 57°F. Since no way was found to predict the probability of commercially significant concentrations of fish in advance, fishermen armed only with the 57°F minimum temperature information became accustomed to prospecting each year.

Cobb Seamount

In 1950, during the John N. Cobb's second cruise, a previously uncharted sea mount was located 270 miles west of Willapa Bay. Subsequenty named Cobb Seamount, it rises from the 1600-fm deep-ocean floor to within 22 fm of the surface.

High-Seas Salmon Assessment Survey and Gear Development

In connection with missions of the International Convention for High Seas Fisheries of the North Pacific Ocean and its successor agency, the International North Pacific Fisheries Commission, EF&GR personnel participated in a high-seas salmon survey off both sides of the Aleutian Islands in 1953, in the Gulf of Alaska in 1955, and south of the Gulf in 1956. The John N. Cobb, operating alone in 1953, fished experimental gillnets, longlines, and a floating trap to compare effectiveness and selectivity for taking the five northeast Pacific salmon species and steelhead trout. In 1955 she was one of three vessels fishing standardized gillnets and longline gear and took salmon as far as 400 miles offshore. This vessel also took part in a multi-vessel operation in 1956 where her assigned area included the previously explored summer albacore grounds off northern California, Oregon, Washington, and British Columbia. Both salmon and albacore were taken but never at the same location. Schaefers and Francis Fukuhara of the Branch of Fisheries Biology shared leadership in 1953, and Schaefers and Powell alternated as Field Party Chief in 1955 and 1956.

Chukchi Sea Baseline Study

In connection with the Atomic Energy Commission's Project Chariot (a proposal to use nuclear force to create a harbor near Point Hope), an expedition headed by Alverson aboard

the John N. Cobb inventoried marine organisms in southeast Chukchi Sea in 1959. Richard McNeely was also on board, as were Albert Sparks, Walter Pereyra, and other scientists from the University of Washington.

Miscellaneous Explorations

Other explorations during the 1950s involved abalone, herring, and scallop in Alaska. Livingston investigated the commercial potential of abalone in the lower outer islands of southeastern Alaska in 1951. The maximum of only 40 lb found by the hired professional hard-hat Alaska salmon trap diver was considered insufficient to be of commercial interest.

Two John N. Cobb cruises led by Lawrence Kolloen, Branch of Fishery Biology, and Smith were designed to determine the availability of herring in late fall and winter; these were conducted in southeastern Alaska in 1952 and in Prince William Sound in 1953. Neither endeavor produced commercially significant catches, but they did provide valuable life history information. A scallop dredge was operated during one cruise off Washington and portions of other cruises in the Gulf of Alaska during the 1950s without finding concentrations large enough to sustain commercial operations.

Fish Pump Experiments

Initial dedicated gear research work began in 1952 with the first of two efforts to develop a system to attract and pump fish such as herring directly from the sea onboard fishing vessels. Ellson was in charge of the first trials. In 1954 the second effort was led by Smith, who added a pulsed electric field to the light attraction/pumping system. This was moderately successful with average catch rates of more than 40,000 small herring per hour. However, this work was never pursued because other systems, such as seines and traps, proved to be more efficient for herring.

Midwater Trawl Development

Starting in 1954 with testing of the Swedish Phantom Trawl, the base became intensely involved with midwater trawl (MWT) development and evaluation. These tests demonstrated the need for accurate net depth monitoring. Cable length-cable angle tables provided with the Phantom Trawl provided only rough estimates in shallow sets and were virtually useless in deeper sets. Two years later, in 1956, Reidar Sands and McNeely from the BCF Gear Research Station at Coral Gables, Florida, participated in the second MWT development cruise. The acoustic-link depth telemeter developed at Coral Gables was used successfully to monitor net depths. McNeely was transferred to Seattle later that year to head up the MWT development effort. By 1960, the acoustic-link telemeter had given way to a direct-wire system (through the trawl cable). Both systems employed pressure potentiometers to indicated depth. Several MWT nets tried during the late 1950s produced large catches (mainly Pacific whiting and rockfish) infrequently.

SCUBA Diving Team

The Base acquired its first SCUBA (Self-Contained Underwater Breathing Apparatus) diving team in early 1959. Greenwood, Peter Larsen (Mate/Fisherman aboard the John N. Cobb at that time),

McNeely, and Wathne were trained by the diving unit at the U.S. Navy's (USN) Freeport Torpedo Station. Several of the Navy divers, including their leader Chief Robert Sheats, later participated in fishing gear research operations. During 1959 and 1960, the diving team became familiar with performance characteristics of groundfish trawls, shrimp trawls, and midwater trawls through direct observations from a towed diving sled or while swimming free and hanging on to various parts of the nets. As a matter of interest, in the spring of 1959, Reader's Digest published an account of how Chief Sheats and other USN divers, who while prisoners during WWII, managed to delude their captors about the location of the Philippine's silver treasure which had been scuttled in Manila Bay for safekeeping during the Japanese occupation.

U.N. Fishing Gear Congress

Sponsored by United Nations' Food and Agriculture Organization, the first International Fishing Gear Congress was held in Hamburg, Germany, in October 1957. Two papers by Base personnel were presented--"A Practical Depth Telemeter for Midwater Trawls," by McNeely and "Correlation of Midwater Trawl Catches with Echo Recordings from the Northeast Pacific," by Schaefers and Powell. Alverson, with the Washington Department of Fisheries at this time, also presented a paper entitled "Trends in Trawling Methods and Gear on the West Coast of the U.S."

During the first half dozen years or so, Seattle exploratory fishing and gear specialists continued with the designation Fishery Engineer. In the mid 1950s this was changed to Fishery Methods and Equipment Specialist for virtually everyone. Not until the early 1960s did position titles reflect the nature of work performed and responsibilities, such as: Electrical Engineer, Electronic Scientist, Fishery Biologist (Research), Fishery Biologist (Supervisor), etc.

Notes on Departing Personnel, 1948-60

Scientific and technical personnel employed at the Seattle EF&GR Base, 1948-60, are listed in the accompanying tables. Following are brief accounts of those leaving federal service or transferring to other positions.

Ellson, the first Base Director, went to Washington, D.C., for about 1 year (1950-51) as Chief of the Exploratory Fishing Section. Upon returning to Seattle, he assumed the position of Base Director another 4 years before leaving federal service to work in the Alaska salmon industry.

Powell spent 4 years (1951-55) in Washington, D.C., first as Assistant Chief and then as Chief of the Exploratory Fishing Section. In 1958, after 3 years as Base Director, he was promoted to Deputy Director, Northwest Region, BCF. To the dismay of his many friends, Powell succumbed to cancer just a few years later.

Alverson left the Base in 1952 for about 6 years to direct groundfish research in the Washington State Department of Fisheries. He returned to take over as Director of the Base in 1958.

Schaefers was promoted to Deputy Chief, Branch of Exploratory Fishing, BCF headquarters, in 1958. During 13 years in the central office before returning to NWAFC, he held increasingly responsible positions in the Branch, Division, and Director's offices

including: Acting Chief of Exploratory Fishing Branch; Deputy Assistant Director, Division of Industrial Research and Services; Deputy Assistant Director for Utilization and Engineering; and Special Assistant to Associate Director for Fisheries. Responsibilities beyond program management included leadership in the design and construction of the BCF research vessels: the Miller Freeman, Albatross IV, David Starr Jordan, Oregon II, Townsend Cromwell, Delaware II, and Kaho plus conversions of several Navy ships. Schaefers served on the U.S. Coast Guard Industry Advisory Committee on Rules of the Road; and on the Fishing Vessel Safety Sub-Committee, Department of State Shipping Coordinating Committee, for the Safety of Life at Sea Convention, Intergovernmental Maritime Consultative Organization (IMCO), United Nations. During his second tour of duty at NWAFC, 1971-81, he was Special Assistant to the Director and Deputy Director.

Livingston transferred to the groundfish research program at the BCF Fisheries Laboratory in Woods Hole, Massachusetts, in 1951.

Smith was promoted in 1955 to Chief, EF&GR Station, Boothbay Harbor, Maine, a subsidiary of North Atlantic Fisheries Exploration and Gear Research, Boston, Massachusetts. He later became Director, EF&GR Base, Northeast Region, when it was consolidated and moved to Gloucester, Massachusetts. After the national reorganization in 1969, Smith held several positions including Fishery Management Council liaison at Woods Hole until his retirement in 1980. In addition to his contributions at Seattle, he led fishing system R&D as related to groundfish electro-trawl, Maine sardine air-curtain, and pot gear for deepwater lobster and red crabs. The 156 ft Delaware II was designed and built while Smith was Base Director.

Greenwood was promoted to Director, EF&GR Base, Great Lakes and Inland Region, in 1960. Headquartered in Ann Arbor, Michigan, the Base included field stations at Erie, Pennsylvania; Sangatuck, Michigan; Mobridge, South Dakota; and Kelso, Arkansas. Under Greenwood's direction for 10 years, the unit was involved in assessment of latent fish stocks of the Great Lakes and the large reservoirs of the Mississippi, Missouri, and Ohio river systems. The proof of availability of latent fish stocks for lengthy periods to one or a combination of fishing methods helped the Great Lakes industry adjust to the violent changes in species composition triggered by the sea lamprey invasion and facilitated introduction of new fisheries in several reservoirs. A unique fishing gear research and development program helped the new farm pond channel catfish industry eliminate prohibitive harvesting costs. This industry and the Lake Michigan alewife fishery have each produced about 50 million pounds of fish annually since the late 1960s.

In 1970, Greenwood transferred to Washington, D.C., where he held positions as Acting Chief, Division of Exploratory Fishing; Chief, Division of Resource Technology; and Assistant for NMFS Support to Associate Director for Fleet Operations, National Ocean Survey, before being transferred back to NWAFC in 1976. He, too, served on the U.S. Coast Guard Industry Advisory Committee on Rules of the Road and the IMCO Fishing Vessel Safety Sub-Committee, plus the Environmental Sciences Advisory Committee of the Washington (D.C.) Technical Institute.

Wathne transferred to the BCF Gear

Research Station at Panama City, Florida, in 1960, where he participated in research on an electro-fishing system for shrimp before transferring to the central office of exploratory fishing in 1965. In 1967, he left federal service for 5 years to work for the Fishery Development Unit of the United Nations' Food and Agriculture Organization (FAO). Upon completion of that assignment, he returned to NWAFC in 1972.

Through 1958, all administrative, secretarial, and other support services were provided by the able group headed by Patricia Terao, which served both the technology and exploratory fishing units. In 1959, Wilma Abbey became the first secretary to work exclusively for exploratory fishing.

NORTH PACIFIC EF&GR, 1960-70

During the 1960s, the program was adjusted to meet the requirements of an agency reorganization, the state of our knowledge of latent resources, and new political-social-scientific-economic situations. The name of the unit became Exploratory Fishing and Gear Research (EF&GR) Base, Northwest Region, subsequent to the Fish and Wildlife Reorganization Act of 1958. Through the 1960s, a major part of operations, in addition to general exploratory fishing, concerned a study of the effects of changing environment upon fish, especially as related to atomic energy activities. Also, new technology led to world-wide efforts to develop electronic counting systems for pelagic and near-bottom fish. Explorations during the 1960s were often combined with gear development work, especially on MWTs for Pacific whiting and other off-bottom species and on fish traps for sablefish.

Bioenvironmental Baseline Studies

The Atomic Energy Commission (AEC) funded studies designed to measure the effects of their projects on the marine environment and organisms, including fish. Following Project Chariot in the Chukchi Sea, AEC funded a study near the mouth of the Columbia River to determine potential changes in fish populations caused by discharge into the ocean of water containing trace amounts of radionuclides. These substances originated from cooling water systems used by nuclear plants at Hanford, Washington. A monitoring program was continued throughout the 1960s until most of the reactors were shut down. Many Base staff members, led alternately by Hiromu Heyamoto, Pruter, and Pereyra, participated in the study, which required surveys with bottom trawls and other sampling equipment several times a year.

The only operations conducted by the Seattle base north of British Columbia in the 1960s were two groundfish surveys by the John N. Cobb in 1961-62 between Cape St. Elias and Kodiak Island. Robert Hitz, Johnson, and Pruter led these expeditions. In 1963 an exploratory fishing and gear research base was established at Juneau to serve the Alaska Region.

Groundfish Explorations

More than 10 groundfish surveys along the Pacific coast, plus the AEC related work off the Columbia River, succeeded in 1) locating clear trawling areas on grounds previously avoided by commercial fishermen, 2) finding fishable concentrations of dover and petrale sole plus Pacific ocean perch

and other rockfish, and 3) defining the bathymetric distribution of sablefish. This work was led at various times by Pruter, Heyamoto, Johnson, Hitz, and Lael Ronholt.

Pelagic Explorations and Fishing Gear

Refined definition of the large Pacific whiting resource, improvements in midwater trawling systems, and growth of the Soviet trawl fishery off the West Coast in the mid 1960s created a dilemma regarding development of a domestic Pacific whiting fishery. Despite a substantial effort which included building a new fish meal plant in Aberdeen and operation of a 10-boat fishing fleet, a combination of low prices, the effect of the Soviet trawl fleet on fish distribution, and other more lucrative opportunities for vessels created an unprofitable situation. Since 1977, however, substantial domestic Pacific whiting production has been experienced thanks to the protective effect of the 200-mile fisheries conservation zone of FCMA plus the advent of joint-venture fisheries in which foreign factory ships are allowed to buy fish directly from U.S. fishermen at sea. McNeely, Leonard Johnson, Hitz, Miles Alton, and Martin Nelson all played important roles in this work.

The Base, in cooperation with the University of Washington, established national and international credibility in the field of electronic in situ fish counting using quantitative echo signal processing systems.

Pelagic species other than Pacific whiting, such as northern anchovies and Pacific saury, have been investigated for commercial potential. Under the direction of McNeely and many others, attracting lights, lampara seines, small mesh midwater trawls, and low-light-level image intensifiers were used with only moderate success.

By the end of the decade, Pacific whiting assessment was supplemented with special winter surveys of eggs, larvae, and juveniles off southern California and northern Mexico in cooperation with the NMFS Southwest Fisheries Center at La Jolla, California.

Shrimp Explorations and Gear

Few cruises during the 1960s were of an exploratory nature because more effort was being devoted to developing a system to reduce the incidental catch of small fish in shrimp catches. Elimination of on-deck sorting increases efficiency, especially with small catches which contain a higher percentage of fish. Jerry Jurkovich, Ian Ellis, William High, and others participated in this work.

A vertical shrimp sampler was designed and used with great success. These experiments verified the phototrophic effect of ambient light on shrimp. Not only do shrimp spread upward through the water column at night and concentrate near the bottom during daylight, but the distribution of shrimp in the water column is also affected by cloud density.

Relatively effective separator trawl nets were developed, but the industry was reluctant to use them due to complexities of rigging and operation of the gear.

Sablefish Explorations and Gear

Regular groundfish explorations and deepwater trawling during the AEC study

revealed a sizeable deepwater sablefish population off Washington, Oregon, and northern California. The largest and most abundant specimens were at depths beyond the capacity of most domestic trawlers. Since sablefish had been observed to readily enter king crab pots used in Alaskan waters, it was decided to try to develop a trapping system to effectively catch this species. This work was begun in the late 1960s by Fred Hipkins and Steven Hughes, but the bulk of the development of this fishery took place in the early 1970s.

Participation in International Decade of Ocean Exploration (IDOE)

The unit participated in two IDOE projects, funded by the National Science Foundation (NSF). In 1963, Pruter, Pereyra, Ivan Fjaerestad, and Arne Leren of the Seattle Base together with A. K. Larssen, a well known commercial fisherman and gear expert, participated in the International Indian Ocean Expedition. They were responsible for carrying out trawl surveys in the Bay of Bengal and Arabian Sea from the NSF research vessel Anton Bruun. Alton, Kenneth Waldron, and Ellis directed exploratory fishing operations with groundfish trawl, Blake trawl, and longline gear from the Hero for Antarctic Resources Investigation, under the auspices of the NSF.

Second World Fishing Gear Congress

The second fishing gear conference sponsored by the U.N. was held in London, England, in May 1963. Two papers by Seattle personnel included: "Development of Cobb Pelagic Trawl," by McNeely and "Prospective Developments in the Harvesting of Marine Fishes," by Alverson and Norman J. Wilimovsky.

ALASKA REGION EF&GR

Increasing need for information by the fishing industry in southeastern Alaska prompted the establishment of an EF&GR Base in Juneau, Alaska, in 1960. Although operated through the BCF Alaska Regional Office, close working associations were maintained between the Juneau EF&GR staff and their Seattle counterparts. Their mutual interests in developing Alaska fishery resources soon resulted in the continuation or expansion of exploratory activities started earlier by Seattle personnel and in joint Juneau-Seattle surveys.

Groundfish explorations

From 1960 to 1967, five exploratory surveys along the continental shelf off southeast Alaska succeeded in 1) finding sizable commercial concentrations of Pacific ocean perch and other rockfish, 2) locating trawlable bottom areas in offshore regions from Sitka to Cape Ommaney, and 3) exploring waters of the inside passage for sablefish. Charles Connelley, the first EF&GR Base Director, initially led this work. Other persons involved in groundfish exploratory surveys included Ronholt, Serge Astrahantseff, and Robert Wolotira. The latter two worked jointly with Hitz and Norman Parks of Seattle EF&GR in developing an extensive trawl survey atlas for Alaskan waters which incorporated information on catches, fishing locations, and bottom trawling success for BCF-NMFS exploratory surveys from 1948 through the 1970s.

Shrimp explorations

The 1960s was a pivotal time period for locating and developing new shrimp fishing grounds in Alaska. The Juneau EF&GR Base undertook six trawl surveys to locate potential shrimping grounds from Prince William Sound to the eastern Bering Sea. The most important regions identified for the shrimping industry included several areas off Kodiak Island, the Alaska Peninsula, and the Shumagin Islands. These locations were destined to soon produce a peak annual harvest of over 120 million lb of shrimp. These exploratory surveys were led by Warren Rathjen, Mitsuo Yesaki, and Ronholt. Shrimp gear development work (including studies of plumb staff beam trawls for small boats, shrimp fish separator trawls, and high opening shrimp trawls) were led by Yesaki and Larssen.

Extensive EF&GR work was also undertaken in locating stocks of prawns or spot shrimp in southeastern Alaska and developing effective shrimp pots. From 1965 to 1968, nearly every bay and passage from Dixon Entrance north to Glacier Bay was test fished and small commercial fisheries were developed out of Ketchikan, Sitka, and Wrangell. Ronholt and Doyne Kessler were substantially involved in this work.

Scallop explorations

In the early 1950s, shellfish surveys by the John N. Cobb, and other work by BCF and the International Pacific Halibut Commission, aroused interest in Alaska scallop resources. In 1963, Rathjen led an EF&GR survey aboard the John R. Manning in the eastern Gulf of Alaska near Yakutat Bay for an initial effort to delineate the extent of several scallop beds. When a downturn in the U.S. East Coast scallop industry occurred in the late 1960s, the John R. Manning survey took on renewed importance. In 1968 and 1969, EF&GR Juneau, in cooperation with the Alaska Department of Fish and Game (ADFG), performed extensive exploratory surveys of scallop stocks from Cape Spencer in southeast Alaska, around the entire rim of the Gulf of Alaska to Unimak Pass and the Aleutian Islands. Gerald Reid and Ronholt led this scallop work.

Personnel Notes, 1960-70

Scientific and technical personnel employed in the unit, 1960-70, are listed in a table. Connelley, the first person associated with the Juneau EF&GR Base, left the federal government in 1961 to work in private industry.

Rathjen left Juneau in 1964 to accept a series of assignments with the U.N. FAO in Barbados, British West Indies, and other Carribbean locations (1965-69), rejoined NMFS in Gloucester in 1969, and is now associated with fisheries development on the East Coast.

Benjamin Jones' background in the fishing industry assisted in the development of new fisheries in regions in and out of Alaska. In 1968, he was detailed to a U.S. State Department program to investigate the potential for developing sustained fisheries in numerous Third World countries in Africa, Southeast Asia, and South America. Jones joined the Juneau EF&GR Base in 1964 and departed in 1970 to join the FAO and direct their marine fisheries development program in Brazil. He was involved with South American fisheries programs until 1977 when he returned to the Center and joined the RACE Division staff.

Yesaki left the Juneau EF&GR staff in 1967 to pursue an extensive career in

fisheries development for the FAO. From 1968 to the present, he has been with fish and shellfish programs for developing nations around the world, from Central America to Brazil, to the Middle East, the Indian Ocean, and south China Sea.

RESOURCE ASSESSMENT AND CONSERVATION ENGINEERING DIVISION, KODIAK LABORATORY

The Center's Kodiak Facility was formed in 1970 when the Juneau EF&GR Base and Ketchikan Food Technology Laboratory were transferred to Kodiak under an Associate Regional Director for Fisheries. This change in location provided opportunities for closer contact between these two segments of BCF (NMFS) fisheries research and development and Alaska's seafood industry. Soon thereafter, the Kodiak facility formally became part of the NWAFC and the EF&GR Base staff became part of the Center's Division of Marine Fish and Shellfish (the forerunner of RACE). At that time, programs underway at Kodiak included Gulf of Alaska and Bering Sea groundfish work, Bering Sea crab assessment, and Gulf of Alaska shrimp assessment and gear development. By 1973, efforts were made to consolidate various aspects of the Center's resource assessment activities. This consolidation resulted in Kodiak's groundfish and gear development activities being transferred to Seattle and the establishment of Kodiak as the focal point of the Center's shellfish resource assessment mission.

During the 1970s, much of Kodiak's assessment effort concentrated on identifying the magnitude and geographic extent of shrimp stocks in the western Gulf of Alaska. Numerous surveys during 1970 through 1974 occurred from Prince William Sound to Castle Cape on the Alaska Peninsula with most efforts concentrated around Kodiak Island. This work was under the direction of Ronholt and included substantial cooperative efforts with the ADFG as well as some of the Center's earliest joint U.S.-U.S.S.R. scientific investigations.

The time period of the mid 1970s marked a shift in regional effort for shrimp assessment to the Alaska Peninsula and Shumagin Islands. Shortly after NMFS shrimp surveys were started in these regions, an extensive commercial fishery was established. By 1976 annual shrimp harvests for the Alaska Peninsula region approached 80 million lb--a phenomenal growth in production of 700% in only 5 years.

Current efforts concerning shrimp assessment focus on surveys in the eastern Aleutian Islands region and triennial investigations of areas in the eastern Bering Sea.

Principal participants in the Kodiak Facility's early shrimp work included Ronholt, Duane Petersen, and Perry Thompson, and more recently it includes Paul Anderson and Franklin Hartsock.

Crab Assessment

Crab stock assessments are the primary responsibility of the Kodiak Facility. Since the Facility was established, annual surveys in the eastern Bering Sea have remained the principal source of status-of-crab-stocks information for the U.S. fishing industry, resource managers, and international fishery negotiations. These Bering Sea surveys are a current version of surveys originally started by the Biological Laboratory in Seattle in the 1950s and

continued by the Auke Bay Laboratory in the 1960s. The Kodiak Facility crab program staff has provided significant contributions to the knowledge of king and snow crab biology and have played major roles in developing fishery management plans, monitoring harvests by foreign nationals, and conveying current and projected stock conditions to the fishing industry. The geographic center for crab assessment work continues to lie in the southeastern Bering Sea; however, segments of the work have stretched into several other regions of Alaska. Persons extensively involved in the crab assessment program include or have included Murray Hayes, Jerry Reid, Alan Beardsley, Jerry Reeves, Robert Otto, Jack McBride, and Richard MacIntosh.

Snail assessment

Another extensive Alaska shellfish resource that is investigated at the Kodiak Facility is marine snails. A commercial fishery by Japan has been underway in the eastern Bering Sea and there continues to exist a substantial potential for domestic fishery for this resource. Extensive investigations of the magnitude and geographic distribution of several species of marine snails was started during the Kodiak Facility's involvement with outer continental shelf environmental studies in the mid 1970s. MacIntosh has remained the person primarily involved with assessing snail resources. He has become one of our country's foremost gastropod experts on the west coast.

Personnel Notes, 1970-81

Scientific and technical personnel employed at the Kodiak Facility, 1970-81, are also listed. Several members of the Kodiak Facility staff have departed Kodiak but have remained with other segments of the Center. Some of those former staff members who are no longer associated with the Center, but have remained associated with Alaska and marine resources include Alan J. Beardsley--currently a successful businessman, elected Mayor of the City of Kodiak, and appointed to the U.S. Department of Commerce National Marine Affairs Advisory Committee; Robert Meyer--private consultant and owner/operator of several marine related businesses in Myers Chuck (a small community in southeastern Alaska); A. K. Larssen--Associate Editor for the Fishermen's News; Jerry Reid--environmental assessment expert for the Alaska Regional Office, U.S. Department of the Interior, U.S. Fish and Wildlife Service; Duane Petersen--Director, Southeast Alaska Office, Environmental Assessment Division, NMFS Alaska Regional Office; and Gale Hudkins--Director of the Alaska State Zoo in Anchorage, Alaska. Another staff member, Perry Thompson, left Alaska and now works at the NMFS Southeast Fisheries Center.

NORTH PACIFIC EF&GR, 1970-81

The exploratory fishing and gear research group remained a unit through the major reorganizations of the late 1960s and early 1970s. It emerged in 1975 as the Resource Assessment and Conservation Engineering (RACE) Division. Designed to play a primary role in the new Marine Resources Monitoring Assessment and Prediction (MARMAP) Program, RACE was supplemented with groundfish and king crab scientists from the former Biological Laboratory and organized to handle MARMAP II--groundfish and shellfish

stock surveys and analyses. During the interim period, 1971-75, the RACE group was one of two components of the Marine Fish and Shellfish (MFS) Division under the direction of Fukuhara. When the two groups were separated into divisions in 1975, Fukahara became Director of Resource Ecology and Fisheries Management Division. Pereyra was named Director of RACE Division. Greenwood transferred back to Seattle from the Office of Fleet Operations (National Ocean Survey, NOAA) to be Deputy Director of RACE Division in 1976. The Alaska Region EF&GR Base, including the Oregon, moved from Juneau to Kodiak in 1970 and became a component of the MFS-RACE activity in 1971.

Both the John N. Cobb and the Oregon were incorporated into the NOAA fleet in 1973 under jurisdiction of the Office of Fleet Operations, NOS, Rockville, Maryland, through the Pacific Marine Center in Seattle.

RACE Division's mission through most of this period corresponds to the present combination of tasks: 1) Shellfish Assessment Task--located in Kodiak, Alaska, and concentrating on Gulf of Alaska and Bering Sea crab and shrimp stocks; 2) Groundfish Assessment Task--with three subtasks handling groundfish stocks in Bering Sea, Gulf of Alaska, and Pacific coast (off Washington-Oregon-Northern California), respectively; 3) Latent Resources Task--concerned with sablefish assessment and other groundfish studies; 4) Pelagic Resource Assessment Task--responsible for acoustic system development and related research and for acoustic-midwater trawl surveys of semi-pelagic species, particularly walleye pollock and Pacific whiting; 5) Conservation Engineering Task--responsible for technical support (sampling gear) of other tasks with limited effort in field of fishing gear research and development; and 6) Foreign Cooperative Research Task--coordinating work of foreign research vessels with U.S. needs through planning and observers placed aboard the foreign vessels.

Murray Hayes has served as Director of RACE Division since Pereyra left the Center in 1977 to enter private enterprise. Jones became Deputy Director when Greenwood retired in 1980.

Special activities during the period included 1) participation in the two NOAA-sponsored underwater habitat experiments, 2) participation in the Bering Sea offshore surf clam joint venture investigation, 3) a survey of Bering Sea king crab with RUFAS (Remote Underwater Fisheries Assessment System) employing closed circuit television, and 4) a survey of Gulf of Alaska seamounts to explore commercial fishing potential.

Alaska Shellfish Assessment

RACE's Kodiak Laboratory each year monitors Bering Sea and Gulf of Alaska king crab, snow crab, and shrimp stocks with enough precision to allow management agencies to set realistic catch quotes. The Kodiak Laboratory has been led respectively by Hayes, Beardsley, and Wolotira from 1971 to date.

Groundfish Assessment

Surveillance of groundfish within the 200-mile fisheries conservation zone from off northern California, along the west coast, through the Gulf of Alaska, and into the Bering Sea is the responsibility of the Groundfish

Assessment Task. Miles Alton has led the task and its predecessor unit since 1973. Since the area is vast and shiptime is limited, the present practice is to survey each of three subareas once every 3 years. The subareas are 1) Bering Sea, 2) Gulf of Alaska, and 3) continental shelf and slope off Washington, Oregon, and northern California. Richard Bakkala, Ronholt, and Thomas Dark, respectively, are responsible for the three subareas. In addition to the triennial surveys, various smaller scale surveys are conducted annually.

Pelagic Resource Assessment

This Task is responsible for acoustic system development and related research studies. However, its primary responsibility is to conduct acoustic-midwater trawl surveys of walleye pollock (in the Bering Sea and Gulf of Alaska), Pacific whiting, and other semi-pelagic species of groundfish, particularly Pacific herring and certain species of rockfish. The Task works directly with each of the subtasks within the Groundfish Assessment Task. During 1974-76 the Task developed a van-contained computerized acoustic system which is now recognized as being unique in terms of its versatility, ease of calibration, history of use, and fish target strength (acoustic reflectivity) measurement capabilities. Nelson has led the Task since it was established in 1974.

Conservation Engineering

The fourth RACE task is Conservation Engineering. This task was directed respectively by McNeely, Greenwood, Jones, and Wathne from 1972 to date. A section of the group, which was under Jurkovich, procures and maintains survey gear and equipment for the whole division. They also design and fabricate special gear according to scientific needs.

Porpoise Mortality

Problems resulting from the tuna industry's practice of using porpoise as an indicator for setting huge seine nets on schools of tuna and subsequently catching porpoise along with the fish, became a sensitive environmental-ecological issue in the early 1970s. McNeely, head of the gear research unit, had become familiar with the tuna seine fishery some years earlier and was detailed to the NMFS Southwest Fisheries Center to lead efforts to solve the problem. McNeely, helped intermittently by other base personnel including William High, Jurkovich, and Daniel Twohig, succeeded in implementing changes in net design and operating procedure sufficient to reduce porpoise mortalities to virtually zero on boats using the system. McNeely received the Department of Commerce's highest award, the Gold Medal, for this achievement and was named the Cetacean Society's "Man of the Year" in 1978.

Research Vessels

Until the NOAA fleet concept was implemented in 1972, the exploratory fishing-RACE unit was involved with only three government vessels--John N. Cobb, Oregon, and John R. Manning. Much of the credit for conceptual thinking and mission accomplishment must go to the crews of these vessels. As shown in the accompanying partial crew lists, many of them served faithfully for years. Numerous charter fishing vessels were used over the

years, and we regret not having a listing of their names and crews.

Staff, Exploratory Fishing and Gear Research Base, Juneau, 1960–70

1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	
■	■										Charles F. Connelley, Jr...Base Director
		■	■	■							Warren F. Rathjen...Base Director
				■	■	■	■	■	■	■	Benjamin F. Jones...FM&ES, Base Director
									x	x	Victor L. Fortin...FB
					x	x	x	x	x	x	Lael L. Ronholt...FB, Deputy Base Director
			x	x	x	x					Mitsuo Yesaki...FM&ES, FB
			x	x	x		x	x	x		Stephen H. Rogers...FB, BT
					x	x	x	x	x	x	Doyne W. (Red) Kessler...FB
					x	x	x	x	x	x	A.K. Larssen...FM&ES
						x	x	x			Sergei N. Astrahantseff...FB
						x	x	x	x	x	Robert J. Wolotira, Jr...FM&ES, FB
								x	x	x	Gerald M. Reid...FB
								x	x	x	Robert M. Meyer, Jr...FB
									x	x	Harold A. (Skip) Zenger, Jr...ET, FB
				x	x						Beverly Eggan...Secretary
						x	x	x	x	x	Sara Anderson...Secretary

x = year present
■ = Base Director
x = Deputy Base Director
FB = Fishery Biologist
FM&ES = Fishery Methods and Equipment Specialist
BT = Biological Technician
FT = Fishery Technician
CS = Computer Specialist

Crew of fisheries research vessel *John N. Cobb*

1979

Master	Thomas Dunator
First Officer	Perry A. Buholm
Chief Engineer	Louis T. Radine
Asst. Engineer	Arthur R. Cooper
Lead Fisherman	Jonas O. Varnes
Skilled Fisherman	George W. Grant (Sr.)
Skilled Fisherman	Karl R. Gustafson
Chief Steward	Robert Blanks

1977

Master	Robert Larsen
First Officer	Thomas Dunator
Chief Engineer	Leroy McDonald
Asst. Engineer	Arthur R. Cooper
Lead Fisherman	Jonas O. Varnes
Skilled Fisherman	Robert Mennucci
Skilled Fisherman	Leo N. Gorn
Chief Steward	Ardan Brezh

1972

Master	Robert Larsen
First Officer	Perry A. Buholm
Chief Engineer	Leroy McDonald
Asst. Engineer	Phillip Johnson
Skilled Fisherman	Ory Helton
Skilled Fisherman	Richard Farrens
Skilled Fisherman	Ivar E. Roeggen
Chief Steward	Jim Geyen

Crew of fisheries vessel *Oregon*

(FRV *Oregon* transferred to State of South Carolina on 10/20/80

1979

Master	Perry A. Buholm
First Officer	Walter E. Hamiester
Chief Engineer	Robert T. Holden
Asst. Engineer	Michael Wesneski
Fisherman	Claude Pierce
Fisherman	Michael Gunderson
Fisherman	Don Hudson
Chief Steward	Dwyane Hunter

1977

Master	Wendell F. Schneider
First Officer	Robert F. Eveland
Chief Engineer	Louis T. Radine
Asst. Engineer	Torval Steen
Lead Fisherman	Daniel Kulusich
Fisherman	Frederick J. Bonde
Fisherman	Jeffrey E. Hanson
Chief Steward	Robert T. Lyons

1972

Master	Wendell F. Schneider
First Officer	Allan Z. Komedal
Chief Engineer	Louis T. Radine
Asst. Engineer	Torval Steen
Lead Fisherman	Daniel Kulusich
Fisherman	Reuel M. Fleming
Fisherman	Henry L. Torgramson
Chief Steward	Arthur W. Ericson

Crew of fisheries research vessel *John N. Cobb*, Supporting Exploratory Fishing and Gear Research Base, Northwest Region, 1950—72 (selected years only)

FRV JOHN N. COBB						CREW
1954	1955	1958	1960	1963	1967	
Ⓐ	Ⓐ					Sheldon W. Johnson...Captain-Fisherman
x						Conrad M. Knutsen...Mate-Fisherman
	x	Ⓐ				Jose Franco...Mate-F, Captain-F
	x	x	Ⓐ	Ⓐ	Ⓐ	Robert P. (Pete) Larsen...MF, Mate-F, Captain-F
		x	x	x	x	Hans Jangard...MF, Mate-Fisherman
x	x	x	x	x		Hugh T. Tiura...Chief Engr.-Fisherman
x	x	x	x			H.G. (George) Wagner...First Asst. Engr.-F.
				x	x	L.C. (Bud) McDonald...First Asst. Engr.-F, Chief Engr.-F
					x	James R. Geyen...First Asst. Engr.-F
x	x					William L. Morgan...Cook-Fisherman
		x	x	x		Ivar M. Fjaerestad...Cook-Fisherman
x						Joseph T. Schleitweiler...Master Fisherman
x						Adolph S. (Curley) Peterson...Master Fisherman
x	x	x	x			Konrad S. Moen...Master Fisherman
	x					Gilbert L. Holland...Master Fisherman
	x					Edward H. Edland...Fisherman
		x	x	x		Arne Laren...Master Fisherman
		x	x			Joseph Donotov...Master Fisherman
				x	x	I.E. Roeggen...Master Fisherman
				x	x	P.L. Johnson...Master Fisherman
					x	P.A. Buholm...Master Fisherman

x = Year present
Ⓐ = Captain-fisherman
F = Fisherman
Engr. = Engineer
Asst. Engr. = Assistant Engineer

Crew of fisheries research vessels *John R. Manning* and *Oregon*, Supporting Exploratory Fishing and Gear Research Base, Alaska Region, 1963—72

FRV JOHN R. MANNING							FRV OREGON				CREW
1963	1964	1965	1966	1967	1968	1969	1969	1970	1971	1972	
Ⓐ											Jewell Pinyon...Captain-F
Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Wendell F. Schneider...Mate-F, Captain-F
F											Earl Bryner...Mate-F
			x	x			x	x			Ruel Fleming...Mate-F
				x	x	x					Ken Junge...Mate-F
									x	x	Allan Z. Komedal...Mate-F
x	x	x									Allan Z. Komedal...Chief Engr.-F
x	x	x	x	x							Phil Johnson...First Asst. Engr.-F
		x	x	x	x	x	x	x	x	x	Louis T. Radine...First Asst. Engr.-F, Chief Engr.-F
				x	x	x					Torval Steen...First Asst. Engr.-F
x	x	x	x	x	x	x	x	x	x	x	Clifton Schille...Cook-Fisherman
x	x	x									Chet Raymer...Master Fisherman
x	x	x									Reg Sierenpiper...Master Fisherman
				x	x	x					Denis Heggewald...Master Fisherman
									x	x	Art Ericson...Master Fisherman
									x	x	Daniel Kulusich...Master Fisherman
										x	Ivar M. Fjaerestad...Master Fisherman
									x	x	Henry Torgramson...Master Fisherman
									x	x	Ruel Fleming...Master Fisherman

x = Year present
Ⓐ = Captain-fisherman
F = Fisherman
Engr. = Engineer
Asst. Engr. = Assistant Engineer

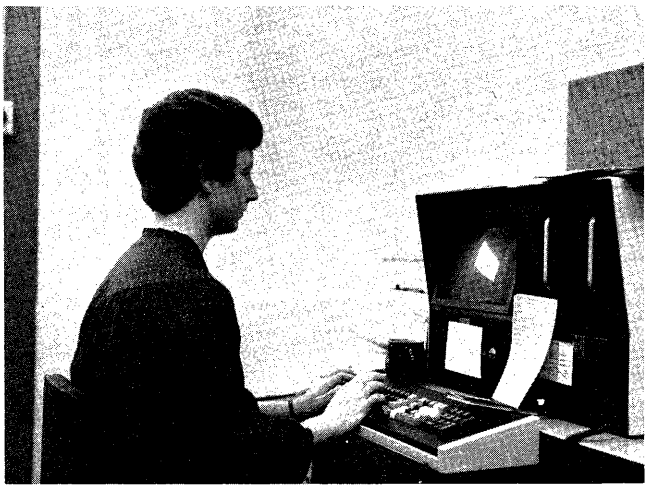
Staff, Resource Assessment and Conservation Engineering Division, Kodiak Laboratory, 1971–81

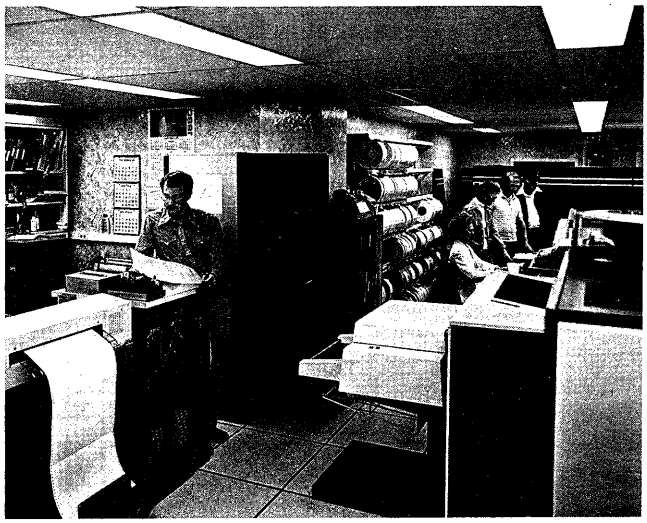
1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	
Ⓐ	Ⓐ	Ⓐ									Murray L. Hayes...Laboratory Director
			Ⓐ	Ⓐ	Ⓐ	Ⓐ					Alan J. Beardsley...Laboratory Director
x	x	x				Ⓐ	Ⓐ	Ⓐ	Ⓐ	Ⓐ	Robert J. Wolotira, Jr...FB, Laboratory Director
x	x	x									Phyllis A. Jackson...Secretary
		x	x	x	x	x					Marilyn Buker...Secretary
						x	x				Ruth W. Kiley...Secretary
								x	x		G. Gail Hudkins...BT, Secretary
									x	x	Deborah L. Greuling...Secretary
x	x	x	x								Lael L. Ronholt, FB
x	x	x	x	x	x	x	x	x	x	x	Doyne W. (Red) Kessler...FB
x	x	x	x	x	x	x	x	x	x	x	Jack McBride...BT, FB
x	x	x	x								Gerald M. Reid...FB
x											A.K. Larssen...FM&ES
x	x										Auggie Barcott...FM&ES
x											Perry A. Thompson, Jr...BT
x	x										Harold H. (Skip) Zenger, Jr...FB
x	x	x									Robert M. Meyer, Jr...FB
x	x	x	x								Duane H. Petersen...FB
	x	x	x	x	x	x	x	x	x	x	Paul J. Anderson...BT, FB
		x	x	x	x	x	x	x	x	x	Richard A. MacIntosh...BT, FB
			x	x	x	x	x	x	x	x	Franklin B. Hartsock...FB
				x	x	x					Jerome E. Reeves...FB
					x	x	x	x	x	x	Robert S. Otto...FB
						x	x	x	x	x	John H. Bowerman, Jr...FB
							x	x	x	x	Therese M. Armetta...BT, FB
				x	x	x	x	x			L.W. (Red) Schaeffer...Clerk-Typist/Receptionist
								x	x		Jeanne E. Evans...Clerk-Typist/Receptionist
									x	x	Denise A. Oest...Clerk-Typist/Receptionist
		x	x								Carolyn Bollman...Librarian
				x	x	x					Molly Endicott MacIntosh...Librarian
						x	x	x	x	x	Kathleen Beyett...Librarian
								x	x	x	J. Eric Munk...FB
							x	x			Allan K. Fukuyama...FB
									x	x	Kristin L. Stahl...FB
									x	x	W. Steven Meyers...BT, FB
							x		x	x	William D. Albers...FB
						x	x	x			Stephan B. Lazarus...BT, CS
								x	x		William F. Johnson...CS
						x	x	x	x	x	Genise L. Alterman...CS
									x	x	Stephen J. Wilson...CS
										x	William P. Osborne...BT
x	x	x	x	x							Jack Fredrickson, Maintenance
				x	x						J. Witlatch...Maintenance
						x	x	x	x	x	James E. (Pete) Harris, Maintenance

x = year present
Ⓐ = Laboratory Director
x = Assistant Laboratory Director
FB = Fishery Biologist
FM&ES = Fishery Methods and Equipment Specialist
BT = Biological Technician
CS = Computer Specialist

Research Support

Donald D. Worlund [1]





Shortly after the formation of the Northwest and Alaska Fisheries Center, the various technical support groups were brought together into what is now the Fisheries Data and Management Systems (FDMS) Division. Its first Director was Reynold Fredin. He was succeeded in 1978 by Donald Worlund with Murray Amos as Deputy Director in charge of data processing. The support groups in FDMS provide assistance to the Center's researchers in statistics, data processing, technical writing, editing, graphics, library services, and manuscript typing.

Automated data processing (ADP) at the Seattle Biological Laboratory began early in 1956 with the lease of an IBM 407 Accounting Machine, a card sorter, and several key punch machines. The equipment was placed in the Biometrics Unit headed by Fredin and was operated under the direction of Dorothy Cox until January 1959, when Ernest Decorvet took over. The accounting machine provided listings, summaries, and frequency distributions of fisheries research data.

In 1957, the University of Washington acquired one of the early IBM computers, an IBM 650. This machine was heavily used by the Seattle

1/ Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

Laboratory, as were the succeeding IBM 709, IBM 7040 and IBM 7040/7094 computers at the University. In 1964 the Biometrics Unit was reorganized as the Biometrics Institute with a separate ADP Unit under the direction of Amos. In 1968 the ADP Unit acquired a small IBM 1130 computer from General Services Administration excess property and discontinued use of the IBM 407 accounting machine. Service for large data processing problems continued to be supplied by the University and later by other outside governmental and commercial sources.

By 1975 the widely dispersed Center data base and the high cost of outside processing were sufficient problems to cause a re-examination of Center data processing. The study resulted in a decision to acquire a larger system which would be located in-house at Seattle with subsidiary service at Auke Bay and Kodiak. Robert Riemann, operations systems analyst, was hired to assist in the technical aspects of the proposed acquisition which resulted in a contract with the Burroughs Corporation for a B7811 computer at Seattle and B2835 computers at Auke Bay and Kodiak in 1979. At the same time, the Center reorganized the ADP Unit into the Office of Fisheries Information Systems (OFIS) with the Director reporting to the Center Director. Present Director of OFIS is Dr. Sam Bledsoe.

PERSONNEL

Early employees of these support groups no longer at the Center include: Biometrics--R. Lander, W. Davis, R. Duncan, H. Gangmark; Data Processing--E. Decorvet, A. DeSanto, E. Richmire; Editing--P. Macy, G. Maxfield, T. Bristol; Graphics--V. Coleman Fiscus; Library--A. Priddy, A. Bleakney.

Present personnel are: Biometrics--R. Kappenman, F. Ossiander; Editing/Technical Writing--R. Pearson (Unit Leader), R. Mitsuoka, S. Waterman; Graphics--J. Peacock (Unit Leader), C. Hastings, N. Williams-Nelson; Library--P. Cook; Manuscript Typing--D. Lindall (Unit Leader), M. Tomita; Data Processing--R. Riemann (Computer Facility Leader), S. Murai, F. Kikuchi, D. Clayton, G. Cheeves, M. Purvis, J. Akada. Temporary employees include: E. Uhlinger, M. Tune, D. Williams, J. DeGooyer, B. Ambo, L. Rutledge, D. Yoshihara, R. Radek, and L. Richey.

Presentations at the 50th Anniversary Symposium, 26-27 October 1981, Seattle, Washington

Effects on Environmental Stress on Fisheries Use and Enjoyment: A Historical Overview

Donald C. Malins [1]

INTRODUCTION

Many stresses impact on fisheries use and enjoyment. They vary from disruption of habitat to the influence of pollution on the health of organisms and the viability of ecosystems. But stress in the context of this paper will be limited to the effects of chemical pollution, the main focus of interest in the Center's Environmental Conservation Division.

What is the legislative basis for our commitment to this important national issue? The National Marine Fisheries Service is responsible for providing data for the conservation and management of fisheries stocks of the United States Continental Shelf. In this capacity, it rightly plays a key role in investigating actual and potential impacts of pollution on these stocks and the ecosystems on which they depend.

Moreover, Congress has recognized the responsibilities of the National Marine Fisheries Service and its predecessor agencies in the conservation and management of living marine resources through a series of legislative mandates. The National Ocean Pollution Research, Development, and Monitoring and Planning Act of 1978 specifically names the National Oceanic and Atmospheric Administration (NOAA) as the leading Federal agency to plan and coordinate ocean pollution monitoring and research: Section 202 of the Marine Protection, Research, and Sanctuaries Act of 1972 directs the Department of Commerce to "initiate a comprehensive and continuing program of research with respect to the possible long-range effects of pollution, overfishing, and man-induced changes in ocean ecosystems." The Magnuson Fishery Conservation and Management Act of 1976 requires the Secretary of Commerce "to initiate a comprehensive program of fishery research, including the impact of pollution...on the abundance and availability of fishery resources."

Until recently, the impact of pollution on marine organisms was addressed primarily after environmental catastrophies had occurred. Yet, lacking adequate information on how toxic chemicals altered living marine systems, it was often impossible to identify, much less quantify, the acute effects of even a massive spill of hazardous material. Even more lacking was information on long-term effects from major spills or from the gradual degradation of the environment from continuous, low-level estuarine and marine pollution (Malins 1980). I

1/ Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

believe that steady progress has been made in the last decade in coming to grips with important issues relating to the short- and long-term impact of pollution on fisheries. However, a number of questions still remain unanswered.

HISTORY

In the Pacific Northwest, a small amount of research was conducted prior to 1970 by Federal agencies on the effects of chemical pollutants on marine organisms. In the spring of 1970, responding to an upsurge of interest in man's impact on oceans, research on the effects of pollution on marine life was initiated at this Center. What then have we learned from this research in the last decade or so?

Using highly sophisticated analytical techniques, many of which were developed in coastal and estuarine environments, such as the New York Bight and Puget Sound (Malins et al. 1980b), we were able to learn where many of these compounds accumulate and, to some extent, how they may adversely affect marine life. But it is only in the last few years that we have begun to really appreciate the immensity and complexity of the problem revealed by these new, highly sensitive techniques.

There are in fact an estimated 63,000 chemicals in common use. The registry of the American Chemical Society contains over 4 million entries and is growing by 6,000 chemicals each week. Many of these chemicals, produced to satisfy technological and economic needs, eventually find their way into the marine environment (Malins 1980). It is estimated, for example, that 4 million metric tons of petroleum enter our oceans each year. Because of threats like this it is necessary to continually expand our understanding of the effects of pollutants on marine organisms. Failure to do so many well adversely affect the viability of our fishery resources and our use and enjoyment of them.

Now, let me mention some important facts about the pollutants themselves. Chemicals such as polychlorinated biphenyls (PCBs) enter marine environments and remain there for long periods of time, partly because of their resistance to chemical and biological changes. We can analyze for many, but by no means all, of these persistent chemicals. Many of these chemicals tend to bind to suspended particles that eventually end up in bottom sediments where important benthic species, such as flatfish reside. Other compounds such as hydrocarbons from fossil fuels are readily transformed in the marine environment through chemical and biological processes into a host of "new" chemicals. Most of these "new" chemicals cannot presently be detected in marine samples, even with our sophisticated analytical techniques (Malins et al. 1980a, Malins and Hodgins 1981).

Despite these problems, however, we are successfully identifying pollutants in marine environments and relating their presence to alterations in the health of important fishery resources.

How do we pursue this type of research? In the Environmental Conservation Division, we take an interdisciplinary approach because this is critical to obtaining a credible perspective of marine pollution. Our research teams are made up of highly trained specialists in areas such as analytical chemistry, biochemistry, clinical

chemistry, ecology, pathology, electron microscopy, immunology, and behavioral biology. Our scientists and technicians work together in a concerted way, applying their particular expertise to the solution of complex problems.

Actually, one of our major concerns is whether pollutants present in marine environments are available to organisms. Many pollutants are found in seawater, but they are not all taken up by marine life to the same extent. For example, PCBs tend to accumulate in fish to a greater degree than do certain metals, such as cadmium. Fish can concentrate water-borne PCBs in their bodies several hundred thousand times the concentrations in seawater; however, cadmium is often concentrated only a few hundredfold at most.

From the point of view of protecting our fishery resources, perhaps the most important question is "Are pollutants affecting the health of marine organisms?" To answer this question we need to know which pollutants organisms are exposed to in the marine environment, which ones they tend to accumulate, what happens to the pollutants inside the animals, and what are the accompanying biological changes are (Malins 1980). With this evidence in hand, balanced and meaningful judgments are possible.

You may wonder how our scientists attack such a multifaceted problem. To begin with, analytical chemists have a firstline responsibility in the interdisciplinary approach. It is their job to find ways to detect and quantify pollutants in seawater, sediments, and organisms. These pollutants, frequently occurring at parts-per-billion or less, have to be analyzed against a background of complex mixtures of hundreds of "natural" compounds. The chemists have a formidable task, and their imagination and ingenuity is constantly challenged as they attempt to distinguish between myriad synthetic chemicals and "natural" substances in the multifactorial world of oceans and estuaries (Malins et al. 1980a, Malins 1981).

CURRENT RESEARCH

The Center's analytical capability resides in NOAA's National Analytical Facility, which was founded in 1976 as part of the Environmental Conservation Division. It is here that analytical chemists and technicians are involved in assessing pollution in coastal waters and estuaries of the United States. They also provide "analytical backup" for laboratory and field studies conducted by other Division scientists and technicians concerned with the fate and effects of pollutants on marine life. The facility utilizes state-of-the-art techniques, such as gas chromatography coupled with mass spectrometry and advanced data processing. Our analytical capabilities match or exceed those found anywhere else in the world. The staff is strongly committed to the development of new techniques; they are constantly alert for new ways of analyzing marine pollutants. Their research has resulted in new procedures for the routine analysis of environmental samples, and their techniques are continually modified to meet changing needs. Analytical methods developed here at the Center are being used in laboratories throughout the world, and we serve as a focal point for intercalibration studies.

The analytical chemists work closely with highly qualified biochemists, pathologists, and other specialists within the Division, as I have indicated. Data on the types and concentrations of pollutants in marine samples are of great importance to our biological scientists, helping them to broaden their understanding of marine pollution--that is, how it may affect the health of important resource species. In a reciprocal way, information from biochemical studies on what happens to pollutants and their metabolites in organisms is helpful to the analytical chemists. It tells them what to look for in organisms exposed to pollutants in the laboratory or field and guides them in research on new methods.

Let me illustrate how the team approach works in practice. In laboratory studies with marine organisms, our biochemists showed that aromatic hydrocarbons labelled with radioactivity are converted to metabolites, some of which are toxic (Varanasi and Gmur 1981). The findings of our biochemists have had a major impact on the scientific community and on those concerned with the fate of chemicals in marine life. Responding to the advances made by our biochemists, our analytical chemists developed methods to analyze for the conversion products in environmental samples (Krahn et al. 1980,1981). Moreover, with immediate access to the latest biochemical findings, our pathologists were able to use this information in attempting to understand the causes of pathological lesions, such as liver tumors in English sole living on heavily polluted sediments in Puget Sound (McCain et al. 1977). Thus, the team approach maximized the acquisition of data obtained on the nature of pollution and its effects on marine organisms.

How are our laboratory and field studies conducted? In the laboratory, experimental conditions relating to how pollutants bring about biological change can be controlled; in the real world of oceans and estuaries, however (where influencing factors are immensely complex), prevailing conditions are usually very difficult to evaluate and control. Thus, laboratory studies are often the only reliable means of obtaining critical information--that is, information that helps us broaden our perspective and increase our understanding of cause-and-effect relationships between pollutants and alterations in the health of organisms.

As an example, in one laboratory study flatfish were exposed for up to 4 months to sediment containing petroleum hydrocarbons. We determined through routine chemical analyses that the flatfish accumulated very few of the hydrocarbons present in the sediment (Figure 1), (McCain et al. 1978, McCain and Malins in press). In a related experiment in which flatfish were exposed to a specific hydrocarbon containing a radioactive label, we followed the hydrocarbon's fate in the fish's body (Varanasi and Gmur 1981). We found that the fish converted the hydrocarbon into a variety of metabolites that remained in the tissues for a long time. Thus, we concluded that flatfish exposed to petroleum in sediments build up metabolic products from hydrocarbons, rather than store the hydrocarbons unaltered (Varanasi and Gmur 1981). These metabolites, some of which are thought to be more toxic than the hydrocarbons themselves, and which escape the analytical chemist's eye, must now be taken into account in making judgments about the effects of hydrocarbons on marine life.

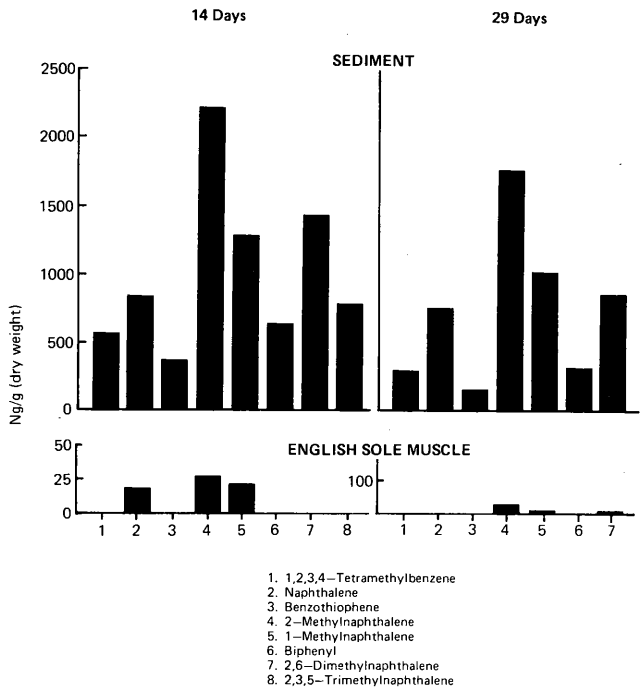


Figure 1
Concentrations of major aromatic hydrocarbons in Prudhoe Bay crude oil (PBCO) contaminated sediments and in the English sole associated with the sediments at 14 and 29 days. Tissue levels are an average of two replicated analyses of 10 g muscle samples from two fish. Control fish tissue did not have detectable levels of PAH.

In this same study, significant biological changes were observed. The petroleum-exposed flatfish had unusually high accumulations of fat in their livers and also showed changes in blood chemistry. They also lost weight and had higher mortalities than unexposed fish (McCain et al. 1978). Thus, by looking into this problem from several directions, we learned how sediment-bound hydrocarbons are "processed" by flatfish into potentially toxic chemicals we cannot routinely detect, and we further identified related and potentially serious biological changes. In fact, the information was extremely useful in planning and understanding field studies and also contributed in a major way to a number of important local and national decisions relating to environmental impacts.

What are some important conclusions from our laboratory studies? It has become apparent that early developmental stages of aquatic species are particularly susceptible to damage from trace amounts of pollutants (Malins and Hodgins 1981). We have, therefore, increasingly focused our studies on effects of pollutants on reproduction and early developmental stages of fish and invertebrates.

Again, to give a specific example, in one experiment we fed high doses of Alaskan crude oil (1000 ppm added in food) to maturing rainbow trout (Hodgins et al. 1977). We started the feeding of the oiled food 7 months before they were due to spawn and continued the feeding through spawning and beyond. Control fish were fed the same diet except that it did not contain the oil. The oiled food was well accepted by the trout. We evaluated mortality of the adults and hatching success of the offspring. Results indicated there was no detected oil-caused mortality during the study, and surviving fish were mostly fat, normal appearing, and vigorous--even after a year on the oiled food. Moreover, there was no significant effect on either egg viability or sperm viability as evaluated by hatching success. The conclusions were that oil fed to the parents had no demonstrable effect on their survival and no effect on subsequent hatching success of offspring.

But there is another side to the coin. Our studies of effects of petroleum on hatching and normal development of a species of flatfish and surf smelt provided quite different results. In these studies the parents were not

exposed to the oil, but the fertilized eggs (embryos) were. That is, the oil was in the water in which the eggs were incubating. Results of the flatfish studies demonstrated that parts-per-billion concentrations of oil can cause mortalities and abnormal changes in flatfish larvae and prevent the development of embryos (Figure 2 and 3). These effects occurred at doses well within the range of concentrations that could occur following an oil spill.

Similar, but not as severe, effects were noted in surf smelt after oil exposure of embryos and larvae (Hawkes and Stehr in press). In addition to the mortality and grossly abnormal development found in a flatfish, damage at the ultrastructural level was noted in surf smelt retinas and brain tissue.

Overall conclusions from these studies on reproduction and hatching success are that: 1) under some conditions and with some fish species oil exposure does cause damage and 2) under other conditions and with other species there is either no evidence of damage, or different patterns of abnormalities occur.

Turning to another subject, we have also participated in field studies relating marine pollution to altered health of organisms. The grounding of the tanker Amoco Cadiz off the coast of France in 1978 was an opportunity to apply techniques we have developed to a real world situation--a massive oil spill. In collaborative efforts between our scientists and other scientists within NOAA, mussels were placed in cages 1 m below the water surface off the coast of France, either directly in the path or away from the path of the oil spill, to determine how the oil might affect their health (Wolfe et al. 1981). Our microscopists found that mussels from the spill zone or in the path of the spill showed abnormalities in their cellular structure, whereas mussels from a reference or "clean" site appeared normal.

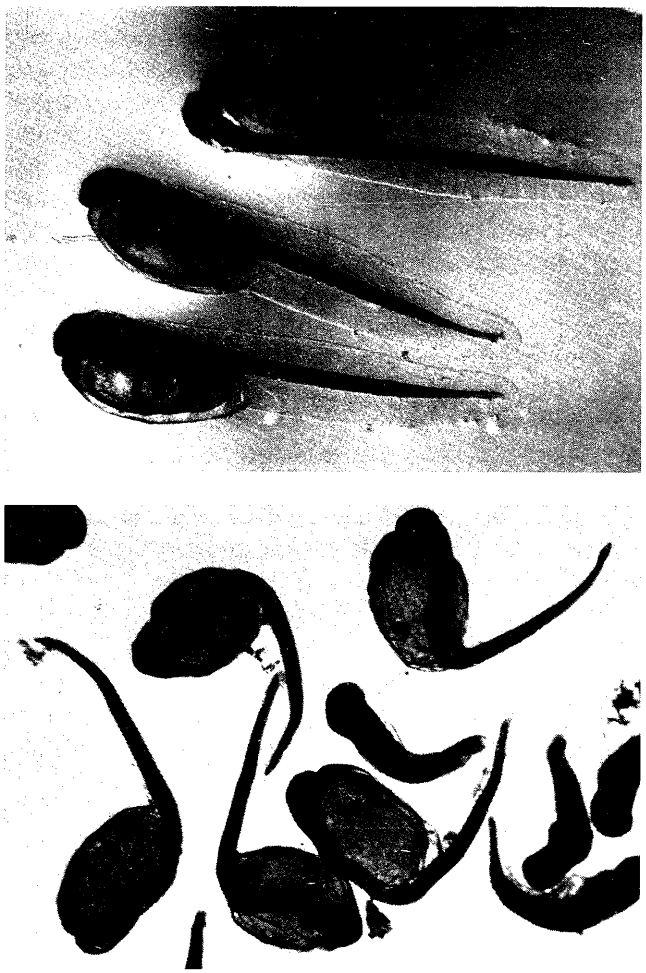


Figure 2
Sand sole *(Psettichthys melanostictus)* eggs exposed to Prudhoe Bay crude oil produced larvae with severe scoliosis. Upper photo, control sand sole larvae; lower photo, eggs incubated for 7 days in a system containing the saltwater-soluble fraction of Prudhoe Bay crude oil resulted in 66% abnormal larvae. Initial concentration of 527 parts per billion (ppb) was decreased to 64 ppb. Embryos were prematurely aborted and larvae hatched with severe scoliosis.

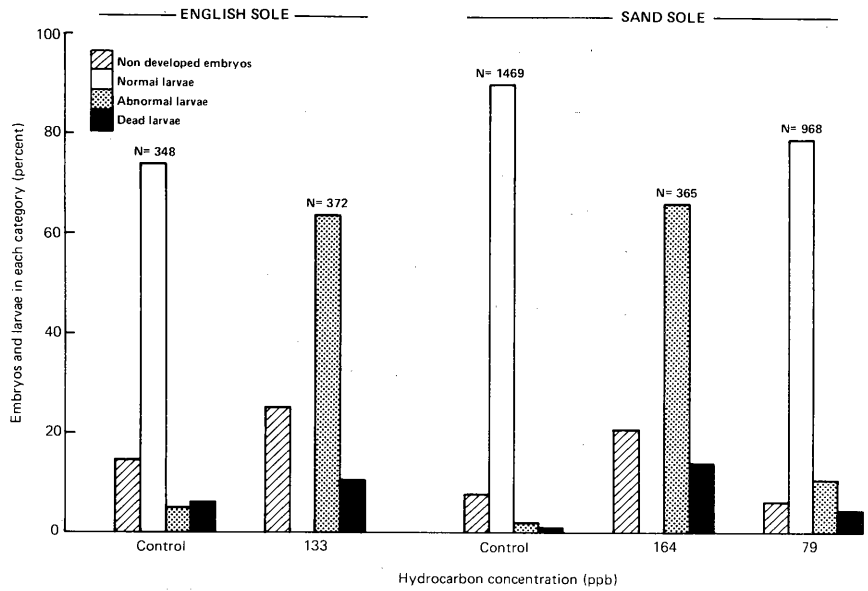


Figure 3
Mortalities and abnormalities in English sole and sand sole embryos and larvae exposed to various hydrocarbon concentrations of the seawater-accommodated fraction of Prudhoe Bay crude oil. Data were collected at the time of hatching (end of an 8-day exposure).

Our chemists found petroleum contamination in the mussels exposed directly in the path of the spill. Using high performance liquid chromatography, they also found evidence of contamination from non-hydrocarbon products of petroleum. In fact a major breakthrough was obtained when they demonstrated for the first time that the products of hydrocarbon conversions I mentioned earlier were particularly associated with mussels obtained from the impact zone.

Thus, employing an interdisciplinary approach, we were able to gather two types of important evidence relating the presence of oil from the Amoco Cadiz to altered health of shellfish. We have studied in similar ways the impacts on marine life of other oil spills, such as the Argo Merchant off Nantucket (MacLeod et al. 1978) and the General M. C. Meigs off the Washington coast (Clark et al. 1978).

We have studied relations between chemicals and disease in marine life closer to home, i.e., Puget Sound. It is important to mention, however, that the presence of trace amounts of toxic chemicals in marine life does not imply, per se, a threat to either the organism or the consumer. Only carefully conducted studies, considering many interrelated factors, can establish whether a significant risk really exists. Revelations of traces of known toxic chemicals in the environment are sometimes misinterpreted by the unskilled or unknowledgeable to spell disaster when, in fact, no significant danger can be established or predicted on the basis of scientific evidence.

To return to the issue of Puget Sound--beginning in 1978 and continuing through the spring of 1981, samples of sediments and selected bottom-dwelling fish and invertebrates were collected from urban embayments, i.e., near industrialized areas, and from nonurban (reference) stations in Puget Sound and adjacent waters. The study was a cooperative effort with NOAA's Marine Ecosystems Analysis (MESA) Puget Sound Program (Malins et al. 1980b).

Our chemists analyzed sediments and tissues for a large number of organic and inorganic chemicals, including aromatic hydrocarbons, PCBs, chlorinated pesticides, other chlorinated organic compounds, and metals. In most cases, the same animals from which tissues were taken for chemical analyses were also examined by our pathologists for grossly visible and microscopic abnormalities. In addition, the community characteristics, such as abundance and species diversity, of invertebrates and fish living in contact with sediment were defined by our biologists.

Aromatic hydrocarbons, PCBs, and chlorinated butadienes were widely distributed in Puget Sound sediments; however, the concentrations varied extensively both among and within embayments. The sediments in embayments adjacent to the most populated areas, Elliott Bay (Seattle) and Commencement Bay (Tacoma), contained the highest concentrations of aromatic hydrocarbons and PCBs; chlorinated butadienes were highest in Commencement Bay where industries that manufacture chlorinated products are located. Table 1 presents comparisons of the concentrations of compounds representative of the three classes of chemicals in sediments from these two bays with concentrations in sediment from Case Inlet (a reference area in Puget Sound) and in sediment from the New York Bight.

As an example of the complexity of the mixtures of chemicals in sediments, more than 500 aromatic hydrocarbons, appearing to be mostly derived from fossil fuels and the combustion of fossil fuels, were revealed in one sample from the Hylebos Waterway in

Table 1
Concentrations [μg/g (ppm) dry weight] of selected pollutants in sediment from various locations in Puget Sound and the New York Bight.[1/]

Pollutant	Puget Sound: Duwamish Waterway (6 samples)	Puget Sound: Hylegos Waterway (5 samples)	Puget Sound: Case Inlet[2/] (2 samples)	New York Bight: Christensen Basin[3/] (3 samples)
	ug/g (ppm) dry weight			
1- to 5-ring aromatic hydrocarbons	11	16	0.3	5.4
Benzo[a]pyrene	0.6	0.5	0.02	0.2
Benz[a]anthracene	1.1	1.2	0.02	1.0
Polychlorinated biphenyls	0.3	0.5	0.002	1.1
Chlorinated butadienes	0.02	0.4	0.007	ND[4/]
Hexachlorobenzene	0.0002	0.03	0.00003	0.005

1/ Analyses by National Analytical Facility, Northwest and Alaska Fisheries Center, Seattle.
2/ A reference site.
3/ Located near the mouth of the Hudson River.
4/ ND = not detected.

Tacoma. Scores of chlorinted compounds, in addition to PCBs and hexachlorobenzene (HCB), were associated with certain embayments. This was especially evident for sediments collected near Tacoma, Port Angeles, Bellingham, and Everett.

To briefly touch on the toxic metals in sediment, arsenic and mercury were detected only in sediment from urban areas, whereas lead was found in both urban and nonurban areas.

Sediment-dwelling worms, clams, shrimp, and crabs from urban embayments contained levels of aromatic hydrocarbons that were higher than levels detected in these animals from nonurban areas. The aromatic hydrocarbons in fish livers from all areas were generally low. As you can guess by now, these compounds were subjected to extensive metabolism and were replaced, in effect, by potentially toxic metabolites we cannot detect at present. Concentrations of PCBs and other chlorinated compounds were generally higher in organisms from urban than from nonurban area.

We have studied the chemicals in sportsfish, such as salmon and cod. I am pleased to report that concentrations of chlorinated compounds and hydrocarbons in edible tissue (muscle) were very low in these fish from both urban and nonurban areas. Concentrations of PCBs in livers of salmon from both types of areas were also low. In sharp contrast, concentrations of PCBs in the livers of English sole caught from urban areas were as much as 15 times higher than those from nonurban areas.

Muscle of English sole, Pacific cod, and salmon from both urban and nonurban areas contained low concentrations of lead and mercury. Arsenic was found in sole muscle from both urban (Duwamish and Hylebos Waterways) and nonurban (Port Susan) areas, and in cod and salmon muscle from Elliott Bay, Commencement Bay, and Point Jefferson.

Bottom fish, crabs, and shrimp had a variety of pathological conditions. The most commonly observed lesions were either associated with infectious agents, or they were caused by unknown factors. Some of the lesions of unknown cause were found only, or were most prevalent, in fish from the urban embayments. In English sole, the fish species most widely distributed throughout Puget Sound, these urban-associated lesions included liver tumors, and "preneoplastic" and necrotic liver lesions. In some cases, the liver neoplasms were grossly visible as nodular discolorations on the liver surface (Figure 4).

Figure 4
English sole liver containing multiple neoplastic nodules.

Fish with the above-mentioned lesions, as well as other types of lesions, had abnormal changes in blood cell counts and in the concentrations of serum

Table 2
Pathological conditions in English sole from the Duwamish River, a polluted estuary in Seattle, Washington, as compared to English sole from McAllister Creek, a reference ("clean") estuary 80 miles south of Seattle.

Abnormalities in English sole	Duwamish River		McAllister Creek	
	Number of fish examined	Frequency of abnormality (%)	Number of fish examined	Frequency of abnormality (%)
Liver tumors				
Adults only (1975)[1/]	62	32	37	0
Adult and juvenile (1978)[2/]	252	8	18	0
Fin erosion[2/]	476	2	71	0
Severe hepatocellular lipid accumulation[2/]	256	45	37	11
Gill hyperplasia[2/]	256	15	37	0

1/ McCain, B.B., et al. (1977)
2/ Malins, D.C. (1980)

components. Some of these changes were indicative of severe organ dysfunction. English sole with liver neoplasms and "preneoplastic" lesions were most prevalent in Seattle's Duwamish Waterway and in Tacoma's Waterways. In the Duwamish Waterway, the prevalence of adult sole with liver neoplasms was found to be as high as 32% (20 of 62 fish) in a study conducted in 1975. More recent studies involving both juvenile and adult sole have found a liver neoplasm prevalence of 8% (20 of 252 fish, Table 2). No sole with liver neoplasms were found in nonurban reference areas.

What can be said about a possible link between the toxic chemicals and the observed diseases? We employed statistical methods to evaluate possible relationships between the prevalence of English sole with liver lesions and the chemical composition of the sediment in areas from which the affected fish were captured. In one method, the sampling stations were arranged into eight groups on the basis of statistical considerations. The highest prevalences of English sole with these lesions were found at stations in two groups. These groups were characterized as having high concentrations of sediment-associated metals and aromatic hydrocarbons. This apparent association between the prevalence of these liver lesions and the sediment concentrations of the two classes of chemicals was supported by the results of another statistical test. The prevalence of English sole with liver tumors and certain other lesions was positively correlated with the relative sediment concentrations of aromatic hydrocarbons and metals, whereas the prevalence of the species with "preneoplastic lesions" was positively correlated only with aromatic hydrocarbons. However, it should be mentioned that English sole are mobile, which must be borne in mind in evaluating the data.

In Puget Sound, urban-associated lesions in shrimp and crabs were limited to necrotic lesions of the gills. Affected shrimp were most prevalent in the Hylebos Waterway, in the upper portion of the Duwamish

Waterway, and in Sinclair Inlet. Crabs with gill necrosis and related abnormalities were most prevalent in the Duwamish Waterway.

The abundance of fish, and the number of fish species, were generally higher in the estuarine bays (Commencement and Elliott Bays) compared to the inlets and open bays. For sediment-dwelling invertebrates, the average highest species richness values were found in the reference areas, e.g., Port Madison, and the outer portions of the estuarine bays, e.g., West Point. The lowest values were in sediments from the urban waterways, e.g., Hylebos Waterway, and inner portions of the urban associated areas, e.g., Budd Inlet. Thus, it appears that disruptions of community composition or structure are related to the stresses of pollution in the industrial areas.

The findings indicated that hundreds of chemicals are present in Puget Sound sediments in trace amounts from as far north as Bellingham Bay to as far south as Budd Inlet (near Olympia). Many of the chemicals are also found in a variety of benthic and pelagic organisms; the question of the threat they pose to these organisms or to the human consumer is not known at present and con only be determined through further research.

Efforts to keep track of pollution in Puget Sound and understand its effects on the resource and the consumer of fishery products will require the following approaches:

The identification of types and concentrations of chemicals, emphasizing accumulations in important marine organisms; the identification of chemicals responsible for altering the health of Puget Sound marine life; the evaluation of the health of marine life through laboratory studies and by monitoring chemical accumulations and biological changes in so-called "indicator" organisms placed in enclosures around Puget Sound; studies of risk assessments to evaluate possible threats to human health; and the establishment of procedures for coordination of activities and dissemination of information among agencies responsible for protecting marine life and human health.

Some of the problems we face in studying the effects of pollution on marine environments have been described, together with selected examples of our findings. Some of our efforts have directly influenced decisions relating to the effects, or potential effects, of pollution on fisheries and their enjoyment. We have provided data and testified at an Adjudicatory Hearing for NOAA on a proposed refinery at Eastport, Maine (Pittston Co.); presented testimony on the Disposal of Dredge Spoil from New York Harbor at the Hearing of the Committeee on Merchant Marine and Fisheries, U.S. House of Representatives; contributed data to and participated in preparation of a synthesis document for the Bureau of Land Management on impacts of petroleum on proposed oil and gas lease areas of Alaska, e.g., Norton Sound and St. George Basin; presented data and testified at the Washington State Energy Facilities Site Evaluation Council Hearing on the proposed Northern Tier Pipeline and contributed to the position of the National Marine Fisheries Service to deny the application; and provided data and advised state and local agencies on continuing problems of chemical pollution in Puget Sound.

CONCLUSION

Overall, it can be argued that the only rational way to protect our fishery resources from the adverse impacts of human activities is through increased understanding and the development of national positions and actions based on that understanding. In all of our efforts in the Environmental Conservation Division, we have been, and will continue to be, acutely conscious of the role we play--which is the acquisition and scientific interpretation of credible data that contribute to balanced administrative decisions on the use and enjoyment of our nation's fishery resources.

REFERENCES

CLARK, ROBERT C., JR., BENJAMIN G. PATTEN, and EDWARD E. DENIKE.
1978. Observations of a cold-water intertidal community after 5 years of a low-level, persistent oil spill from the General M. C. Meigs. J. Fish. Res. Board Can. 35(5):754-765.

HAWKES, J. W., and C. M. STEHR.
In press. Cytopathology of the brain and retina of embryonic surf smelt (Hypomesus pretiousus) exposed to crude oil. Environ. Res.

HODGINS, H. O., W. D. GRONLUND, J. L. MIGHELL, J. W. HAWKES, and P. A. ROBISCH.
1977. Effect of crude oil on trout reproduction. In Douglas A. Wolfe et al. (editors), Fate and effects of petroleum hydrocarbons in marine ecosystems and organisms, p. 143-150. Pergamon Press, Oxford/New York /Toronto/Sydney/Paris/Frankfurt.

KRAHN, MARGARET M., DONALD W. BROWN, TRACY K. COLLIER, ANDREW J. FRIEDMAN, RAND G. JENKINS, and DONALD C. MALINS.
1980. Rapid analysis of naphthalene and its metabolites in biological systems: determination by high-performance liquid chromatography/fluorescence detection and by plasma desorption/chemical ionization mass spectrometry. J. Biochem. Biophys. Methods 2(4):233-246.

KRAHN, MARGARET M., JEROME V. SCHNELL, MARIANNE Y. UYEDA, and WILLIAM D. MACLEOD, JR.
1981. Determinations of mixtures of benzo[a]pyrene, 2,6-dimethylnaphthalene and their metabolites by high-performance liquid chromatography with fluorescence detection. Anal. Biochem. 113(1):27-33.

MACLEOD, WILLIAM D., JR., MARIANNE Y. UYEDA, LAWRENCE C. THOMAS, and DONALD W. BROWN.
1978. Hydrocarbon patterns in some marine biota and sediments following the Argo Merchant spill. In In the wake of the Argo Merchant, proceedings of a symposium held January 11-13, 1978, p. 72-79. Univ. R. I., Kingston, Cent. Ocean Manage. Stud.

MALINS, DONALD C.
1980. Pollution of the marine environment. Environ. Sci. Technol. 14(1):32-37.

MALINS, DONALD C.
1981. The chemical and biological degradation of petroleum: a foremost challenge for the analytical chemist. In Petroleum and the Marine Environment, proceedings of the Petromar 80 conference in Monaco sponsored by Eurocean (Association Europeenne Oceanique), p. 319-343. Graham & Trotham Ltd., London.

MALINS, DONALD C., and HAROLD O. HODGINS.
1981. Petroleum and marine fishes: a review of uptake, disposition, and effects. Environ. Sci. Technol. 15(11):1272-1278, 1280.

MALINS, D. C., M. M. KRAHN, D. W. BROWN, W. D. MACLEOD, JR., and T. K. COLLIER.
1980a. Analysis for petroleum products in marine environments. Helgol. Meeresunters. 33(1-4):257-271.

MALINS, DONALD C., BRUCE B. MCCAIN, DONALD W. BROWN, ALBERT K. SPARKS, and HAROLD O. HODGINS.
1980b. Chemical contaminants and biological abnormalities in Central and Southern Puget Sound. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Off. Mar. Pollut. Assess., NOAA Tech. Memo. OMPA-2, 295 p. (Available from U.S. Dep. Commer., Natl. Tech. Inf. Serv., Springfield, Va., as PB81-1558-97).

MCCAIN, B. B., H. O. HODGINS, W. D. GRONLUND, J. W. HAWKES, D. W. BROWN, M. S. MYERS, and J. H. VANDERMEULEN.
1978. Bioavailability of crude oil from experimentally oiled sediments to English sole (Parophrys vetulus), and pathological consequences. J. Fish. Res. Board Can. 35(5):657-664.

MCCAIN, B. B. and D. C. MALINS.
In press. Effects of petroleum hydrocarbons on selected demersal fish and crustacea. In Ecological stress and the New York Bight: science and management. Estuarine Res. Fed., Columbia, S.C.

MCCAIN, BRUCE B., KENNETH V. PIERCE, S. R. WELLINGS, and BRUCE S. MILLER.
1977. Hepatomas in marine fish from an urban estuary. Bull. Environ. Contam. Toxicol. 18(1):1-2.

VARANASI, USHA, and DENNIS GMUR.
1981. Hydrocarbons and metabolites in English sole (Parophrys vetulus) exposed simultaneously to [^{3}H]benzo[a]pyrene and [^{14}C]naphthalene in oil-contaminated sediment. Aquat. Toxicol. 1(1):49-67.

WOLFE, D. A., R. C. CLARK JR., C. A. FOSTER, J. W. HAWKES, and W. D. MACLEOD, JR.
1981. Hydrocarbon accumulation and histopathology in bivalve moluscs transplanted to the Baie de Morlaix and the Rade de Brest. In Amoco Cadiz, consequences d'une pollution accidentelle par les hydrocarbures (Amoco Cadiz, fates and effects of the oil spill), p. 599-616. Cent. Natl. Exploit. Oceans, Paris, France.

Effects of Environmental Degradation on the Freshwater Stage of Anadromous Fish

Wesley J. Ebel [1]

INTRODUCTION

This chapter traces the Northwest and Alaska Fisheries Center's (NWAFC) research on environmental aspects from 1931 to the present. Most of this research effort focused on providing information to describe the effects of various environmental perturbations which existed or were predicted to occur. Some of these studies led to establishment of criteria for water quality standards for fish; other studies led to establishment of programs to provide solutions to environmental insults such as the fish passage problems caused by construction of dams.

EARLY RESEARCH EFFORTS (1931-50)

From 1931 to 1950, very little effort was expended on environmental studies because the projected level of development with exception of dam construction in the Pacific Northwest was not perceived to be of sufficient magnitude to cause serious environmental problems to the fishery resources. Most of the research effort of the laboratory was therefore centered on studies related to management of the various fisheries. As early as 1933, however, studies were begun to deal with the fish passage problems resulting from construction of Bonneville, Rock Island, and Grand Coulee Dams on the Columbia River. These studies included thorough surveys of tributary streams to determine distribution of salmonid populations in relation to installation of irrigation diversion screens, an evaluation of the relocation of the anadromous fish runs cut off by Grand Coulee Dam, and a review of available knowledge on fish facilities for passing salmon at dams (Stansby 1979).

The tributary surveys clearly showed the proper location for placement of irrigation diversion screens and eventually resulted in a major program of installation and evaluation of these screens throughout the Columbia River drainage. This program continues today.

The relocation of the anadromous fish runs cut off by Grand Coulee Dam began in 1939. It consisted of trapping adult salmon and steelhead and transporting them to holding areas where they matured, and the eggs could be taken and transferred to satellite hatcheries at Icicle Creek (near Leavenworth), Entiat, and Winthrop, Washington. Fish were reared to

1/ Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

smolting size at these sites and released into the Wenatchee, Entiat, and Methow River drainages; several years' evaluation of this program indicated conclusive success (Fish and Hanavon 1948; Fulton and Pearson 1981).

In later years, however, continued dam construction seriously reduced these and other fish runs in the upper Columbia River, and it became clear that adequate knowledge was not available to design efficient fish passage facilities at dams. Fish behavior studies were therefore initiated in 1950 to begin gathering the information needed to design both adult and juvenile fish passage facilities. Thus the NWAFC's first major research effort relating to environmental problems was centered on fish behavior work designed to find solutions to fish passage problems caused by dams.

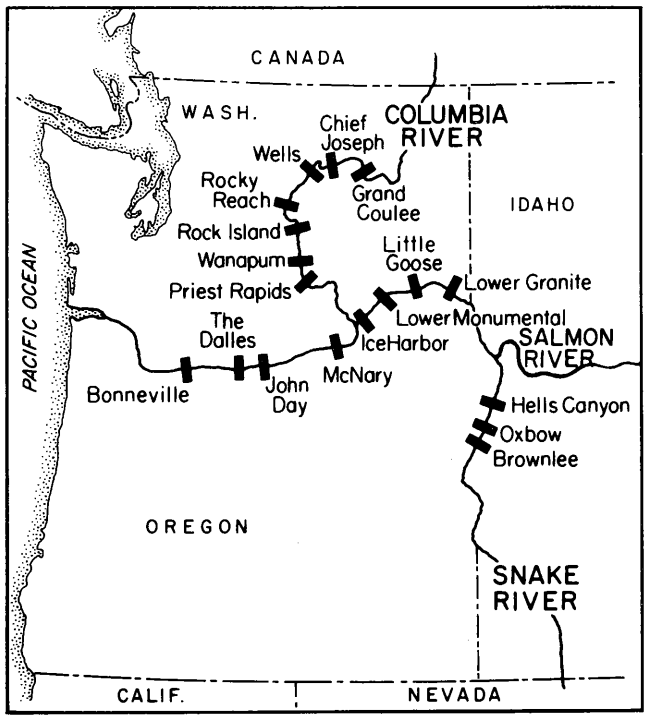


Figure 1
Location of main stem dams in the Columbia River Basin.

FISH PASSAGE RESEARCH (1950-81)

By 1950, the large scale development of the Columbia River Basin for hydroelectric power was underway. Three huge dams affecting anadromous fish were already in operation (Rock Island, Bonneville, and Grand Coulee), and 15 more major dams, which would seriously threaten the survival of salmon and steelhead runs, were being proposed (Figure 1).

For the next three decades, scientists of the Coastal Zone and Estuarine Studies (CZES) Division (formerly Fish Passage Research Program) of the NWAFC and its predecessor agencies were engaged in large scale research efforts to obtain information related to the behavior, abilities, and physiology of the migrant fish. The dams produced sudden, enormous changes in the environment of anadromous fish: huge lakes replaced swift flowing rivers; spawning grounds were inundated; water temperature regimes were modified; predator, competitor, and disease relations were upset; and food supplies were affected. The necessity for providing safe passage over the physical obstructions of dams was an obvious reality. Of equal importance was the need to protect the fish when the changes made by dams in the basic environment were too severe. Because there were to be many dams, the cumulative effect of small losses, injuries, or delays at each dam became a serious threat.

Adult Fish Passage at Dams

Although fishways had been in use for many years the large scale fishway construction necessary on the Columbia River, and the variety of new situations that had to be faced, required more information on fish behavior and abilities than was available. Some of the questions that needed to be answered were surprisingly simple, such as: At what rate do fish ascend fishways? What is the maximum water velocity through which fish can swim? How does light affect the rate of ascent in fishways? Other questions had a direct bearing on the cost of fishways, such as: How large a fishway is needed for a given number of fish? How steep can a fishway be without causing fish to tire or fail to ascend? How long can a fishway be without fatiguing fish? To gain answers to these and similar questions, a special laboratory for fishery-engineering research was constructed at Bonneville Dam (Collins and Elling 1960). Here it was possible to measure the reactions of anadromous fish under controlled experimental conditions while the fish were actually migrating. Fish were diverted from one of the major fishways into the laboratory (Figures 2 and 3) where their responses to full-scale fishway situations were observed and recorded. Fish then swam out of the laboratory to continue their migration upstream.

Experiments conducted at the laboratory provided data on the spatial requirements of salmon in fishways (Elling and Raymond 1959), on rates of movement of fish ascending fishways, and on the effects of fishway slope (Collins et al. 1961) and fishway length (Collins et al. 1962) on fish performance. Scientists measuring both performance and physiological indices such as blood lactate and inorganic phosphate could find no evidence of fatigue from ascending fishways when proper hydraulic conditions were obtained (Conner et al. 1964). It was concluded that the ascent of a properly designed fishway was only a moderate exercise for fish, possibly similar to swimming at a "cruising" speed that can be maintained over long periods of time.

Tests to measure swimming abilities indicated that the critical velocity of water occurred at flows between 8 and 13 feet per second (fps) (Weaver 1962). Velocities above this range proved to be an obstacle to a significant number of fish, although some individual fish had a much greater ability. The maximum observed swimming speed was 26.7 fps by a steelhead trout.

Examination of fish preferences for light conditions revealed marked differences in species (Long 1959). Steelhead, given a choice of light and dark channels, selected a dark channel. Chinook salmon appeared indifferent under the same conditions and moved randomly into both light and dark channels. Steelhead moved more quickly through fishways that were darkened yet--in passing through pipes and open channels--showed an increase in passage speed when light was added (Slatick 1970). Presented with a choice of channels with a high velocity (13 fps) and a low velocity (3 fps), both salmon and steelhead showed a strong preference for the high velocity.

Full-scale models of complete fishway designs (Figure 4) were tested n the laboratory before being put into use at a dam. Even after being constructed at a dam, new fishway designs were carefully evaluated in actual operation (Weaver et al. 1972).

The search for information on the

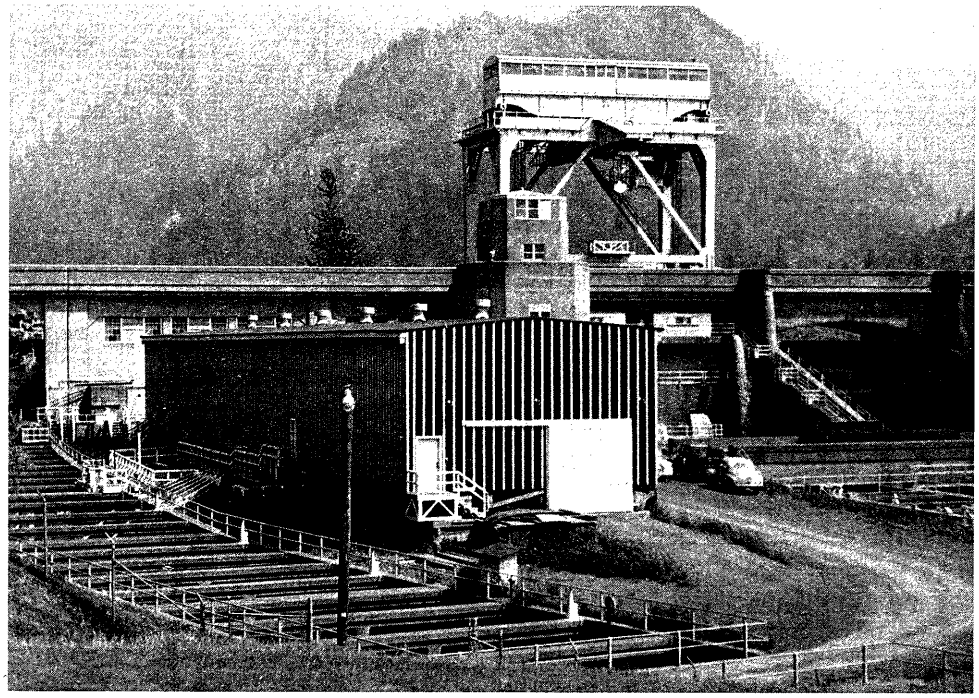


Figure 2
Fisheries-Engineering Laboratory adjoining Washington-shore fishway at Bonneville dam.

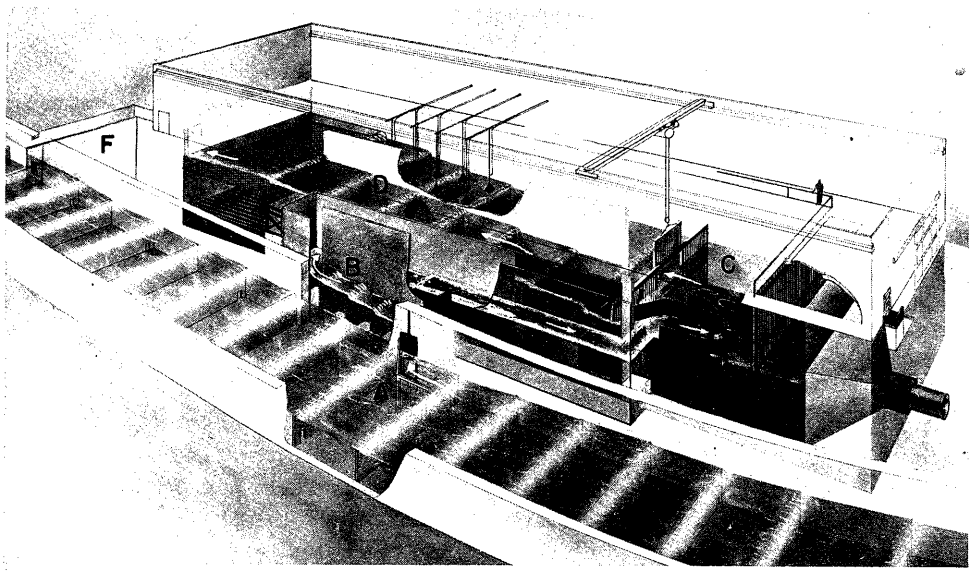


Figure 3
Sketch of Fisheries-Engineering Research Laboratory showing its relationship to the Washington-shore fishway. Fish are diverted from the main fishway by a picketed lead (A) and ascend the entrance fishway (B) to a collection pool (C) in the laboratory. After release, they pass through an experimental area (D) to the flow introduction pool (E) and then out the exit fishway (F) where they return to the main fishway.

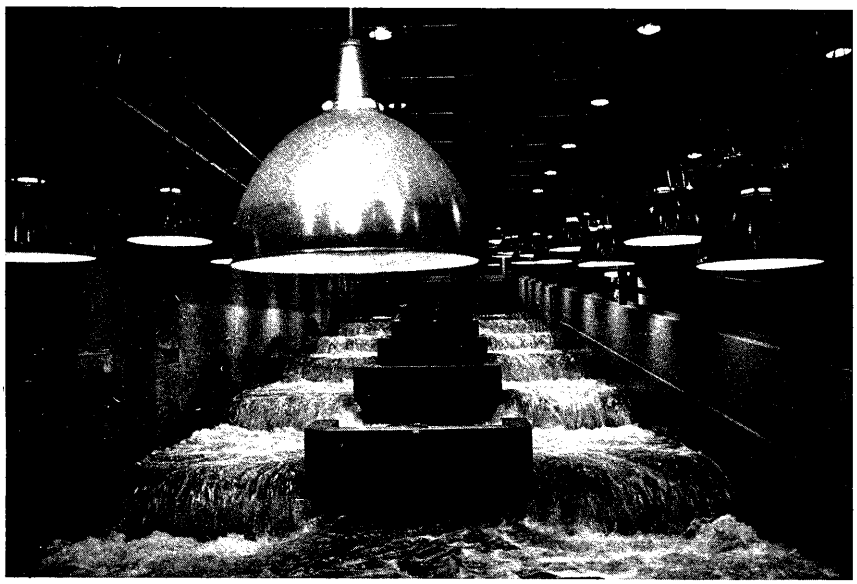


Figure 4
Ice Harbor design fishway in operation in the Fisheries-Engineering Laboratory.

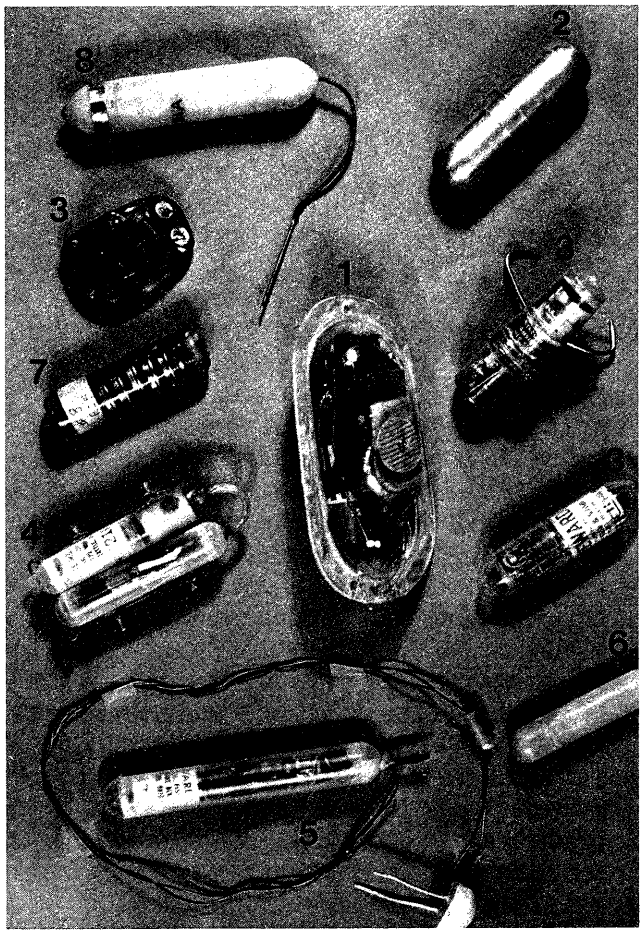


Figure 5
Electronic tags: (1) first sonic tag, (2, 3) early model external sonic tags, (4) twin back-pack sonic tag, (5) sonic tag (crystal fastened on fish's snout, (6) temperature sensitive sonic tag, (7) current model internal sonic tag, and (8) radio tag.

Figure 6
Manned radio tracking station at Lower Monumental Dam.

The search for information on the behavior of adult fish was also extended into river situations. Individual fish were tracked by means of sonic and radio tags (Figures 5 and 6) to determine their patterns of movement approaching dams, under a variety of flow conditions, for improving the design and placement of fishway entrances (Monan et al. 1975). Tracking studies of fish movements after leaving fishway exits showed the importance of the proper location of fishway exits because of the possibility of the fish being swept back downstream over the spillway of the dam (Monan and Liscom 1975).

Juvenile Passage at Dams

Young salmon migrants on their way to the sea in the Columbia River may have to pass over as many as nine major dams. Losses of juveniles that passed downstream over spillways were found to be generally very small. For young fish that passed through the turbines, however, the hazards were great. From 9 to 30% of the fish passing through the turbines were lost at each dam from direct and indirect factors (Bell et al. 1967; Long et al. 1968).

Fish guiding.--A major research effort was undertaken by NWAFC scientists to find a way to divert young migrants away from turbine intakes. Laboratory and field studies included the use of electricity, lights, louvers, water jets, air jets, traveling screens, and sound.

Investigations into the use of electricity included studies of electrical parameters harmful to fish (Collins 1952), most effective in creating electrotaxis (Collins et al. 1975), and eliciting sensory avoidance responses. Success in laboratory

experiments led to large-scale field tests of the use of pulsed direct current to guide downstream migrants (Figure 7) (Pugh et al. 1970). Limitations to the practical use of electrical guidance in diverting fish from turbines became apparent. Major field applications required guiding migrants of several species over a broad range of sizes. Voltages needed to affect the small fish were lethal to large fish and, therefore, a sequence of electrical fields was required necessitating elaborate systems of electrodes (Collins et al. 1975). Guiding effectiveness of electricity for all juveniles decreased rapidly as the water velocity increased, thus limiting its potential application to situations where flow could be controlled to less than 1 fps.

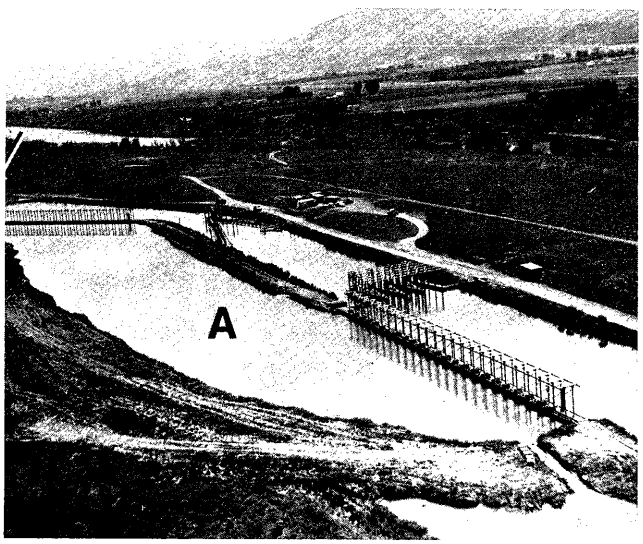


Figure 7
Physical facilities of experimental fish-guiding site at Prosser, Washington. Waterflow is from right to left. Experimental canal (A) had v-type electrode array, an array trap, and a water-velocity control structure to divert excess flow through a water-bypass channel which was screened at both ends to prevent entry of fish. Arrow points to rotary drum screens used to evaluate fish-guiding efficiency of electrical field created by electrode array.

Experiments to guide downstream migrants with louvers in large-scale mixed and floating installations revealed that louvers were practical only where water flows could be carefully controlled and floating debris was not a problem (Bates and Pesonen 1960). Electrical fields tested in conjunction with louvers proved to be no more effective than louvers alone (Pugh et al. 1967).

The capacity of jets of water and air to guide young migrants was examined. Although water jets were effective in diverting fish at appropriate approach velocities, the angle of array and jet pressure, the extensive maintenance of equipment, and the high volumes of water required made this technique impractical. A screen of bubbles created by air jets diverted young migrants effectively during daylight, but poorly during darkness (when most fish migrate) even when the bubble screen was lighted. The poor results in darkness precluded the use of this device as a functional method for collecting fish.

Sound, as a medium for guiding fish, was also explored in the laboratory and under field conditions. Broad-spectrum noisemakers did not divert fish successfully, but specific high intensity frequencies produced orientative responses. A maximum avoidance response was obtained with the low frequencies of 35 to 170 Hz but problems associated with practical application precluded its use in large-scale installations at dams (Vanderwalker 1967).

Arrays of fixed and moving lights were also examined for their potential in guiding young fish. They were found to be relatively ineffective during bright daylight and also during periods of high turbidity which are frequent at

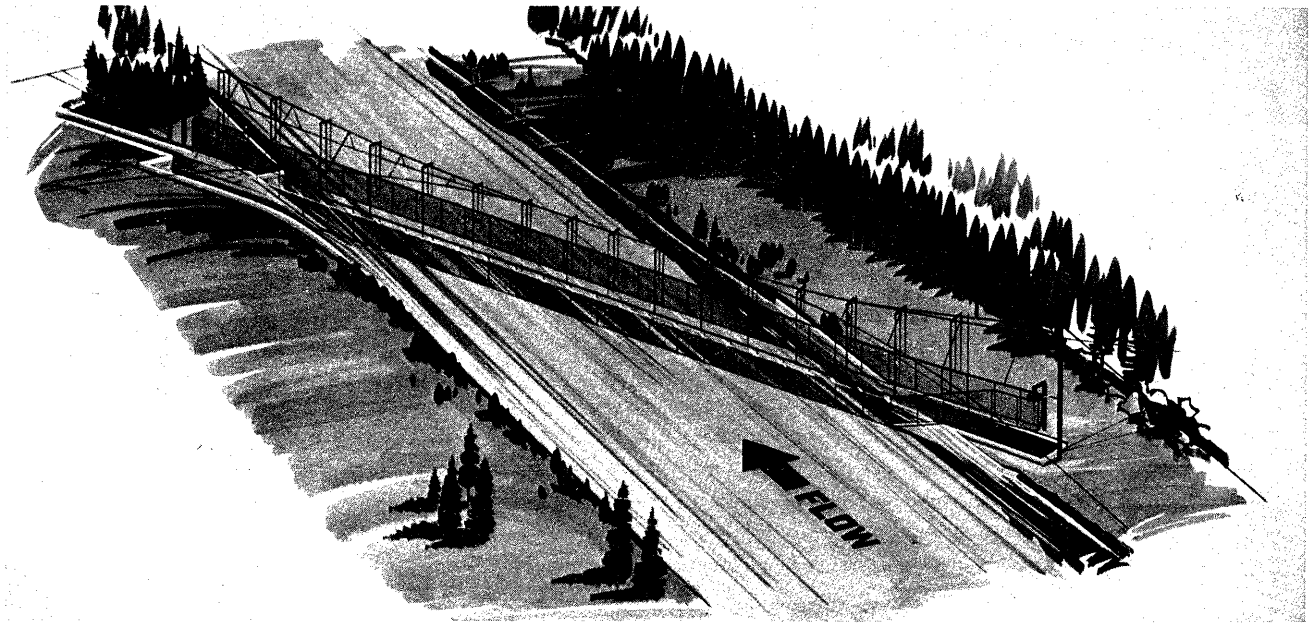


Figure 8
Sectional view of model v screen installed and tested during 1967 in the Stanfield Irrigation Canal, a diversion of the Umatilla River near Echo, Oregon.

the time of major juvenile migrations in the Columbia and Snake Rivers.

Rotary screens had been used successfully on a number of installations on the tributaries of the Columbia and Snake Rivers to prevent young migrants from entering irrigation water diversions. The technical problems involved and the cost of such fixed mechanical devices for screening entire turbine intakes on a main stem dam made this approach impractical. A continuously traveling screen suspended at an angle to the stream flow to divert young fish was tested at the Stanfield Irrigation Canal near Echo, Oregon, (Figure 8) (Bates 1970). Although successful in diverting fish in a 28-ft wide flume in velocities up to 6 fps, it presented significant engineering and cost problems when extrapolated to a full size installation at a major dam.

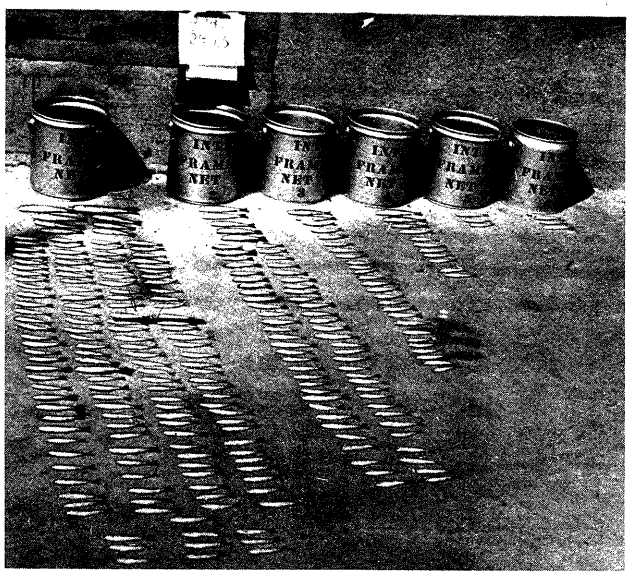
Turbines.--At the same time that studies were undertaken to find a practical way to divert downstream migrants away from turbine intakes, another large-scale research effort was directed toward evaluating and reducing losses of young fish that were passing through the Kaplan turbines used on the Columbia River. A giant recovery net that strained the entire discharge of a turbine was developed for use at Bonneville Dam. Distribution of fingerlings in the turbine intake was measured (Figure 9), and through the use of specially designed release capsules and the recovery net, the relation of distribution to injury was studied (Long and Marquette 1967). The nature and extent of the injuries to juvenile migrants passing through turbines was detailed and related to various modes of turbine operation. Several techniques to reduce mortality, including entrained air, were tried, but none sufficiently reduced turbine mortalities.

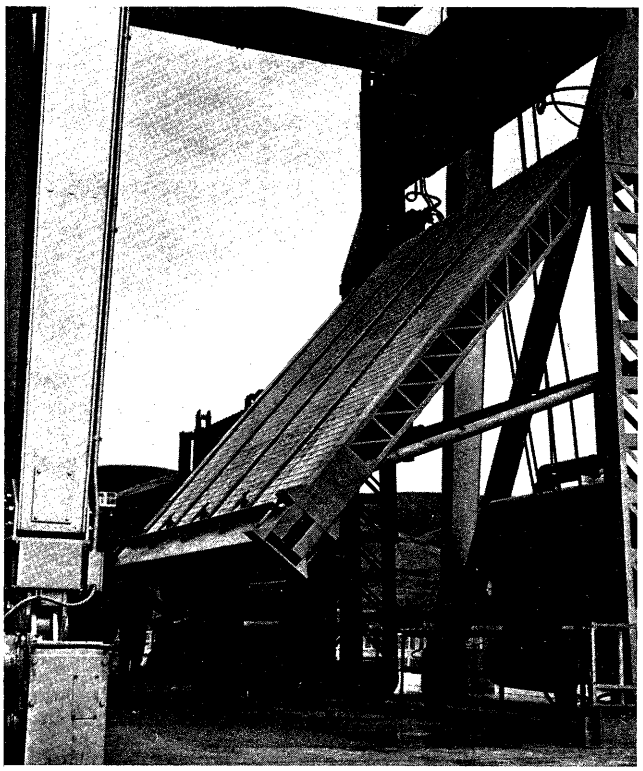
Because fish were concentrated near the ceiling of the turbine intake, a system for diverting juveniles out of the turbine intake through the use of a specially designed traveling screen was feasible (Figure 10) (Smith and Farr 1975; Matthews et al. 1977). A diversion system was developed that took advantage of existing gatewells, used for storing gates for unwatering turbines, to collect the fish for subsequent passage around the dam. Once the fish had bypassed the dam, they were returned to the river to

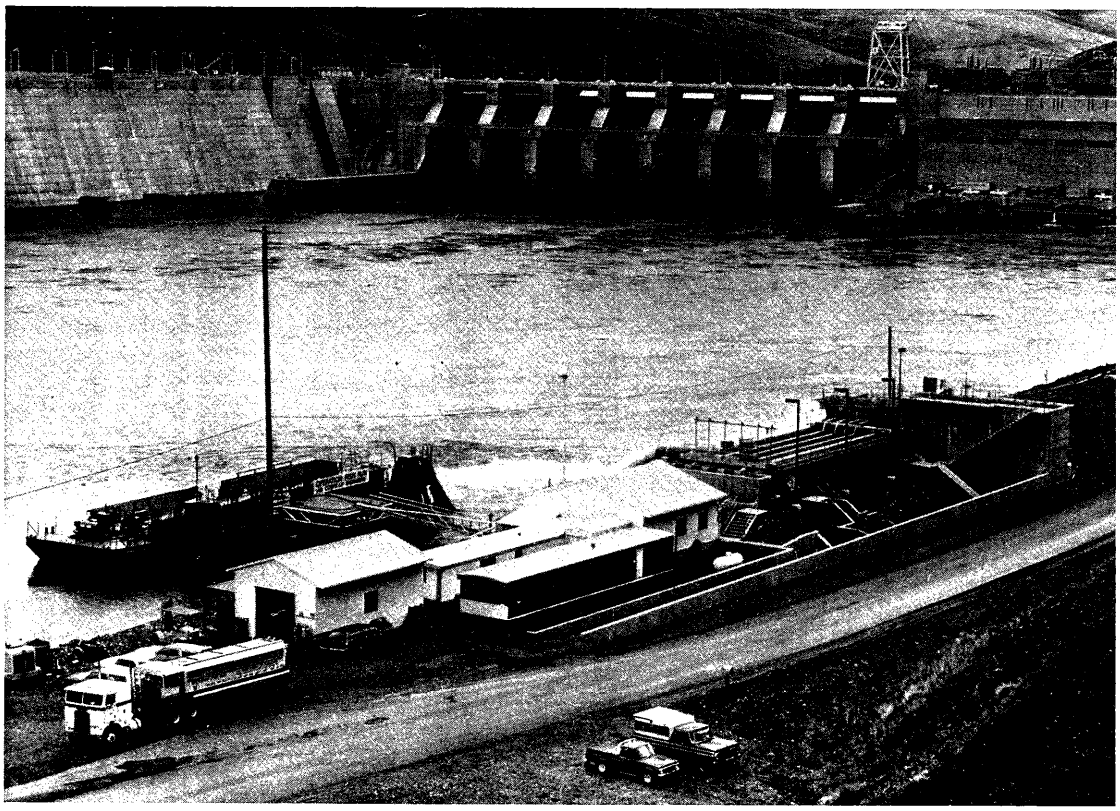
Figure 9 (top left)
Actual catch of juvenile salmonid migrants in fyke nets placed in turbine intakes at Bonneville Dam.

Figure 10 (top right)
Traveling screen developed by NMFS for collection of juvenile salmon from turbine intakes.

Figure 11 (bottom)
At dams juvenile fish can be loaded into trucks or barges for transport to release sites below Bonneville Dam.







continue their migration or were transported downriver by barges or trucks (Figure 11). Research designed to improve this type of diversion and bypass system is currently in progress. Additional research is also underway to devise other methods for bypassing fish. These include 1) use of scanning sonar to detect abundance of fish at dams so that operations of the dam can be modified (such as turning off turbines and spilling water) to pass juvenile fish and 2) development of simpler diversion devices such as stationary screens and forebay skimmers for diversion of fish from the turbine intakes (Krcma et al. 1980).

Passage Through Impoundments

One basic question that had to be answered was whether the impoundments behind the dams were in themselves barriers to the migration of fish. The ability of adult salmon and steelhead to move through the impounded river was assessed by the analysis of differences in counts at Rock Island Dam over a 27-year period from 1933 to 1960. It was found that the counts of adult chinook, sockeye, and coho salmon and steelhead at Rock Island Dam did not change significantly in 27 years, in spite of the creation of four impoundments and dams downstream (Zimmer and Davidson 1962).

Assessment of the ability of adult chinook salmon to pass through a large impoundment was made at the 57-mile long Brownlee Reservoir (Trefethen and Sutherland 1968). Fish, with sonic tags attached, released in the reservoir near the dam passed through the impoundment, reached the spawning grounds, and spawned successfully. Other studies carried out in reservoirs formed by lower head dams (100 ft or less) in the Columbia River also indicated that passage of adults through these impoundments was not a serious problem.

Juvenile migrants were not as fortunate in migrating through the large reservoirs behind high dams. Research studies made in the Brownlee Dam impoundment showed that adult fish were able to migrate through the long reservoir successfully, but the young fish found conditions too severe. A high degree of thermal stratification develops in the reservoir with surface temperatures reaching levels lethal to young salmon while the cooler subsurface water becomes deficient in oxygen (Raleigh and Ebel 1968). The impoundment, for all practical purposes, was an impassable barrier for juvenile salmon and steelhead.

Research on the effects of the impoundments behind "river run" dams (all about 100 ft high) on the Columbia River showed that the average impoundment delayed young migrants about 3 days (Raymond 1968). The freshets and floods that had rapidly carried young fish to the sea were being controlled. Thus, a favorable seasonal occurrence under which juvenile salmonids had evolved had been eliminated. In the impoundments, the water (and the fish) moved more slowly. Studies showed that fish from the upper river were delayed almost a month in reaching the estuary (Ebel et al. 1979). This delay in migration through the river extended the exposure of the young fish to hazards such as disease and predation.

Temperature regimes in the river, because of the greater surface area and volume of the impoundments, shifted and increased during the late summer and early fall when high water temperatures can become critical, particularly to adult spawning salmonids. The habitat

of many of the salmon's competitors and predators was improved. Passage success of juvenile salmonids related to 1) the length and volume of the impoundment, 2) the relative volume of flow through the impoundment at the time of migration, and 3) both the physical and biological environment in the impoundment.

A recent analysis, relating the size of adult populations returning to the Snake River to the passage conditions they encountered as juveniles showed that adult return percentages were well correlated with survival rates of corresponding juvenile smolt populations that had produced the adults (Raymond 1979). For example, during two extremely low flow years (1973 and 1977) survival of juvenile migrants was estimated at <5%. The low survival was due to adverse conditions in the impoundments and the fact that all juvenile migrants had to pass through the turbines of seven or eight dams on their way to the sea. The corresponding adult populations returning during these years were at record lows. During high flow years (1971 and 1973), juvenile passage success was substantially higher and adult returns were correspondingly higher.

In the late sixties, however, studies revealed that substantial losses to juvenile migrant populations were occurring even during high flow years. These studies also revealed that supersaturation of atmospheric gases in the Columbia and Snake Rivers was widespread with levels reaching 143% during high flow periods (Ebel 1969). Gas bubble disease (Figure 12) caused by these high levels was prevalent among the juvenile and adult salmonid populations migrating at that time (Beiningen and Ebel 1970; Ebel 1971). Further investigation showed that large

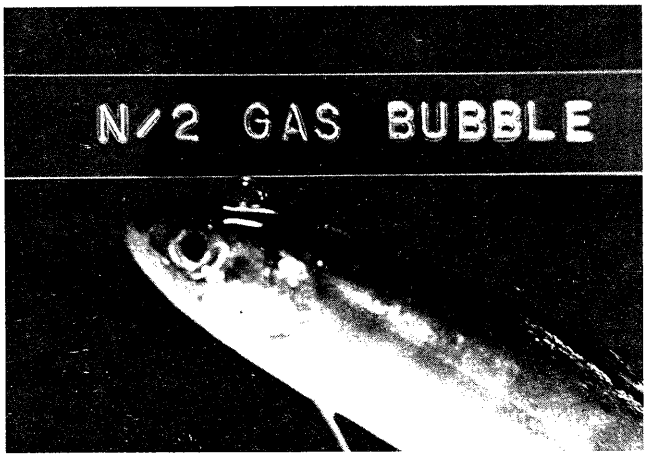


Figure 12
Juvenile salmon with gas bubble disease from the Columbia River.

volumes of water passing over the spillways of most of the dams completed at that time entrained air and plunged it to substantial depths and caused the widespread supersaturation. The long series of reservoirs formed by the dams prevented equilibration of the atmospheric gas, resulting in the exposure of juvenile and adult migrants to high levels of supersaturation over hundreds of kilometers of their migration route. Because of the seriousness of the situation, a large-scale, multi-agency effort was launched to solve the problem, with NWAFC researchers providing a majority of the research information (Johnsen and Dawley 1974). The problem was solved by installing spillway deflectors at key dams which prevented plunging and entrainment of air by the water being spilled (Figure 13).

Concurrently (1968), research was begun at Ice Harbor Dam to determine the feasibility of collecting smolts at dams and transporting them downstream as a method of reducing downstream losses (Ebel et al. 1972). The results of this early work were encouraging,

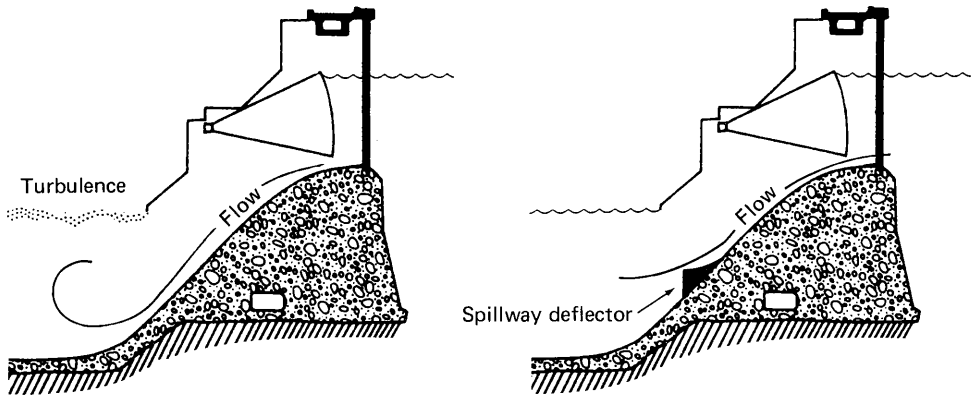


Figure 13
Diagramatic sketch of typical spillway deflector installed at key dams in the Columbia River.

and research continued at Little Goose Dam when it was completed in 1971 (Ebel 1979) and at Lower Granite Dam in 1975 (Park et al. 1980). The main objective of this research was to determine whether adult returns could be increased both to the fishery and to the parent stream or hatchery by collecting and transporting juveniles. It proved to be extremely successful for steelhead, and was sufficiently successful for chinook salmon to encourage the U.S. Army Corps of Engineers (CofE) to begin a major collection and transport operation from Little Goose, Lower Granite, and McNary Dams (Smith et al. 1981). This effort continues, along with research which is now centered on studies designed to improve the system for chinook salmon.

Because of the success of the work with naturally migrating smolts, research was initiated in 1978 to determine the homing imprint requirements that would allow transportation of various species of salmonids directly from hatcheries without impairing the fish's homing abilities. The primary objectives of the homing research are as follows: 1) determine whether homing requires a single imprint or a series of stimuli (sequential imprinting) for various stocks of salmonids; 2) determine a triggering mechanism to activate the homing imprint in salmonids; and 3) determine the relationship between the physiological condition of fish and their ability to imprint, e.g., by measuring gill Na^+-K^+ ATPase activity, etc. The ability to activate the imprint mechanisms at the proper time should assure a suitable homing cue that, coupled with transportation, should result in high smolt survival and ensure adequate return to the homing site or hatchery.

Preliminary adult return data from experiments conducted in 1978 and 1979 show that transporting the fish under various treatment conditions resulted in improved survival, but homing to the parent hatchery was diminished (Slatick et al. 1981). There was, however, one notable exception. Steelhead trucked from Dworshak Hatchery, held in the Clearwater River, and then subsequently barged to a release location downstream from Bonneville Dam returned at a higher rate at all locations (the fishery below Bonneville, the sport fishery in the Clearwater River, and Dworshak Hatchery) than controls released at the hatchery. These data suggest that if the proper treatment can be isolated, it is possible to transport directly from a hatchery to

downstream locations and still maintain suitable homing to the parent hatchery. Additional research into this area is obviously needed and continues at this time.

Effect of Temperature Changes

The passage of the Federal Water Quality Act of 1965 required the establishment of water quality standards for protection of aquatic life throughout the United States. In the process of establishing standards during 1958-68, state and federal water pollution control agencies recognized water temperature as an important factor affecting aquatic life. In attempting to define temperature requirements in the standards, however, pollution control authorities found that information was insufficient on the precise limits needed to protect various aquatic ecosystems.

The Columbia River Thermal Effects Study was initiated in 1968 in response to the specific problem of inconsistent temperature standards adopted for the Columbia River by Oregon and Washington (Environmental Protection Agency et al. 1971). To resolve these inconsistencies, improved knowledge on temperature requirements of the Columbia's Pacific salmon and improved techniques for evaluation and prediction of temperature in the Columbia system were needed.

About the time these standards were established, public and private electric power interests in the Northwest announced forecasts of vastly increased power demands. The hydroelectric power potential of the Northwest was nearly exhausted, and thermal power sources were planned to meet future needs. This presented further potential for modification of the thermal regime of the Columbia River system. Initially, power producers assumed they could use Columbia River system waters for once-through cooling at thermal power plants. The prospect of numerous discharges of large quantities of heated effluents to inland waters made it imperative to obtain better information as quickly as possible to establish temperature standards that could be defended with adequate scientific data.

Center scientists participated in this multi-agency study and contributed a substantial portion of the information obtained. Research by Center scientists included studies on adult salmon behavior in relation to river temperatures (Monan et al. 1975; Stuehrenberg et al. 1978), thermal tolerance of juvenile salmonid and nonsalmonid fish (Snyder et al. 1970), thermal tolerance of salmonids in relation to nitrogen supersaturation (Ebel et al. 1971), thermal shock and survival of juvenile salmonids (Snyder 1970), effects of temperature acclimation on resistance to thermal challenge (McConnell and Blahm 1979), thermal tolerance of zooplankton (Craddock 1970), timing and movement of juvenile salmon (Raymond 1969), and temperature prediction (Water Resources Engineers 1969).

Studies on adult migrational behavior showed that fish ceased migrating into the Snake River from the Columbia River when the temperature of the Snake River exceeded the Columbia River by about 5°C and that generally upstream migration slowed or ceased at temperatures exceeding 21.1°C.

Thermal tolerance of juvenile chinook, chum, coho, and sockeye salmon and steelhead was tested at the Prescott Field Station located on the lower

Columbia River. Columbia River water, with ambient water quality changes, was used to determine whether temperature tolerances determined in the existing water quality of the Columbia River differed from previously published data obtained in other laboratories.

Generally, the tests showed that thermal resistance was reduced by 3° to 5°C from previously published laboratory findings. The occurrence of supersaturation of atmospheric gas in the water, at the time most of the tests were performed, was determined to be the most important factor reducing temperature tolerance. This was confirmed in the laboratory in a controlled test.

Thermal tolerance tests conducted on nonsalmonids included eulachon, yellow perch, threespine stickleback, and white sturgeon. Eulachon were less tolerant than salmonids, whereas yellow perch, threespine stickleback, and sturgeon were more tolerant. There were no previously published data for comparison; LD 50s ranged from 22°C for eulachon to 34°C for yellow perch.

Tests of thermal shock were also conducted on juvenile salmon and trout. These tests were performed to simulate passage of fish through thermal effluent produced by a nuclear power plant. Test temperatures ranged from 26° to 30°C, a range known to represent temperatures that could be produced by the currently designed power plants. Generally, the tests showed that 50% mortality usually occurred within 2 hours of exposure. This was believed to be much longer than natural migrants would be exposed in a thermal plume, unless the reactor was located in the lower river where flow reversals occur and the fish would be held in the plume for an extended duration.

At the laboratory in Seattle, yearling sockeye and coho salmon and steelhead were tested to determine the effects of previous temperature acclimation on their resistance to high temperatures. The fish were acclimated to 5°, 10°, 15°, 20°, and 23°C. They were tested at 28°, 30°, and 32°C.

At all test temperatures the trend, as acclimation temperature increased, was toward increased resistance to loss of equilibrium and to death. Resistance was highly positive at 28°C, much less at 30°C, and barely evident at 32°C, suggesting that 28°C is perhaps a critical upper limit for acclimation to significantly influence resistance to heat.

Studies on timing, distribution, and movement of juvenile salmon in relation to river temperatures were conducted throughout the Columbia and Snake Rivers to predict the possible effects of temperature increases at various locations and seasons of the year. Although the studies showed that peak migrations of salmon and steelhead occurred in May and June when effects of temperature increases would be minimal because of high river flow, substantial numbers of fish were present in the river from March to September. Notable was the major migration of fall and summer chinook salmon through the mid-Columbia (the Hanford area) in July and August when temperatures were often as high as 21.1°C. These studies also showed that a significant number of the fish were shore oriented, which also had a bearing on the effect that thermal plumes from nuclear plants might have on juvenile migrants.

Lethal temperature for the zooplankton Daphnia sp. and Bosmina sp., the most abundant cladocerans in the lower Columbia River, was found to be around

27°C; thus, standards set for salmonids would also protect these important cladocerans known to be a selected food source for many of the fish in the river.

A temperature prediction model was formulated for the Columbia River and proved to be quite accurate for average temperatures with a maximum error of 0.67°C. Center scientists provided much of the data for this model which was eventually formulated by Water Resources Engineers for the Federal Water Quality Administration (now EPA). The model showed that from April through November 1967, the existing Hanford reactor complex raised the simulated water temperature an average of 1.11°C at the confluence of the Snake River, which on initial observation did not appear to be a serious problem. However, fishery scientists from the Center showed that during periods of low flow and high atmospheric temperature, the potential increase was substantially greater than 1.11°C. In addition, it was pointed out that fish live in the river 24 hours a day, 365 days a year and are subjected to whatever temperature that prevails at any time. They are not fortunate enough to be subjected to only computed average temperatures.

In summation, as a result of this multi-agency effort, the conflict of standards for the Columbia River was resolved and optimum temperatures for production of fish resources in the Columbia River were recommended for migration routes, spawning areas, and rearing areas. The upper allowable temperature for any species of juvenile salmonid should be a minimum of 3°C below the ultimate, upper lethal temperature; 20°C was considered to be adverse for salmonids and 17°C was considered to be the upper end of the optimum temperature range for juvenile salmonids. Between 17° and 20°C, any increase in temperature was considered to be detrimental to juvenile salmonids.

ENVIRONMENTAL RESEARCH

Shortly after the passage of the Water Quality Act of 1965, other environmental laws (e.g., National Environmental Policy Act, 1970; Marine Resources Protection and Sanctuary Act, 1972; and the Clean Water Act, 1977) were passed. At about the same time, the Bureau of Commercial Fisheries was transferred from the Department of Interior to the newly established National Oceanic and Atmospheric Administration (NOAA) in the Department of Commerce and renamed the National Marine Fisheries Service. These events resulted in broader responsibilities in environmental areas for the NMFS Fishery Centers and the NMFS Regional Offices. As a result, additional research into various areas which were previouusly not included in the overall mission of the Bureau of Commercial Fisheries was inititated.

Offices of Habitat Investigation, Marine Pollution, and Environmental Research laboratories were established in NOAA, and increased investigative responsibilities were assigned to the Centers. These investigations included baseline habitat studies, studies to determine the effect of various pollutants, studies to evaluate proposed developments involving dredging in estuaries, and studies to evaluate natural disasters such as hurricanes and the eruption of Mount St. Helens.

NWAFC scientists have concentrated on several programs designed to evaluate

the effects that major federal and nonfederal activities would have on resources of the Northwest. The following is a brief synopsis of some of the studies which have provided information to help protect and manage (enhance) the Columbia River aquatic resources.

Fire Retardants

Increased use of chemical fire retardants to combat forest fires in the Columbia River drainage caused concern by fishery agencies over the possible impact of these retardants on fish life, particularly juvenile salmonids. Center scientists determined the toxicity of these retarants to fish by use of flow-through bioassays. The results provided information which was used by the U.S. Forest Service, the Bureau of Land Management, and state agencies to establish more environmentally sound application practices (Blahm 1978).

Dredging

Maintenance of the Columbia River ship channel by the CofE requires dredging nearly 5 million yd^3 of material each year from the river below Bonneville Dam. Several studies have been conducted by Center personnel to determine the impact of this dredging on the fishery resources of the Columbia River (Blahm et al. 1979a). Several methods of dredging were assessed, e.g., flow-lane disposal (Blahm and McConnell 1979) and agitation dredging (Blahm et al. 1979b) for shallow channels. Studies indicated minimal impact if proper operating procedures were followed. The CofE now use the recommendations developed from these studies when dredging.

Creation of subtidal habitat from dredged material was also investigated (McConnell et al. 1978). The studies indicated that biological productivity, while not greatly increased in the test area, was not decreased. Emergent plants and upland grasses grew well, and suitable water-oriented bird habitat was created.

Offshore ocean disposal of dredged material was also investigated and provided the information for an environmental impact statement for this procedure (Durkin and Lipovsky 1977). The study indicated some temporary adverse effects to aquatic biota, but recovery was quite rapid in the disposal sites selected. Continued use of these sites, however, will require additional assessment.

Mining

Preliminary studies of black sand mining in the ocean near the Columbia River have indicated that very little impact will occur on the fishery resources. Because obstructions could inhibit the Dungeness crab fisheries at certain times of the year, the state of Washington has required a 2-year sampling program to be initiated as mining occurs.

Eruption of Mount St. Helens

The eruption of Mount St. Helens in May 1980 resulted in the deposition of millions of tons of ash, mud, and debris into the Toutle, Cowlitz, and Columbia Rivers. Scientists of NMFS were in a position to help assess the effects of the eruption because field studies were underway at the time. Data were obtained on changes in water quality, fish behavior and survival, and impacts of the clean-up procedures.

Water quality data indicated that temperature and turbidity in the Toutle and Cowlitz Rivers were lethal for fish from 1 to 2 weeks immediately after the eruption. Bioassays and field sampling in the Columbia River and its estuary indicated that turbidity was increased from a normal 5 to 1,680 Jackson turbidity units (JTU). Direct mortality of most aquatic organisms in the Columbia River and its estuary was not apparent; however, some benthic organisms were covered with silt. Behavior patterns of fish and other aquatic organisms were altered for a short period. For example, demersal organisms normally found near the bottom were captured near the surface, and frequency distribution patterns of juvenile salmon and steelhead entering the estuary were substantially changed.

Continued water quality sampling has indicated a steady decline in turbidity. Dredging and other clean-up activities conducted by the CofE was governed mainly by imminent threats of flooding; however, some aquatic degradation was minimized by altering clean-up procedures based on recommendations from the NMFS which were developed from the water quality monitoring. Scientists of NMFS will continue assessing the effect of the eruption to the extent possible.

Columbia River Estuary Data Development Program

Increased emphasis from all quarters for more development in the Columbia River estuary prompted the Pacific Northwest River Basins Commission to begin a 5-year, multi-agency estuarine study in 1979. The study was designed to provide information on various estuarine habitats for controlling agencies which make decisions on proposed developments. Adequate information on the impacts of these developments would allow decisions to be made which would minimize the adverse impact on aquatic resources.

The role of Center scientists in this study is to identify key fish species utilizing the estuary and determine their food habits and geographic and temporal distribution. The study is about 75% complete but was terminated in September 1981 because of budget cuts.

Oil Spill Response

Center personnel are also part of an oil spill response team set up to respond to oil spills in the Columbia River. The mission of Center personnel is to provide biological information to assess the impact of spills. In June 1978, an oil spill did occur and Center scientists responded with timely information on the biological impact. The impact was minimal, and clean-up operations conducted by the U.S. Coast Guard were efficient.

FISHERIES ENHANCEMENT (1969-81)

The Fisheries Enhancement Task of the NWAFC was begun in 1968 to conduct research in advanced fish culture technology and to increase the production of Columbia River salmon. In 1969, this emphasis was broadened to include many aspects of marine aquaculture; and the program was located at the Manchester Marine Experimental Station (Figure 14) near Manchester, Washington.

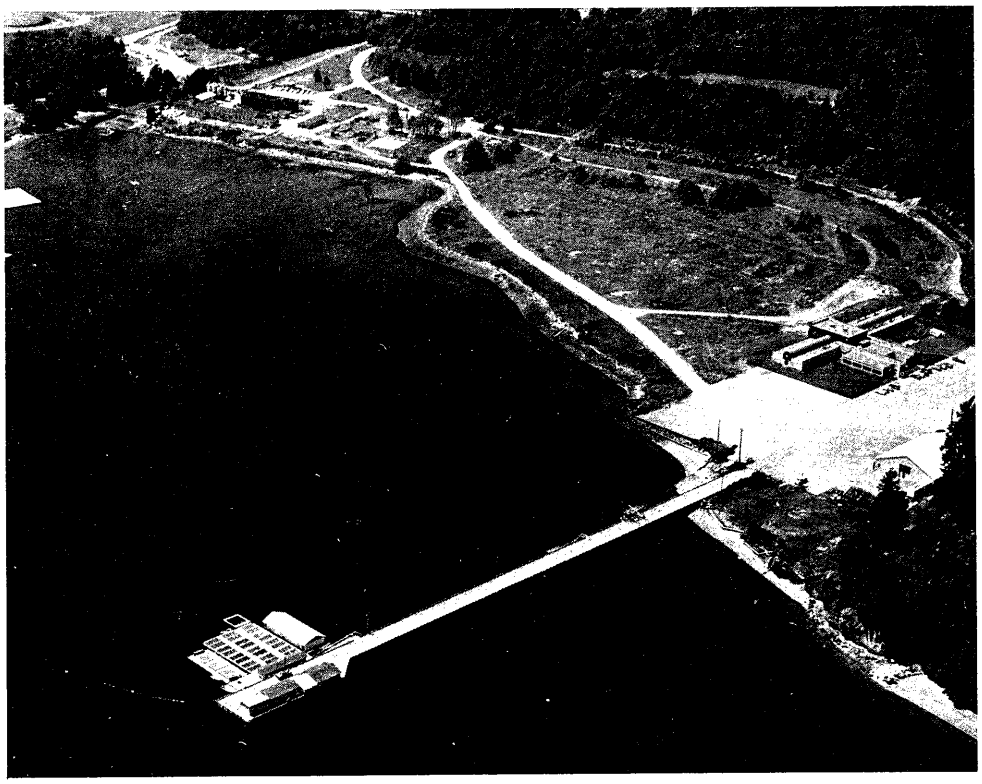


Figure 14
Manchester Marine Experimental Station on Clam Bay, near Manchester, Washington.

Net-Pen culture

During the period 1969-71, the major research emphasis was on culturing Pacific salmon in floating cages (net-pens) in seawater. The initial studies in seawater adaptation, nutritional requirements, diseases, and general husbandry of coho and chinook salmon in seawater cage-culture systems provided encouraging and promising data (Harrell 1973; Novotny 1972). The results indicated that chinook and coho salmnon could be reared from an entry size of 5 to 20 g to a size of 200 to 500 g in 8 to 10 months in seawater with reasonable efficiency and survival (Mahnken 1970). This provided the impetus for two exciting projects:

1. The development of a complete, large-scale pilot farm to demonstrate that coho and chinook salmon could be grown from the fertilized egg to a marketable size of 250 to 500 g in 18 months. The product would be a pan-sized salmon that would provide a meal for one or two persons from a single fish and would not compete with the wild-caught adult salmon trade.

2. The development of cooperative research with the Washington Department of Fisheries to determine if regional salmon sports fisheries could be enhanced by releasing salmon from the floating net-pens after the fish had been cultured there for extended periods.

Both of these projects were successful. The demonstration pilot farm was jointly funded by NOAA and private industry, and over 65 tons of pan-sized coho and chinook salmon were sold to test markets during the 2-year life span of the pilot farm. There are now two commercial salmon-culture farms operating in Puget Sound that produce over 500 tons of pan-sized salmon each year and at least one farm in British Columbia (Novotny 1975; Mahnken 1975; Mahnken and Waknitz 1979).

Programmed releases of tagged coho and chinook salmon, cultured in floating cages at Manchester, demonstrated that this tactic of delaying the release could alter the normal migrations. Delayed release coho salmon from the pilot farm studies remained in Puget Sound and contributed heavily to the local sport fishery. In addition, as

the fish approached maturity, they returned to the net-pen release site (Manchester) and not to the freshwater hatchery site where they originated. This was one of the first demonstrations of "imprinting" salmon in seawater. Another cooperative project involved culturing, imprinting, and releasing coho salmon from a diked tidal lagoon. This study successfully demonstrated that the coho salmon could migrate out to sea following normal routes but would return exclusively to the lagoon release site. This presents the possiblity of establishing terminal fishing areas, where all returning adults could be harvested (Novotny 1975, 1980).

Cooperative delayed release studies were established with the Washington Department of Game and sport fishermen's clubs to determine if the delayed release programs could be applied to sea-run cutthroat trout. We found that sea-run cutthroat trout cultured in net-pens for one summer and released in Hood Canal contributed to the Hood Canal sport fishery at a rate of 20 to 1 when compared to normal hatchery releases.

As a result of these studies, pen-culture delayed release programs are now routinely used by native Indian projects and the Washington Fisheries and Game departments in both seawater and freshwater lake systems.

Task scientists monitored the environment during the pilot farm studies and after the installation of the first commercial farm. They determined the effects of intensive net-pen culture operations on benthic fauna and the natural environmental factors that would limit cage culture operations.

In conjunction with the salmon research, Task scientists studied the possibilities of culturing "companion crops" (molluscs, crustaceans, and marine plants) in net-pens in association with salmon (Hunter 1975; Prentice 1975). Task scientists and graduate students successfully cultured the commercially valuable spot prawn, Pandalus platyceros, from the fertilized egg through maturity (full cycle) and demonstrated that the prawns could live and grow in the same pens with the salmon and go through a successful mating at maturity (Rensel and Prentice 1977, 1979, 1980).

Captive Broodstock Studies

Healthy, fast-growing coho and chinook salmon and cutthroat trout held back from test-marketing or release were raised in separate net-pens for potential experimental broodstocks. With coho salmon, growth was accelerated, and large numbers of mature 2-year old fish of both sexes weighing from 1.5 to 4.5 kg with varying degrees of egg viability in the females were produced. The results of these efforts were later expanded by the commercial farms for the production of their own accelerated 2-year old broodstocks. Task scientists have had limited success in culturing fall and spring chinook salmon to maturity and are continuing with this effort. There is a pressing need to preserve certain races of chinook salmon that represent threatened stocks (such as Snake River fall and White River spring chinook salmon). Culturing the fish to maturity may be the only solution to preserving these races (Joyner and Mahnken 1975).

Task scientists were successful in culturing sea-run cutthroat and rainbow trout to maturity with a high degree of egg viability (80 to 90%). Hybrid

rainbow steelhead trout crosses were grown to maturity as 2-year old spawners weighing from 2 to 5 kg. Some females were held for three consecutive spawnings (5-year olds) from the seawater net-pens. The sea-run cutthroat trout broodstock program has been so successful that the Washington Department of Game has been able to meet all of its egg requirements for their Shelton Hatchery from captive broodstocks.

The excellent success with the broodstock program led Task scientists to conduct experimental culture programs with the Atlantic salmon. The first broodstocks proved to be quite resistant to stresses and seawater diseases; hearty males and females, with a high degree of egg viability (60 to 95%), matured as 4-year old adults. The resulting progeny were normal, healthy fish.

The Atlantic salmon resources of the northeastern United States have been in jeopardy for many years due to overfishing of the adult stocks by foreign fleets on the high seas, regional fisheries, and degradation of the freshwater habitat. Although the high-seas fishing has been banned in recent years, and many of the poor freshwater habitats have been restored, there are not enough adult brood fish to supply all of the eggs that are needed by the new Atlantic salmon hatcheries on the northeastern coast of the United States (Mahnken and Joyner 1973). The successful Atlantic salmon broodstock studies by the Center scientists at Manchester, Washington, led to a cooperative Atlantic salmon restoration project between the NMFS Northeast and Northwest Regions. Limited quantities of eyed eggs from Maine were shipped to the Center's Manchester and Seattle facilities. Task scientists are now culturing the progeny from these selected strains to maturity in net-pens at Manchester.

The favorable sea temperatures and sheltered waters of Puget Sound present an ideal environment for culturing Atlantic salmon to maturity. From the small numbers of eggs supplied by the Northeast Atlantic Salmon Commission each year, Center scientists will be able to produce enough captive brood fish to return over 3,000,000 eyed Atlantic salmon eggs to northeast salmon hatcheries in this important restoration program.

Disease Research

One of the major problems that confronted Task scientists from the very beginning of the marine salmon culture programs has been diseases caused by infectious bacteria. Some of these diseases are the result of pathogenic bacteria normally found in the marine environment (namely those that cause vibriosis); others originate with the fish in their freshwater environment and are carried in a latent stage (Harrell and Schiewe 1974; Harrell et al. 1976b; Novotny 1978). Task scientists have developed rapid diagnostic procedures that allow most fishery workers to identify approximately 80% of the vibriosis problems within 1 or 2 days (Harrell et al. 1975; Novotny et al. 1975).

The major problems associated with the intensive culture of salmon in the marine environment are caused by vibriosis, which prevails under certain stress conditions. Task scientists identified a number of serotypes of *Vibrio anguillarum* (Harrell and Schiewe 1974; Harrel et al. 1976), the pathogenic bacteria that cause vibriosis, and they developed the first multiple vaccines used to prevent this

highly infectious fish disease (Harrell et al. 1976a; Harrell 1978; Novotny et al. 1978). Task scientists demonstrated the practicality and usefulness of vibrio vaccines and assisted commercial salmon growers and state and federal agencies with practical applications of vibrio vaccines. They also were instrumental in assisting in and advising on the development of the first private industries established for the commercial production of fish vaccines. There are now at least three firms in the United States and two in Canada producing fish vaccines.

Task disease specialists identified problems in the culture of broodstocks due to latent freshwater diseases, such as furunculosis and bacterial kidney disease, and to infections of major organ tissues by sporozoan parasites and marine viruses (Ellis et al. 1978; Novotny 1978).

Nutritional Studies

Task scientists cooperate with other Center scientists in the field of salmon nutrition. There is a pressing need in aquaculture to develop as many alternate and economical sources of protein supplements for fish feeds as can be found. The major source of protein for most trout and salmon diets comes from high-quality fish meals. Herring and anchovy meals are becoming more costly and more difficult to obtain each year; however, any substitutions for the herring meal portions of salmon diets must be of sufficient quality and contain the proper amino acid balance to promote the growth and development of normal organ tissues.

Tests have been conducted on meals prepared from dogfish (sharks), single-cell protein (primarily yeasts), and various types of waste products produced in fish processing operations. In general, the research has demonstrated that between 25 and 50% of the herring meal portions of salmon diets can be replaced with these more economical sources of protein without affecting growth or survival (Spinelli and Mahnken 1976; Mahnken et al. 1980)

Ultraviolet Light

Task scientists have been able to use the successes in culturing the marine pandalid prawns to conduct a series of experiments demonstrating the significance of ultra-violet (UV) light in our environment. Atmospheric scientists are concerned about the depletion of ozone in the earth's upper atmosphere as a result of the excessive use of fluorocarbons by industrialized societies. The ozone layer prevents excessive amounts of UV light from reaching the earth's surface. Controlled laboratory experiments were conducted at the Manchester Marine Experimental Station, using the cultured larvae of the pandalid prawns as sensitive, biological test organisms. In nature, these larvae are found at the surface of the sea during a portion of the early larval stages. Consequently, increases in UV radiation might affect the normal development of these animals. After a series of tests under regulated UV light in the laboratory, it was found that increases in the amount of UV light could seriously reduce survival in the critical larval stages. Many organisms that represent important sources of food for salmon in the ocean are frequently found near the surface at some time in their lives (Damkaer et al. 1980).

Research with UV light has demonstrated

that certain frequencies of light are more destructive than others. Tests conducted on the effects of varying frequencies of light on salmon eggs indicated that this was also true for fish. The results of the experimentation with salmon eggs may lead to the possibilities of culturing in the presence of only certain frequencies of light which would not harm the eggs but which might reduce diseases.

Genetic Studies

Since 1977, more of the scientific expertise within the Task has been devoted to solving problems related to management and enhancement of the dwindling stocks of chinook and coho salmon and steelhead of the Columbia River system. For example, Task geneticists have been researching the identification of racial stocks of fish by using naturally occurring biochemical markers. Small samples of organ tissue are collected for processing and for the electrophoretic separation of the various biochemical markers. Scientists can use these markers to separate unique stocks of fish during the commercial fishing season on the lower Columbia River. This provides fishery managers with the ability to assess the proportions of critically important stocks entering the fishery each period and to regulate accordingly. It is possible that the same techniques may be used in the future to identify stocks of salmon in the international, commercial salmon fishing zones between the United States and Canada (Utter et al. 1976a; Utter et al. 1976b).

Smoltification

Task scientists have also been conducting extensive field research on the physiological mechanisms that control the "smolting" process in juvenile salmon and the relationship of these mechanisms to survival in seawater. Anadromous salmon and trout go through progressive, hormone-related physiological and morphological changes prior to and during the normal transition that permits them to migrate from a pure, freshwater environment to full seawater with a 3.4% salt concentration (Folmar 1979; Folmar and Dickhoff 1980). Because the state and federal hatcheries on the Snake and Columbia Rivers are required to produce many millions of salmon and steelhead to augment the wild populations that have declined steadily with the progressive construction of dams, it has become increasingly important to maximize the survival of the fish released from the hatchery systems. Thorough studies have been conducted at over 30 hatcheries on coho and chinook salmon and steelhead to determine: 1) the relationships of quantitative changes in the gill enzyme, Na^+-K^+ adenosine triphosphatase (ATPase) to other smoltification indices and seawater adaptation (Zaugg 1970; Zaugg and McLain 1972; Adams et al. 1975; Clarke et al. 1978; Prentice et al. 1979; Folmar et al. 1980); 2) the relationships of thyroid hormones to smoltification and seawater adaptation (Prentice et al. 1979; Folmar and Dickhoff 1980; Folmar et al. 1980); 3) changes in plasma electrolyte levels during the smolting process (Zaugg and McLaine 1970; Prentice et al. 1979; Folmar and Dickhoff 1980; Folmar et al. 1980); and 4) the relationship of fish health in the normal hatchery populations to smoltification indices and survival.

Scientists and technicians collected thousands of random samples from the many populations of hatchery salmon and

steelhead before and after the normal spring smolting periods. The hatcheries were visited at intervals of 1 to 2 weeks. Gills and blood serum were analyzed for Na^+-K^+ ATPase enzyme, thyroid hormones, and electrolyte levels. Blood samples for basic hematology and tissue samples for histopathological examination were collected in large numbers to provide a sound statistical base for normal populations. Morphological data on individual fish were collected, and live samples were transported as far as 600 miles to the seawater rearing pens at Manchester to determine relative seawater survival. Continuous records of growth, survival, visual morphology, and causes of death were maintained during the 4 to 12 months of seawater culture.

Almost all of the groups and/or stocks studied were representative of tagged populations. Data on the returning adults from these hatchery releases are now being assembled and analyzed. Preliminary examination of some of the available data from juveniles moving into the estuary indicates that migration rates of coho salmon are correlated to peak Na^+-K^+ ATPase enzyme activity levels in the gills, and the survival of test fish transferred to seawater at Manchester is positively correlated to increasing activity of the thyroid hormone, thyroxine. The data collected from the many hatcheries sampled indicated that peak enzyme and hormone levels do not occur at the same time and that each hatchery should be treated as a separate entity to maximize survival after release.

Simultaneously, the collection of fish health information provided significant data regarding hatchery fish populations. Although most hatchery stocks proved to be in excellent condition, some populations were found to be in trouble. In one case, chemical bath treatments for therapeutic purposes just prior to release did not alter the normal gill Na^+-K^+ ATPase profile but apparently substantially reduced comparative seawater survival after the fish were transferred to net-pens at Manchester. Similarly, several other stocks of salmon had normal gill Na^+-K^+ ATPase enzyme profiles but suffered from severe anemia, latent bacterial kidney disease infections, or both; thus survival in the sea is expected to be poor (Novotny and Harrell 1979). Poor returns of adults from one release group that normally would have been expected to be high correlates with heavy latent bacterial kidney disease infections in the juveniles.

Similar studies were conducted during the same time periods on stocks of hatchery fish that were involved in extensive imprinting and "homing" experiments in Washington, Oregon, and Idaho. The objectives of the disease portion of the homing studies were primarily to determine if the fish's capabilities of imprinting to release sites were in any way compromised.

Task scientists have been conducting experiments to determine the best possible techniques for altering and controlling smoltification. In the future, as more information becomes available regarding the most favorable time periods for passage into the ocean, fish hatchery managers may be able to alter the timing of release, through controlled smoltification, to coincide with the most favorable oceanic conditions.

GENERAL EXPERTISE AND RECOGNITION

The expertise provided by the CZES Division's scientists has been recognized both nationally and internationally (Joyner et al. 1974). Scientists have been called upon to assist in planning fish-passage facilities, aquaculture development projects, and biotelemetry projects. They have been requested to provide environmental assessment and impact information. They have also established training programs for Northwest Indians (Novotny 1969) and have provided detailed information for federal participation in the management of salmon resources in the Pacific Northwest under the legal jurisdiction of the Judge Boldt decisions (Waknitz et al. 1978). They have also provided training for French and Polish scientists and technicians.

Several of the Division's scientists have been called upon to serve on continuing international cooperative programs, such as the U.S.-Japan Natural Resources Cooperatives (UJNR) and the U.S.-France Scientific Missions (NOAA-CNEXO). Similar cooperatives are being proposed by the Polish government (Harache and Novotny 1976).

This recognition of the expertise of the Division's scientific staff is supported by the excellent program of documentation of research results through the publication of scientific and technical literature for fisheries experts, commercial fish farmers, water management entities, power producing entities, the general public, and other groups. Over 500 scientific and technical publications and processed reports are proof of the excellent work conducted by Division scientists in the past 50 years.

FUTURE EMPHASIS

On the basis of future needs for information relative to environmental factors affecting the fishery resources of the Columbia River and the Pacific Northwest, the CZES Division of the Center believes its research emphasis should be focused on the following areas:

Fish Passage

Fish passage problems of both adult and juvenile anadromous fish still exist and will undoubtedly be further exacerbated by future developments of all types in the Pacific Northwest.

Adult passage facilities still need improvement to eliminate delays and losses; for example, improvement of environmental conditions in the river at the entrance to fishway facilities. Information is needed to determine what the optimum conditions are at specific sites.

Juvenile passage facilities are operational for some types of dams, but improvements need to be made. Most dams in the Columbia River do not have juvenile passage facilities, and new technologies will have to be developed to provide effective juvenile passage facilities at all dams.

Collection and transportation systems now in use are effective for steelhead, but considerable improvement is needed to achieve optimal effectiveness for other species such as spring chinook salmon. Additional research is needed to isolate areas in the collection and transportation system where improvements can be made.

Habitat Investigations

Future developments such as increased port dredging to improve ship entrances, industrial plant construction, offshore mining, increased oil tanker traffic, and siting of future coal storage facilities could potentially cause further degradation of an already altered aquatic environment. Information will be needed on the impacts of these activities to the aquatic habitats supporting existing and future fishery resources.

Additional dredging of various types is planned for several ports in the Northwest to deepen and widen ship channels. For example, plans are underway to deepen and widen the Columbia River ship channel; this requires over 10 million yd^3 of material to be removed and deposited somewhere in the aquatic environment. Detailed knowledge of the biological communities in the dredge area will be critical in recommending measures to minimize detrimental impacts to the fishery. Thus, emphasis on research to characterize habitats and assess impact of various perturbations to the environment should continue.

Fishery Enhancement

Fishery enhancement has become an important research area primarily because the attempt to restore the declining fishery resources with hatchery production has not achieved the intended objectives. On the contrary, the fishery resources continue to decline in terms of contribution to the catch in spite of increased hatchery production. Thus, research focused on methods to increase quality and survival of both wild and hatchery salmonid stocks becomes a viable option.

Recent research results indicated that continued research with the goal of increasing quality and survival of smolts released from hatcheries can reverse the downward trend with minimal increase in costs. Research on smoltification, disease, nutrition, and genetics appears to have the greatest potential for improving the fishery. The key to determining an evaluation of certain enhancement strategies is knowledge of early ocean behavior and survival.

Little is known of the fate of juvenile salmonids during the first 6 months of their ocean residence. Knowledge of nearshore ocean factors affecting early ocean life of various salmonid stocks is critical to solving the mysteries of differential survival of stocks. Thus, research centered on the early, ocean life history of salmonids should also be emphasized. The ultimate goal would be to understand the nearshore ocean ecosystem which salmonids occupy in their first year of life.

The three areas of research relating to environmental effects described above are among those which the Center should emphasize in the future. Research designed to provide captured broodstock for threatened or endangered salmonid species should also continue to be emphasized if restoration projects now underway are to be successful.

REFERENCES

ADAMS, B. L., W. S. ZAUGG, and L. R. MCLAIN.
1975. Inhibition of salt water survival and Na-K-ATPase elevation in steelhead trout (Salmo gairdneri) by moderate water temperatures. Trans. Am. Fish. Soc. 104:766-769.

BATES, D. W.
1970. Diversion and collection of juvenile fish with traveling screens. U.S. Fish Wildl. Serv., Fish. Leafl. 633, 6 p.

BATES, D. W., and A. PESONEN.
1960. Efficiency evaluation Tracy fish collecting facility. U.S. Dep. Inter., Bur. Reclam., Reg. 2, Cent. Val. Proj. Calif., Sacramento, Calif., 70 p.

BEININGEN, T., and W. J. EBEL.
1970. Effect of John Day Dam on dissolved nitrogen concentrations and salmon in the Columbia River, 1968. Trans. Am. Fish. Soc. 99:614-671.

BELL, M. C., A. C. DELACY, and G. J. PAULICK.
1967. A compendium on the success of passage of small fish through turbines. Unpubl. Rep., 268 p. U.S. Army Corps. Eng., North Pac. Div., P.O. Box 2870, Portland, OR 97208. (Contract DA-35-026-dCIVENC-66-16.)

BLAHM, T. H., J. T. DURKIN, R. L. MCCONNELL, G. DAVIS, and T. C. COLEY.
1979a. Portland Harbor predredge and disposal study. Unpubl. rep., 24 p. Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E, Seattle, WA 98112. (Contract DACW56-78-F-0575 to U.S. Army Corps Eng., North Pac. Div., Portland, Oregon.)

BLAHM, T. H., and R. J. MCCONNELL.
1979. Impact of flow-lane disposal at Dobelbower Bar. Unpubl. rep., 25 p. Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E, Seattle, WA 98112. (Contract DACW57-76-F-0918 to U.S. Army Corps Eng., North Pac. Div., Portland, Oregon.)

BLAHM, T. H., R. J. MCCONNELL, and L. G. DAVIS.
1979b. Effect of agitation dredging on benthic communities, water quality, and turbidity in Chinook Channel. Unpubl. rep., 19 p. Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E, Seattle, WA 98112. (Contract DACW57-76-0123 to U.S. Army Corps Eng., North Pac. Div., Portland, Oregon.)

BLAHM, T. H.
1978. Toxicity of chemical fire retardents to juvenile coho salmon and rainbow trout. PhD Thesis, Univ. Idaho, 36 p.

CLARKE, W. C., L. C. FOLMAR, and W. W. DICKHOFF.
1978. Changes in gill Na^+-K^+ ATPase, plasma sodium and thyroid hormone levels during adaptation of juvenile coho salmon to seawater. Am. Zool. 18(3):652.

COLLINS, G. B.
1952. Factors influencing the orientation of migrating anadromous fishes. U.S. Fish Wildl. Serv., Fish. Bull. 52:375-396.

COLLINS, G. B., and C. H. ELLING.
1960. Fishway research at the fisheries-engineering research laboratory. U.S. Fish. Wildl. Serv., Circ. 98, 17 p.

COLLINS, G. B., C. H. ELLING, J. R. GAULEY, and C. S. THOMPSON.
1961. Effect of fishway slope on performance and biochemistry of salmonids. U.S. Fish Wildl. Serv., Fish. Bull. 63:221-253.

COLLINS, G. B., J. R. GAULEY, and C. H. ELLING.
1962. Ability of salmonids to ascend high fishways. Trans. Am. Fish. Soc. 91:1:1-7.

COLLINS, G. B., P. S. TREFETHEN, and C. D. VOLZ.
1975. Factors affecting electrotaxis in salmon fingerlings. Processed Rep., 43 p. Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E, Seattle, WA 98112.

CONNER, A. R., C. H. ELLING, E. C. BLACK, G. B. COLLINS, J. R. GAULEY, and E. TREVOR-SMITH.
1964. Changes in glycogen and lactate levels in migrating salmonid fishes ascending experimental "endless" fishways. J. Fish. Res. Board Can. 21:255-290.

CRADDOCK, D. R.
1970. Thermal effects on an important zooplankton (Dophnia pulex) of the Columbia River. Unpubl. manuscr., 46 p. Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E, Seattle, WA 98112.

DAMKAER, D. M., D. B. DEY, G. A. HERON, and E. F. PRENTICE.
1980. Effects of UV-B radiation on near-surface zooplankton of Puget Sound. Oecologia (Berl.)

DURKIN, J. T., and S. J. LIPOVSKY.
1977. Aquatic disposal field investigations, Columbia River disposal site, Oregon; Appendix E: Demersal fish and decapod shellfish studies. U.S. Army Corps Eng., Waterways Exp. Stn., Vicksburg, Miss., Tech Rep. D-77-30. 184 p. (Available from U.S. Dep. Commer., Natl. Tech. Inf. Serv., Springfield, Va.)

EBEL, W. J.
1969. Supersaturation of nitrogen in the Columbia River and its effect on salmon and steelhead trout. U.S. Fish. Wildl. Serv., Fish. Bull. 68:1-11.

EBEL, W. J.
1971. Dissolved nitrogen concentrations in the Columbia and Snake Rivers in 1970 and their affect on chinook salmon and steelhead. U.S. Dep. Commer., NOAA Tech. Rep., NMFS, SSRF-646, 7 p.

EBEL, W. J.
1979. Transportation of chinook salmon, Oncorhynchus tshawytscha, and steelhead, Salmo gairdneri, smolts in the Columbia River and effects on adult returns. Fish. Bull., U.S. 78:491-505.

EBEL, W. J., E. M. DAWLEY, and B. H. MONK.
1971. Thermal tolerance of juvenile pacific salmon and steelhead trout in relation to supersaturation of nitrogen gas. Fish. Bull., U.S. 69:833-843.

EBEL, W. J., D. L. PARK, and R. C. JOHNSEN.
1972. Effects of transportation on survival and homing of Snake River chinook salmon and steelhead trout. Fish. Bull., U.S. 71:549-563.

EBEL, W. J., G. K. TANONAKA, G. E. MONAN, H. L. RAYMOND, and D. PARK.
1979. Status report--1978, the Snake River salmon and steelhead crisis: its relation to dams and the national energy shortage. Processed Rep., 37 p. Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E, Seattle, WA 98112.

ELLING, C. H., and H. L RAYMOND.
1959. Fishway capacity experiment, 1956. U.S. Fish. Wildl. Serv., Spec. Sci. Rep. fish. 299, 26 p.

ELLIS, R. W., A. J. NOVOTNY, and L. W. HARRELL.
1978. A report of kidney disease in a wild chinook salmon, Oncorhynchus tshawytscha, in the sea. J. Wildl. Dis. 4:120-123.

ENVIRONMENTAL PROTECTION AGENCY, ATOMIC ENERGY COMMISSION, and NATIONAL MARINE FISHERIES SERVICE.
1971. Columbia River thermal effects study, Volumes 1 and 2. U.S. Environ. Prot. Agency, Reg. 10, Seattle, Wash., 102 p. and 64 p., respectively.

FISH, F. F., and M. G. HANAVON.
1948. A report upon the Grand Coulee fish-maintenance project 1939-1947. U.S. Fish Wildl. Serv., Spec. Sci. Rep. 55, 63 p.

FOLMAR. L. C.
1979. Some physiological changes in coho salmon (Oncorhynchus kisutch) during smoltification and seawater adaptation. PhD Thesis, Univ. Washington, Seattle, 153 p.

FOLMAR, L. C., and W. W. DICKHOFF.
1980. The parr-smolt transformation (smoltification) and seawater adaptation in salmonids: a review of selected literature. Aquaculture 21:1-37.

FOLMAR, L. C., W. W. DICKHOFF, and W. S. ZAUGG.
1980. A comparison of smoltification and seawater adaptation patterns in coho (Oncorhynchus kisutch) and chinook salmon (O. tshawytscha) and steelhead trout (Salmo gairdneri). Aquaculture (in press).

FULTON, L. A., and R. E. PEARSON.
1981. Transplantation and homing experiments on salmon, Oncorhynchus spp., and steelhead trout, Salmo gairdneri, in the Columbia River system: fish of the 1939-44 broods. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-12, 97 p.

HARACHE, Y., and A. J. NOVOTNY.
1976. Coho salmon farming in France. Mar. Fish. Rev. 38(8):1-8.

HARRELL, L. W.
1973. Mass mortalities in Puget Sound aquaculture. In Proceedings of the 24th Annual Northwest Fish Culture Conference, p. 1-3.

HARRELL, L.W. and M. H. SCHIEWE.
1974. Further studies of two strains of pathogenic vibrios in salmon in Puget Sound. In Proceedings of the 24th Annual Northwest Fish Culture Conference, p. 50-52.

HARRELL, L. W.
1978. Vibriosis and current vaccination procedures in Puget Sound, Washington. Mar. Fish. Rev. 40(3):24-25.

HARRELL, L. W., H. M. ETLINGER, and H. O. HODGINS.
1975. Humoral factors important in resistance of salmonid fish to bacterial disease. I. Serum antibody protection of steelhead trout (Salmo gairdneri) against vibriosis. Aquaculture 6:211-219.

HARRELL, L. W., H. M. ETLINGER, and H. O. HODGINS.
1976a. Humoral factors important in resistance of salmonid fish to bacterial disease. II. Anti-Vibrio anguillarum activity in mucus and observations on complement. Aquaculture 7:363-370.

HARRELL, L. W., A. J. NOVOTNY, M. H. SCHIEWE, and H. O. HODGINS.
1976b. Isolation and description of two vibriosi pathogenic to Pacific salmon. fish. Bull., U.S. 74:447-449.

HUNTER, C. J.
1975. Edible seaweeds--a survey of the industry and prospects for farming the Pacific Northwest. Mar. Fish. Rev. 37(2):19-26.

JOHNSEN, R. C., and E. M. DAWLEY.
1974. The effect of spillway flow deflectors at Bonneville Dam, on total gas supersaturation and survival of juvenile salmon. Unpubl. rep., 23 p. Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E, Seattle, WA 98112. (Contract DACW-57-74-F-0122 to U.S. Army Corps Eng., North Pac. Div., Portland, Oregon.)

JOYNER, T., and C. MAHNKEN.
1975. Rebuilding salmon fisheries in New England. Natl. Fisherman Yearb. Issue 1975, 55(13):42-46.

KRCMA, R. F., W. E. FARR, and C. LONG.
1980. Research to develop bar screens for guiding juvenile salmonids out of turbine intakes at low head dams on the Columbia and Snake Rivers, 1977-79. Unpubl. rep., 49 p. Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E, Seattle, WA 98112. (Contracts DACW57-79-F-0163 and DACW57-79-F-0274 to U.S. Army Corps Eng., North Pac. Div., Portland, Oregon.)

LONG, C. W.
1959. Passage of salmonids through a darkened fishway. U.S. Fish. Wildl. Serv., Spec. Sci. Rep. Fish. 300, 9 p.

LONG, C. W., and W. M. MARQUETTE.
1967. Research on fingerling mortality in Kaplan turbines. In Proceedings of the 6th Biennial Hydraulics Conference, October 18-19, 1967, Moscow, Idaho, p. 1-36. Wash. State Univ., Pullman.

LONG, C. W., R. F. KRCMA, and F. OSSIANDER.
1968. Research on fingerling mortality in Kaplan turbines 1968. Unpubl. rep., 7 p. Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E, Seattle, WA 98112

MAHNKEN, C. V. W.
1975. Status of commercial net-pen farming of Pacific salmon in Puget Sound. In J. W. Avault, Jr., and R. Miller (editors), Proceedings 6th Annual Meeting of the World Mariculture Soceity, p. 285-298. La. State Univ., Baton Rouge.

MAHNKEN, C., and T. JOYNER.
1973. [Salmon for New England fisheries.] Part III: Developing a coastal fishery for Pacific salmon. Mar. Fish. Rev. 35(10):9-13.

MAHNKEN, C. V. W., A. J. NOVOTNY, and T. JOYNER.
1970. Salmon mariculture potential assessed. Am. Fish Farmer 2(1):12-15, 27.

MAHNKEN, C. V. W., J. SPINELLI, and F. W. WAKNITZ.
1980. Evaluation of an alkane yeast (Candida sp.) as a substitute for fish meal in Oregon Moist Pellets: feeding trials with coho salmon (Oncorhynchus kisutch) and rainbow trout (Salmo gairdneri). Aquaculture 20:41-56.

MAHNKEN, C. V. W., AND F. W. WAKNITZ.
1979. Factors affecting growth and survival of coho salmon (Oncorhynchus kisutch) and chinook salmon (O. tshawytscha) in saltwater net-pens in Puget Sound. 1979 Proc. World Mari. Soc., Honolulu, HI, 10:280-305. In J. W. Avault, Jr. (editor) Proceedings of the 10th Annual Meeting of the World Mariculture Society, p. 208-305. La. State Univ., Baton Rouge.

MATTHEWS, G. M., G. A. SWAN, and J. R. ROSS.
1977. Improved bypass and collection system for protection of juvenile salmon and steelhead trout at Lower Granite Dam. Mar. Fish. Rev. 39(7):10-14.

MCCONNELL, R. J., and T. H. BLAHM.
1970. Resistance of juvenile sockeye salmon (Oncorhynchus nerka) to elevated water temperatures. Processed Rep., 8 p. Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E, Seattle, WA 98112.

MCCONNELL, R. J., S. J. LIPOVSKY, D. A. MISITANO, D. R. CRADDOCK, and J. R. HUGHES.
1978. Habitat development field investigations, Miller Sands marsh and upland habitat development site, Columbia River, Oregon; Appendix B: Inventory and assessment of predisposal and postdisposal aquatic habitats. U.S. Army Corps Eng., Waterways Exp. Stn., Vicksburg, Miss., Tech. Rep. D-77-38, 344 p. on 4 microfiche. (Available from U.S. Dep. Commer., Natl. Tech. Inf. Serv., Springfield, Va.)

MONAN, G. E., J. H. JOHNSON, and G. ESTERBERG.
1975. Electronic tags and related tracking techniques aid in study of migrating salmon and steelhead trout in the Columbia River basin. Mar. Fish. Rev. 37(2):9-15.

MONAN, G. E., and K. L. LISCOM.
1975. Radio tracking studies to determine the effects of spillway deflectors and fallback on adult chinook salmon and steelhead trout at Bonneville Dam, 1974. Unpubl. rep., 37 p. Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E, Seattle, WA 98112. (COntract DACW57-74-F-0122 to U.S. Army Corps Eng., North Pac. Div., Portland, Oregon.)

NOVOTNY, A. J.
1969. BCF begins mariculture training program for Northwest Indians. Commer. Fish. Rev. 31(10):11-13.

NOVOTNY, A. J.
1972. The marine culture of vertebrates. In Aquaculture--potential in the Maritimes region. Proceedings of a symposium sponsored jointly by the Federal Department of Fisheries and the Canadian Society of Environmental Biologists, April 25, 1972, Halifax, Nova Scotia, p. 38-53.

NOVOTNY, A. J.
1975. Net-pen culture of Pacific salmon in marine waters. Mar. Fish. Rev. 37(1):36-47.

NOVOTNY, A. J.
1978. Vibriosis and furunculosis in marine cultured salmon in Puget Sound, Washington. Mar. Fish. Rev. 40(3):52-55.

NOVOTNY, A. J.
1980. Cage culture of salmonids in the United States. In Proceedings of the Cage Fish Rearing Symposium, 26-27 March 1980, Reading , England, p. 3-14. Univ. Reading, London and South Eastern Branch. Inst. Fish. Manage., Old Harlow, Essex, England.

NOVOTNY, A. J., and L. W. HARRELL.
1979. Appendix C: fish health, a general evaluation. In FY1978-79 report, Project 817, a study to assess status of smoltification and fitness for ocean survival of chinook, coho, and steelhead, 59 p. Unpubl. rep. Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E, Seattle, WA 98112.

NOVOTNY, A. J., L. W. HARRELL, and C. W. NYEGAARD.
1975. Vibriosis: a common disease of Pacific salmon cultured in marine waters of Washington. Wash. State Univ., Pullman, Coll. Agric., Coop. Ext. Serv., Ext. Bull. 663, 8 p.

NOVOTNY, A. J., M. SIEGEL, and S. WATERMAN (editors).
1978. Health, disease and disease prevention in cultured aquatic animals. Mar. Fish. Rev. 40(3):1-7.

PARK, D. L., T. E. RUEHLE, J. R. HARMON, and B. H. MONK.
1980. Transportation research on the Columbia and Snake Rivers, 1979. Unpubl. rep., 28 p. Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E, Seattle, WA 98112. (Contract DACW68-78-C-0051 to U.S. Army Corps Eng., North Pac. Div., Portland, Or.)

PRENTICE, E. F.
1975. Spot prawn culture: status and potential. In C. W. Nyegaard (editor), Shellfish farming in Puget Sound, proceedings of a seminar, p. 1-11. Washington State Univ., Pullman, Coll. Agric. Coop. Ext. Serv.

PRENTICE, E. R., F. W. WAKNITZ, and K. X. GORES.
1979. Appendix B.. Saltwater adaptation of coho salmon , spring, and fall chinook salmon and steelhead. In FY1978-79 report, Project 817, a 192 p. Unpubl. rep. Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E, Seattle, WA 98112.

PUGH, J. R., G. E. MONAN, and J. R. SMITH.
1967. Efficiency of a combined electrode and louver array in guiding juvenile steelhead trout (Salmo gairdneri). Trans. Am. fish. Soc. 96:422-423.

PUGH, J. R., G. E. MONAN, and J. R. SMITH.
1970. Effect of water velocity on the fish-guiding efficiency of an electrical guiding system. U.S. Fish Wildl. Serv., Fish. Bull. 68:307-324.

RALEIGH, R. F., and W. J. EBEL.
1968. Effect of Brownlee Reservoir on migration of anadromous salmonids. In Proceedings of the Reservoir Fishery Resources Symposium, April 5-7, 1967, Athens, Georgia, p. 415-443. Am. Fish. Soc.

RAYMOND, H. L.
1968. Migration rates of yearling chinook salmon in relation to flows and impoundments in the Columbia and Snake Rivers. Trans. Am. Fish. Soc. 97:356-359.

RAYMOND, H. L.
1969. Effect of John Day Reservoir on the migration rate of juvenile chinook salmon in the Columbia River. Trans. Am. Fish. Soc. 98:513-514.

RAYMOND, H. L.
1979. Effects of dams and impoundments on migrations of juvenile chinook salmon and steelhead from the Snake River, 1966 to 1975. Trans. Am. Fish. Soc. 108:505-529.

RENSEL, J. E., and E. F. PRENTICE.
1977. First record of a second mating and spawning of the spot prawn, Pandalus platyceros, in captivity. Fish. Bull., U.S. 75:648-649.

RENSEL, J. E., and E. F. PRENTICE.
1979. Growth of juvenile spot prawn, Pandalus platyceros, in the laboratory and in net-pens using different diets. Fish. Bull., U.S. 76:886-890.

RENSEL, J. E., and E. F. PRENTICE.
1980. Factors controlling growth and survival of cultured spot prawn, Pandalus platyceros, in Puget Sound, Washington. Fish. Bull., U.S. 78:781-788.

SLATICK, E.
1970. Passage of adult salmon and trout through pipes. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 592, 18 p.

SLATICK, E. L., G. GILBREATH, and K. A. WALCH.
1981. Imprinting salmon and steelhead trout for homing, 1980. Unpubl. rep., 21 p. Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E, Seattle, WA 98112. (Contract DE-A179-80-BP-18236 to Bonneville Power Admin., Portland, Oregon.)

SMITH, J. R., and W. E. FARR.
1975. Bypass and collection system for protection of juvenile salmon and trout at Little Goose Dam. Mar. Fish. Rev. 37(2):31-35.

SMITH, J. R., G. M. MATTHEWS, L. R. BASHAM, B. MONK, and S. ACHORD.
1981. Transportation operations on the Snake and Columbia Rivers, 1980. Unpubl. rep., 31 p. Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E, Seattle, WA 98112. (Contract DACW68-78-C-0051 to U.S. Army Corps Eng., North Pac. Div., Portland, Oregon.)

SNYDER, G. R.
1970. Survival times of juvenile salmonids exposed to water temperatures causing thermal "shock." Unpubl. rep., 13 p. Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E, Seattle, WA 98112.

SNYDER, G. R., D. R. CRADDOCK, and T. H. BLAHM.
1970. Thermal effects studies on the lower Columbia River; 1968-70. West. Proc., 50th Annu. Conf. West. Assoc. State Game Fish Comm., Victoria, B.C., July 13-16, 1970:65-89.

SPINELLI, J., and C. MAHNKEN.
1976. Effect of diets containing dogfish (Squalus acanthias) meal on the mercury content and growth of pen-reared coho salmon (Oncorhynchus kisutch). J. Fish. Res. Board Can. 33:1771-1778.

STANSBY, M. E.
1979. Federal fishery research in the Pacific Northwest proceeding formation of Northwest Fish. Cent., U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., 35 p. (Available from U.S. Dep. Commer., Natl. Tech. Inf. Serv., Springfield, Va.).

STUEHRENBERG, L. C., K. L. LISCOM, and G. E. MONAN.
1978. A study of apparent losses of chinook salmon and steelhead based on count discrepancies between dams on the Columbia and Snake Rivers, 1967-68. Unpubl. rep., 49 p. Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E, Seattle, WA 98112. (Contract DACW57-67-C-0120 to U.S. Army Corps Eng., North Pac. Div., Portland, Oregon.)

TREFETHEN, P. S., and D. F. SUTHERLAND.
1968. Passage of adult chinook salmon through Brownlee Reservoir, 1960-62. U.S. Fish Wildl. Serv., Fish. Bull. 67:35-45.

UTTER, F. M., F. W. ALLENDORF, and B. MAY.
1976a. Genetic dilineation of salmonid populations based on electrophoretic data. In T. Y. Nosho and W. K. Hershberger (editors), Salmonid genetics: status and role in aquaculture: a workshop report, p. 8-11. Univ. Washington, Seattle, Div. Mar. Resour., Sea Grant Program, WSG WO 76-2.

UTTER, F. M., F. W. ALLENDORF, and B. MAY.
1976b. The use of protein variation in the management of salmonid populations. Trans. 41st North Am. Wildl. Nat. Resources Conf.:373-383. Wildl. Manage. Inst., Washington, D.C.

WANDERWALKER, J. G.
1967. Response of salmonids to low frequency sound. In W. N. Tavolga (editor), Marine bioaccoustics, Volume 2, p. 45-58. Pergamon Press; Oxford, London, New York, Paris.

WAKNITZ, W., C. MAHNKEN, and J. MEYER.
1978. A compilation of wild and hatchery production for salmon and steelhead trout in eight fishery zones of the Boldt case area. Unpubl. rep., 57 p. Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E, Seattle, WA 98112.

WATER RESOURCES ENGINEERS.
1969. Mathematical models for the prediction of thermal energy changes in impoundments. Water Resour. Eng., Inc., Walnut Creek, Calif.

WEAVER, C. R.
1962. Influence of water velocity upon orientation and performance of adult migrating salmonids. U.S. Fish Wildl. Serv., Fish. Bull. 63:97-121.

WEAVER, C. R., C. S. THOMPSON, and F. OSSIANDER.
1972. Evaluation of fish passage in the vertical slot regulating section of the south shore ladder at John Day Dam. Unpubl. rep., 58 p. Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E, Seattle, WA 98112. (Contract NPPSU-PR-71-2509 to U.S. Army Corps Eng., North Pac. Div., Portland, Oregon.)

ZAUGG, W. S.
1970. Comments on the relationship between gill ATPase activities, migration, and salt water adaption of coho salmon. Trans. Amer. Fish. Soc. 99:811.

ZAUGG, W. S., and L. R. MCLAIN.
1970. Adenosinetriphoshatase activity in gills of salmonids: seasonal variations and salt water influence in coho salmon, (Oncorhynchus kisutch). Comp. Biochem. Physiol. 35:587.

ZAUGG, W. S., and L. R. MCLAIN.
1972. Changes in gill adenosinetriphosphatase activity associated with parr-smolt transformation on steelhead trout, coho, and spring chinook salmon. J. Fish. Res. Board Can. 29:167-171.

ZIMMER, P. D., and C. C. DAVIDSON.
1962. Annual fish passage report--Rock Island Dam Columbia River, Washington, 1960, U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 419, 22 p.

Environmental Stress and the Use and Enjoyment of Marine Resources: The Future

John S. Gottschalk [1]

INTRODUCTION

> "We know that the white man does not understand our ways. One portion of the land is the same to him as the next, for he is a stranger who comes in the night and takes from the land what ever he needs. The Earth is not his brother but his enemy, and when he has conquered it, he moves on."
> - Chief Seattle, writing to President Franklin Pierce in 1855.

Chief Seattle, were he reincarnated today, would find very little to suggest that he was wrong in his earlier assessment of the white man's approach toward stewardship of the earth. His criticism was based not only upon an understanding of the white man's attitude toward the Earth's resources. He also comprehended the first rule of ecology, for he went on to say "All things are connected. Whatever befalls the earth befalls the sons of the earth." It seems especially appropriate to preface this discussion of the environmental factors underpinning our "use and enjoyment" of marine resources with the wisdom of this "savage" chieftain, whose words so remorsefully highlight the cause of the problems we face today and in future resource management.

As a preface to this essay I will first dwell on the primary problem facing the world: how to manage our affairs prudently, with a human population capable of increasing exponentially beyond the apparent support capability of the available resources. Stated another way, can we restrain our apparent urge to self-destruct and instead create a socioeconomic system that can allow posterity to look forward to an existence above the subsistence level? There seems to be little doubt that in the short term of the next century we will run the risk of seeing Malthus vindicated, but there are other indications that suggest a Malthusian outcome is not inevitable. There are signs and omens that suggest there can be improved protection for the world ecosystems and thus, continued use and enjoyment of marine resources.

DEMOGRAPHIC BACKGROUND

In the United States, the population doubled nearly 5 times in the 19th Century, beginning with a population of 5.3 million and ending with 76 million. By 1950 it had doubled again,

1/ International Association of Fish and Wildlife Agencies, Washington, DC 20036.

to 150 million; and all projections indicate there is no way to escape a population of less than 300 million by the year 5000 (Brown 1981). Experts consider us a "developed country"; that is, one which has enjoyed the blessings of the industrial revolution. We have seen our average standard of living improve in parallel with increases in the Gross National Product. Our experience, until we recently began to realize that "there is no free lunch" especially as regards petroleum, has been vastly different from that of much of the world. In many countries populations have increased with little, if any, improvement in the standard of living.

At the time of the Birth of Christ, the world contained about 250 million people. It took 17 centuries for the first doubling after that, in 1650. Then, in less than two centuries, in 1830, we reached one billion. We doubled again in 1925 to two billion, in less than half a century; and we doubled again, to four billion in 1974, in just half a century (Cook 1980). If we were to continue breeding the way we have, and there were no interference, benign or catastrophic, the world would contain some 30 billion by the end of the 21st Century.

RESOURCE AVAILABILITY

Given the rate at which the developed countries, particularly the United States, are consuming resources, there is no apprehension that the world's population will ever reach that level. We would have exhausted our essential resources long before approaching that point. In fact, the world appears already to have achieved a population resource equation that is stressed by under-supply rather than over-supply. Demand has outstripped availability of many resources in many parts of the world; thus per capita production of essentials is down, even though gross or total production may have increased.

The Global 2000 Report of the Council on Environmental Quality projects a 90 percent increase in food production, but only at much greater cost in fertilizers and other developments. That increase would be counterbalanced by a population increase that will reduce the increase in per capita food availability to 15 percent.

Petroleum production will peak in the 1990's and fade away early in the 21st Century; fuelwood demand will exceed supply by 25 percent before the end of the century. Other finite fuels are maldistributed throughout the world and will continue to be controlled by the more affluent nations. Nonfuel minerals, with some exceptions, will be readily available at century's end, but costs of extraction and of refinement may make some of them prohibitively expensive.

The outlook for water is grim. It is being wasted by those who have plenty and used to the last drop by those who have little. Deforestation and overgrazing add to the already complicated picture by hastening runoff and limiting the recharge of dwindling underground reserves.

Forests are disappearing throughout the world to supply timber and firewood and to open land for agricultural development.

Soil losses in most parts of the world are excessive and will require large expenditures to bring them under control. A recent study by the Department of Agriculture suggests that

even in this country, where we have had governmental support for prudent soil care for at least 50 years, it would cost $103 billion over the next 50 years to reduce soil losses to acceptable levels.

FACTORS AFFECTING PRODUCTION OF FISHERY RESOURCES

To bring this discussion closer to the symposium theme, the projections for the world's fisheries are not much brighter. In the 1950's and '60's there were forecasts that the oceans would "feed the world" with production of as much as 300 million metric tons (t) annually. There is every indication that fish production has levelled off and that world catches in the order of 70 million t are a more reasonable expectation. Should management succeed in bringing catches to the level of 85 million t by the end of the century, the catch per capita would still drop 30 percent because of the increased population (Council on Environmental Quality 1981).

As this symposiuum will doubtless reveal, various factors (some independent, others acting together) have tended eventually to limit or decrease production from the marine fisheries. Several of the most important of these factors, especially overfishing, fall in the category of fisheries management and will be reviewed in a later session. Political stricture on size or volume of fish taken and consumer rejection based on prejudice against particular species or products, are others. In the long view, however, the most important factor affecting the sustained production of fish is that of sustained habitat viability. Neither economic, social, nor technological problems mean much if habitat is lost.

One of the most serious contemporary habitat problems affecting marine resources is that of petroleum pollution. It is well known that oiling causes various reactions among the living species of sealife; Malins (1979) suggests that the magnitude and persistence of damage in any location is a function of:

1. the chemical composition and physical properties of the petroleum;
2. the quantity and duration of the oil spill;
3. the seasonal, oceanographic, and meteorological conditions existing during the exposure;
4. the nature of the exposed ecosystem;
5. the type of habitat involved;
6. the geographical location; and
7. the type and extent of cleanup undertaken (Malins 1979).

The world has been fortunate that there has been only one large scale oil spill in the last few years. This is undoubtedly due to recognition of the immense cost of clean-up, the cost of oil wasted at $33 or more per barrel, and the cost of dealing with an outraged public. While major spills have declined there are still numerous ones of a minor nature, 1127 having been registered by the Coast Guard from January 1974 to August 1975 (Marx 1981).

Of particular interest and concern to the residents of the Pacific Northwest is the loss of fishery wealth due to the impoundment of transit or spawning streams used by anadromous species. Dr. Ebel has just reported that a major function of the scientists at Montlake has been to determine the factors affecting the lives of salmon and

steelhead in the Columbia River system. Particular emphasis has been on the effects of the construction and operation of the 27 dams that have been built on the Columbia and its tributaries since the first major barrier, Rock Island Dam, was erected in 1933. To say the least, the Columbia River program has inherited the experience of Sysiphus. That there are any salmon left in the Columbia drainage at all is a tribute to the scientists, managers, and engineers whose work must have been tinged with feelings of frustration and desperation as one problem solved was replaced by another equally difficult (Ebel 1981).

When one considers the immensity of the changes that have occurred in the Columbia River Basin, the problem of the dams falls into perspective as but another in a long series of growing insults to the river environment that have decimated the River's commercial salmon production from a high of near 50,000,000 pounds in 1916 to but 5,000,000 pounds in 1979. Prominent among these are changes in land-use due to agriculture, forestry, mining, and urbanization that have resulted at one time or another in dewatered spawning streams; death of spawners and returning young through irrigation diversion; increased temperature and turbidity; changes in rate and time of runoff; log and logging debris jams; deteriorated chemical nature of water; introduction of toxic materials and exotic predator species; and channel and estuary modification by dredging and filling (Howard 1981). It is obvious why the anadromous species of the Columbia River are in dire straits; equally apparent is why the continued scientific study of means for the preservation of salmon in this system is imperative (National Marine Fisheries Service 1981).

Many if not all of the same factors to a greater or lesser degree have been faced by the managers of anadromous fisheries in other parts of North America. The distress of the salmon runs of the Sacramento drainage in California has become increasingly severe. Adverse changes in water quality in the Sacramento and the estuary of that river and of the San Joachin have recently been brought into prominence by plans to divert virtually the entire flow of the Sacramento around the estuary, there to be pumped southward to supply water demands in southern California (Yocom 1981). To further complicate the problem most of the upstream flow of the Trinity River, accounting for 90 percent of its upstream spawning area, is already diverted into the Sacramento. The Trinity is a principal tributary of the Klamath River, whose salmon runs have been impaired by this reduction in available spawning grounds. The same fate hangs over the Eel River, whose upper reaches are scheduled to be diverted to the Sacramento.

Some have assumed that the critical problem was the transport of immature salmon in the Sacramento River downstream into the estuary. However, in recent years there has been a notable decline in the numbers of striped bass spawning and using the estuary and San Francisco Bay. The deterioration of water quality in the estuary as a result of the large diversions may well be the cause not only of the decline of the striped bass, but also another factor in excessive mortality of juvenile salmon. Moreover, there are other species of fish in the Bay whose requirements are little known that may be adversely affected by the changes in water character in the estuary upon the consummation of this gigantic diversion.

On the east coast of North America, many of the same problems described above have been present for many years. Until the period of the 1960's there was little done to restore the anadromous fisheries of the northeastern United States. An integrated program of improvement of spawning streams through both pollution abatement and removal of, or passage over, fish barriers plus greater stocking efforts seem to have been successful in starting the restoration of salmon in the Penobscot and Connecticut Rivers.

In the Chesapeake Bay, however, the anadromous species including the American shad and striped bass have suffered a severe decline in the last few years. There has not been a highly successful survival of bass larvae since the large year class of 1970, and the last 3 years have seen a collapse of the spawning shad population. The precise cause of these declines has not yet been determined. However, since the exploitation of these two species has never been deemed to be excessive in relation to estimated populations, it is assumed that environmental changes are responsible.

The destruction or impairment of estuaries has been a critical problem of major dimensions for years. They have been ruthlessly dredged for sand, gravel, and oystershell on the one hand and as thoughtlessly filled with dredge spoil, trash, and toxic wastes from industrial development and housing and restoration projects--resulting in all types of rural, urban, and industrial pollution. It is remarkable that any have survived as natural components of the marine ecosystem, despite substantial interest in their preservation even up to the halls of the United States Congress. Until recently, it appeared that the estuaries would have a respite from their despoilers, but even now there are schemes afoot to permit attacks on them and other wetlands by lowering the governmental wetland protection standards.

Demands for these changes stem from a variety of exploitative commercial activities, but those related to our coastal resources come primarily from the energy problems caused by the imminent exhaustion of petroleum supplies. Nearly every major port in America is being examined from the standpoint of its potential as a coal shipping center. The Congress has already authorized dredging of Chesapeake Bay to a 52-foot depth (a large project that, despite the comments and conclusions in the environmental impact statement, will have profound environmental effects). In the Strait of Juan de Fuca plans are brewing near Port Angeles, Washington, to establish a major oil terminal to serve as the port for the Northern Tier Pipeline Company (Larkins 1981). Up to the present, the potential for environmental disaster due to an oil spill has been largely waved aside or ignored.

Still another area of concern related to the energy problem is the sudden growth of interest in the development of small hydroelectric generating plants. A major problem that had to be overcome before anadromous fish restoration could progress in New England was the presence of numerous dams originally built without regard for fish passage. A common activity in the early days of the Federal Aid in Fish Restoration Program was the identification and removal or laddering of these structures. Under the impetus of new federal legislation, which mandates that the major utilities buy the power produced, there has been an

avalanche of applications for small hydro installations. In most instances there is adequate technology to insure the movement of spawning fish past the structures. The real problem will be whether there will be state and federal funds to enforce conservation stipulations and whether policies will be changed to permit construction without essential passage facilities (Chasan 1981).

Alaska, to return to problems of more immediate concern to this symposium, is not exempt from looming threats to the viability of its natural environments. Active planning is under way for power plants on the Stikine and Susitna Rivers, and there are many other smaller hydroelectric developments that are in some stage of planning. All will have some impact on Alaska's fisheries.

It is well known that the edges of the land masses surrounding the Arctic Ocean are considered to be among the more promising regions for oil exploration and exploitation. A few years ago a study conducted by the Council on Environmental Quality identified those areas most subject to oil development that also had uniquely high fish and wildlife resource values. The two most important such areas were in the Bering Sea and Prince William Sound. To date, formal steps to lease these offshore areas have been delayed, and it is to be hoped that leasing can be held off until there are more sophisticated techniques available for both the actual drilling and dealing with accidental spills. Both environmental deterioration and interference with fishing activities would result from premature activity in these highly important fishing areas.

Meanwhile, also in Alaska, another threat to the anadromous fisheries is looming as a result of the requirement in the Alaska National Interest Lands Conservation Act that 4.5 billion board feet of timber be harvested from the Tongass National Forest in southeast Alaska over a 10 year period. When the acreage set aside for native use, state claims, and rocky or protected wilderness have been subtracted from the total acreage of harvestable timber in the Tongass, there is some question whether enough timber remains to meet the statutory mandate and at the same time protect the old growth timber adjacent to several hundred miles of salmon and trout spawning streams in the forest. Certainly, it can be done only if the Forest Service and the State of Alaska provide the funds both for basic research on quality characteristics and for annual planning and surveillance of cutting.

This essay makes no pretense to present a comprehensive review of the environmental stresses that are affecting the fisheries around the world. It is fair to assume that the same factors are at work in other regions. Indeed the popular environmental and fisheries periodicals seldom fail to include an item about some disappearing habitat somewhere in the world. Recently the magazine Sea Frontiers contained an article reporting the destruction of mangroves in the Malay Archipelago. All mangrove forests except those in New Guinea are considered to be endangered. In the Philippines, less than a quarter remains of the country's original 1,112,000 acres of mangroves. Interestingly, 435,000 acres have been converted to fish ponds. At current rates of destruction, 59,300 acres per year, or all of their mangroves, will be gone within about 5 years (Scott 1981). Who knows the consequences to marine animals that find the mangrove habitat essential to their survival?

What I have described represents but a small sampling of the broad assault upon the ocean environment. The most obvious effects are those in the estuaries and streams where human activities are visible to the public. By virtue of their immensity there has been a tendency over the years to consider the oceans immune to the effects of unrestrained use. Men have used the oceans in a dozen ways and doubtless more will evolve in the future to fill the demands of an expanding population. Many of these are neutral in terms of their environmental impacts, but incremental effects of others could spell ruin. It is hoped that the tendency to view the oceans as convenient dumping grounds for all kinds of wastes that we have no ready place for on shore is finally coming to an end.

PUBLIC POLICIES AND THE MARINE ENVIRONMENT

It is no surprise that the great promise of the bounty from the sea so loudly heralded in the 1960's has dwindled in today's harsh economic realities. The widespread interest in ocean development has settled down to the over-riding search for oil and a few minerals, notably manganese. Current government preoccupation with achieving a balanced budget while promoting immense outlays for defense leaves little room for more than the most essential and sometimes mundane housekeeping chores related to marine resources.

To those of us in the profession, it sometimes seems that public interest in and support for ocean exploration, development, or protection seems to range from complacency to ignorance. An effort to stimulate broad public concern by a coalition of national conservation organizations under the program "The Year of the Coast" did little more than cause a few stifled yawns. The warnings of marine ill-health by such well-know celebrities as Cousteau and Heyerdahl seem to be brushed aside for what are perceived to be more urgent matters. Underneath this general public apathy lies the unspoken feeling that the oceans are too big to be hurt by man's activities. The great oil spill tragedies have been all but forgotten.

Those who "use" the ocean continue to see it as a resource to be mined rather than managed. Some of the experiences of the regional fishery management councils exemplify that attitude, especially where hard decisions between a conservative policy and one of exploitation have been involved. The tragedy of the common still stalks our oceans.

In the process of determining the benefits and costs of competing resource uses as, for example, the use of flowing water to support life in a spawning stream versus its use in irrigation, economic analytical techniques seldom provide a comprehensive balancing of all the benefits or all the costs. Not only must the techniques of evaluation be improved and the basic theory itself developed so that amenity values and societal costs can be adequately considered, there must be a strong governmental concern for these matters.

These needs can only be recognized and dealt with effectively in two places, academia and government. The reason is simply that the ocean resources are public resources; there is no incentive for the investment of private capital in either the essential research or the

development of the programs needed for securing the future of the "wealth of the sea." If government at either the federal or state level fails to recognize this basic responsibility, we indeed stand on the threshold of marine resource disaster. The difference between today and 1931, I would remind you, is a matter of some 2.5 billion more people in the world. We in the United States have nearly doubled our own population in that same period.

The other option available for the financing of essential ocean fisheries programs is to plan for the imposition of royalties for the extraction of the publicly owned sea resources. This concept was considered and rejected in the debate leading to the enactment of the Magnuson Fishery Conservation and Management Act of 1976. If indeed the government disavows its responsibility for fisheries management, protection, and enhancement, the only other alternative would be to establish a fee system for domestic as well as foreign participants in the fishery.

Certainly it is time that the commercial fishing industry engages in some original and far-sighted thinking about its future. The ability of the oceans to produce food, especially the protein-rich varieties that a hungry world so badly needs, must be protected and extended in the very basic interest of the future of mankind. We can no more turn away from the support of scientific management and protection of the ocean's condition than we can ignore the lessons of the past with respect to soil erosion and fertility losses. In the minds of many, these have become issues that are non-debatable.

THE LONG-RANGE OUTLOOK

The extent of growth in the human population vs resources of this country and the world was sketched in the earlier paragraphs. The purpose, of course, was to provide a basis for considering the role of the marine resources in the world's future. It would be too much to say that all of the problems besetting our use and enjoyment of those resources would be eliminated if we were successful in stabilizing the human population at something better than starvation levels. However, the fact remains starkly and inevitably, that unless we do succeed in levelling off our population growth, there will be little hope for mankind in general and none whatever for marine resources. Hungry mobs provide little support for prudent resource management.

Many have viewed the future of mankind with great alarm. The Roman historian Livy, nearly 2000 years ago, wrote that "Contemporary history displays our nation suicidally eating up its mighty resources." We too, are living in a world dependent on finite resources. The specter of a race whose powers of reproduction have remained undiminished while building an immunity to the ravages of the "Four Horsemen of the Apocalypse" is cause for genuine concern.

There seems to be little doubt that most of the world's leaders are aware of the ominous portent of an unlimited population/limited resources equation, yet because it must be dealt with in terms of some of humanity's most revered and personal liberties, few have been motivated to strong action. In certain instances, governmental efforts to slow population growth have not been overly successful, but in

still others, dramatic results have been achieved in a remarkably short time. China, Indonesia, Costa Rica, and Barbados, an interesting variety of nations, have all achieved an essentially stabilized population. Their success depended on forthright government efforts to promote family planning. Incentives for limiting children, disincentives for having children, provision of family planning assistance complete with birth control devices, and the availability of abortions have proved to be effective. Other countries have begun to embark on the same programs and are beginning to see immediate results.

In other countries, those with higher standards of living, greater freedom for women to move into the mainstream of economic and professional life, and higher education levels, birth rates levelled off without government assistance. Austria, Belgium, East Germany, Luxembourg, Sweden, United Kingdom, and West Germany are in this group (Brown 1981).

Our use of resources has already taken decisive turns. In this country alone we have reduced our petroleum consumption significantly since 1973, which is important when it is realized that we are by far the largest single consumer of petroleum in the world. This trend will continue as more and more of our home heating and industrial demand switches to coal. The coal option will not be an unmitigated blessing; lower air quality would seem to be an inevitable accompaniment of increased coal use. However, it is at least a source that may keep the world's wheels turning until we have moved into the era of solar energy.

No thoughtful person can pretend to predict with precision what will happen in the long-range future. However, we can suggest those things that must be done if we are to achieve certain social or economic objectives. With respect to our marine resources, we know that we must carefully guard against thoughtless destruction or deterioration of the environment. As a generality, nearly everyone would agree to that. The questions are what constitutes intolerable destruction or impairment, and how do we go about preventing it?

The answer to those questions can be found primarily in a continuation and expansion of the scientific research that has brought civilization to its present levels. We will continue to need to know more about how the oceans work, the relationships between their components, and what the effects of human-induced changes are in both the parts and the whole.

Moreover, what we learn must be communicated to the public in ways that will do more than merely enlighten. It must motivate action by individuals to make rational decisions in relation to resource issues. There was a day when it was enough for the scientist to publish his results; his peers would subject his finding to appropriate reviews and ultimately they would be incorporated in public policy or not, as the political fates would have it. Today, those who will be affected by the results of research are becoming more involved in identifying problems, observing the course of studies, and finally supporting the evident conclusions. This has happened on the Great Lakes where water quality progams were developed in this way (Alexander 1980); that process is being duplicated by the Environmental Protection Agency to implement the results of its water quality studies on Chesapeake Bay.

Finally, to prevent special interests

from forever dominating the political process of making resource allocations, there must continue to be a vital force of citizen opinion marshalled in support of prudent resource use. Contrary to what some have thought, the environmental movement is far from moribund. At the moment it seems to be growing from the stimulation of adversity. The Sierra Club has just delivered its million-signature petition calling for the ouster of James Watt as Secretary of the Interior. The National Wildlife Federation now boasts 4.5 million members and has set its sights clearly on the need to protect the world's resources from avaricious interests. The same may be said for most of the other national conservation organizations. Despite comments earlier about the apathy of the public concerning threats to the marine resources, experience has shown it can be dissipated when a major issue, however local, is clearly presented.

Realistically, it must be recognized that not all of the environmental battles will be decided in favor of prudent resource use. Therefore, one might assume that we must continue to anticipate a gradual decline in the quality of the environment. That such is not the case is demonstrated by what has happened to America's surface waters over the past decade. Save for the "acid rain" problem there has been a demonstrable improvement in quality over much of the country. The threat of chlorinated hydrocarbons permeating the ecosystem has been moderated, and the fish-eating birds that were on their way to extinction 15 years ago have at least been reprieved. That end would not have been realized in the absence of a strong alliance between scientists, administrators, and the public. The example persists, and what has been done can be repeated.

The full extent of conversion to a population stabilized in relation to its resource base, marine or otherwise, will require profound and extensive changes in life styles, economic parameters, social relationships, land use, and every conceivable aspect of human life. Brown (1971) outlines what has been and is being done. We are indeed facing a revolution; whether it will be constructive or destructive depends on whether we learn to live within our global means.

There is a role in this revolution for the scientists at Montlake, as there is for all those who strive to explain the complex working of the world, as we look ahead to the next 50 tension-fraught years. You and people like you who have the knowledge, the intellect, and a dedication to a livable earth can continue to contribute to our understanding of the vital role of the natural systems on which mankind depends. You and your associates have the ability as scientists, and the obligation as responsible members of the human race, to interpret your knowledge and your insights to promote greater public understanding of the significance of the resources with which you deal; you and your colleagues can provide a critical technological leadership to support the growing body of the public that increasingly understands that a healthy natural environment is vital to man's future. You, and all of us, can echo the words of Chief Seattle, "And what is it to say goodbye to the swift and the hunt, and the end of living and the beginning of survival?"

REFERENCES

ALEXANDER, J.
1980. Environmental Management Strategy for the Great Lakes. In Proceedings of the Annual Meeting of the Environmental Protection Agency's Chesapeake Bay Program, p. 18-28. U.S. Environ. Prot. Agency, Reg. 3, Chesapeake Bay Program, Annapolis, MD.

BROWN, LESTER R.
1981. Building a sustainable society. The Worldwatch Institute. W. W. Norton Co., New York, N.Y., 433 p.

COUNCIL ON ENVIRONMENTAL QUALITY.
1981. Global 2000 report to the President: entering the Twenty-first Century. U.S. Gov. Print. Off., Washington, D.C., 411 p.

CHASAN, DANIEL JACK.
1981. Harnessing the old mill stream. Pac. Northwest 15(7):8,10,12.

EBEL, WESLEY J., JR.
1982. Effects of environmental degradation on the freshwater stage of anadromous fish. In Fifty Years of Cooperation and Commitment: 1931-81, the Northwest and Alaska Fisheries Center, p. 147-180. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-34.

HOWARD, WILLIAM.
1981. [Statements on ocean dumping presented at House committee meetings in Washington, D.C.] Coastal Zone Manage. 12(17) and 12(18), various pagination.

LARKINS, H. A.
1981. Letter of 30 September 1981 to Colonel Leon K. Moraski, District Engineer, Seattle District, U.S. Army Corps of Engineers, on applications for permits for the Northern Tier Pipeline Company. Northwest Reg. Off., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115.

MALINS, DONALD C.
1979. Statement of Donald C. Malins, National Oceanic and Atmospheric Administration. In Campeche oil spill, joint hearing before the Committee on Commerce, Science, and Transportation and Committee on Energy and Natural Resources, U.S. Congress, Senate, December 5, 1979, Washington, D.C., Serial 96-66, p. 210-216. U.S. Gov. Print. Off., Washington, D.C.

MARX, WESLEY.
1981. The last resource: prospects for a watery planet. Sierra Club Books, San Francisco, Calif., 320 p.

NATIONAL MARINE FISHERIES SERVICE.
1981. Columbia River Fisheries Development Program. Informal rep., 34 p. Northwest Reg. Off., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115.

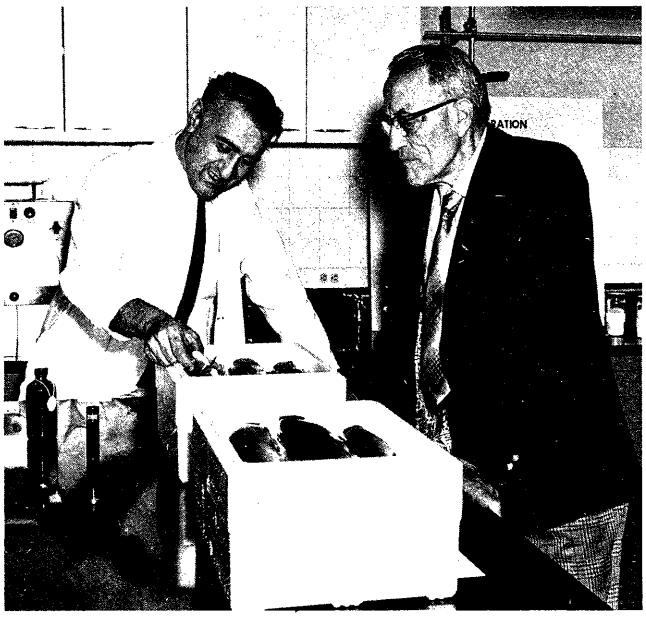
SCOTT, GEOFFREY A. J.
1981. Mangroves and man in the Malay Archipelago. Sea Front. 27(5):258-266.

YOCOM, THOMAS G.
1981. Testimony before the California State Water Resources Board, 22 September 1981, Sacramento, California. Tiburon Fish. Lab., Southwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 3150 Paradise Dr., Tiburon, CA 94920.

Utilization Research, 1931-1981: A Historical Overview

John A. Dassow [1]

Preparation of trawl-caught fish for research on problems connected with processing (left to right, George Kudo and Fuad Teeny, chemists, and Herman Groninger, biochemist; Utilization Research Division in 1968).



John Spinelli, chemist, shows Dr. Lauren Donaldson, noted aquaculture expert of the University of Washington, the improved flesh color in pen-reared coho salmon that had natural carotenoid extract added to the diet. Photo taken at the Open House in 1974.

INTRODUCTION

Our review of Fishery Utilization research properly begins in May 1933 when Roger Harrison, chemical engineer, and Andrew W. Anderson, fishery technologist, arrived to initiate the technological research program in Seattle in the new Bureau of Fisheries Building. Before picking up the thread of the technological research at that time, however, I would like to refer briefly to the background from which Harrison and Anderson emerged.

Fishery technology or, as we refer to it now, fishery utilization, had been a federal research activity of considerable scope for many years prior to the opening of the Seattle laboratory in 1931. A compilation by Maurice E. Stansby records technological research at 17 locations in the United States starting in 1878 in Gloucester, Massachusetts, to four locations in 1931--Gloucester, Massachusetts; College Park, Maryland; San Diego, California; and Washington, D.C. The research facilities in most cases were temporary; however, it is significant that of the various locations, Gloucester and Seattle are the locations that as of 1981 have

1/ Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

retained technological research facilities over the longest periods during the 103 years from 1878.

The scope of this technological research from 1878 to 1931 is even more significant because it demonstrates the continuity of problems associated with Utilization Research to the present day. This is not surprising to anyone who knows the scientific literature of fisheries chemistry and technology. What is dismaying to those of us who have been in utilization research for a few decades is a failing of many students of Fishery Food Science. They arrive on the scene convinced that all important findings on the chemistry, composition, nutritional value, spoilage, refrigeration, and waste utilization of fish and shellfish were accomplished in the last 5-10 years. Therefore, the conclusion is that the literature prior to that is ancient history, not science. Let me be specific on this matter of the enduring nature of good technological research. Consider the basic proximate composition of fish. Food composition tables today include analytical data that are still useful from Dr. W. O. Atwater's classical studies in the 1880's, Dr. Ernest Clark's and R. W. Clough's analyses in the National Canner's Association laboratory in the 1920's, and E. H. Coulson's mineral analyses from 1929 to 1935. Recently, for reply to a dietician, I found Coulson's iodine data of 45 years ago comparable on similar species to recent published data and more complete on the variation in salmon and shrimp. Other examples from the 1920's of the technological base prior to 1933 are the refrigeration and canning studies by Harden Taylor and Harry Beard, respectively, and research on the spoilage of fish and oysters by Ernest Clark, Donald Tressler, and others. Norman Jarvis' studies and compilations of canning and curing technology are still in demand after 40 years. The works of J. M. Lemon on chilling and freezing fish from 1930 to 1950 are still widely used for reviews and textbook presentations. The tools for research are sharper today and certainly far more costly; however, the use of good science of the past is important to utilization research today and tomorrow.

For our overview, I would like to divide our discussion into the five decades. In each period the backdrop of industrial developments and problems is appraised first because, without industry, utilization research is a biography of knowledge with little application. For this reason, the research direction and events of utilization research are summarized primarily by their relation to industry, not the research leaders or scientific staff. In the history section of this publication, the personal research recorded is more complete. The final and obvious topic for our review is the assessment of economic benefits. In my experience, estimation of benefit/cost ratios for government research has a large margin of error potential depending on one's skill in the science of reasonable assumptions; however, we will consider recent examples of research benefits.

UTLILIZATION RESEARCH DIRECTIONS AND ACCOMPLISHMENTS

By 1933, the scientific disciplines were established for fishery utilization research--chemistry, physics, biochemistry, microbiology, and engineering. The technological areas of the earlier studies are equally familiar--chemical composition;

nutritive value; spoilage of fish and shellfish; processing technology including handling, chilling, freezing, canning, salting, curing, drying; and waste utilization. These then were the basic research areas for the new Fisheries Technological Laboratory when Roger Harrison assumed direction in May 1933.

1931-1941

Looking back at the Pacific Coast Fisheries of the 1930's, salmon canning clearly was the dominant industry of the Northwest and Alaska with 115 operating canneries in Alaska during the 1931 season and 48 in the Puget Sound and Columbia River areas. Farther south, sardine canning was a major industry but showing the first signs of decline. Tuna had developed a firm base since 1927 of about 1.2 million cases but showed no signs of the spectacular growth ahead. In Alaska, halibut fishing and salmon trolling started in the spring for a 6-month season, and the codfish schooners with their stacks of dories headed for the Bering Sea. About the same time, shrimp, Dungeness crab, herring, and bottomfish were small but important fisheries in communities along the coast. The economic depression of the 30's handicapped fishermen and processors alike. The number of operating salmon canneries in Alaska dropped 30 percent in the early 30's. In Bristol Bay an excellent sockeye (red) salmon run glutted the canneries and prices to the fishermen sometimes dropped unbelievably low--some landings at one cent a pound.

At the new Seattle Fisheries laboratory, the first task for Harrison and Anderson was to finish the fish meal and oil studies and reports from the extensive research conducted at Gloucester, Massachusetts, and at Reedville, Virginia. Research on utilizing waste from the various salmon species was the first major study during the 1930's and included definitive studies of the chemical and physical properties of salmon oils including their vitamin A and D content and the production of edible quality oil for use in canned salmon. Interest in freezing foods, both commercially and for personal use, developed rapidly in this period and the small laboratory staff initiated major research on freezing and storage of various species of salmon and bottomfish. One pioneer study with private funding was the potential use of cereal antioxidants to inhibit the development of rancidity. With the arrival of Maurice Stansby in 1937, research was expanded to include chemical studies of rancidity development in frozen salmon and chemistry of freshness and spoilage changes in fresh salmon. In the fish meal and oil studies and frozen fish research, it is significant that the laboratory laid a firm base during these years for analytical methodology and improved measurement of chemical changes in fishery products. The results published by Harrison, Stansby, Anderson, and others established the reputation of the Seattle laboratory at an early date.

At the close of the decade, the technological laboratory undertook a prophetic assignment--an investigation of the feasibility of a king crab fishery in Alaska including methods for harvesting and processing king crab. The subsequent exploratory and technical studies were directed by Harrison with seven research specialists. The field investigations used experienced fishermen and chartered fishing vessels and provided the first systematic record of the Alaska king crab industry potential.

The report of the study, published in May 1942, noted another finding of interest, "Alaskan waters hold an enormous reserve of edible fish--notably sole and pollock--which is at present wholly unutilized." Another indication of the Federal interest in fishery development in Alaska occurred in the last year of this period when the new Fishery Products laboratory was completed in late 1940 in Ketchikan and Stansby transferred to Ketchikan as the first director. However, the logical course of these and other developments was interrupted by the events of December 7, 1941, and World War II.

1941-1951

Wartime priorities soon imposed changes and expansion of the research program at the technological laboratory and the new satellite laboratory at Ketchikan. Industry shortages of vital materials and resources for food production were anticipated and research was soon underway on the feasibility of substitute containers for fresh and canned fish to save on tinplate. A possible shortage of agar, the seaweed extractive, was feared and a project on possible use of substitute seaweeds was started. Vitamin A in fish livers and proper sampling and analytical methods became important. A major project was established to determine the requirements for production and storage of dehydrated fish. Pilot dehydrating equipment was designed and constructed to demonstrate engineering essentials and the production of a test product.

In Ketchikan, studies were undertaken early in the war to determine the potential use of a wide variety of marine resources for food. The fishing industry was beset with the highest demand for fishery products in its history at a time when wartime activities and restrictions made offshore fisheries expansion a hazardous undertaking. My introduction to exploratory fishing occurred during this time at the Ketchikan laboratory, when a Seattle trawlers' association sent several vessels to explore for bottomfish in southeast Alaska. I went aboard one of the trawlers to collect species for preservation studies. The trawlers found rough bottom along with a variety of flounders, rockfish, and walleye (Alaska) pollock but little real production. At the laboratory we tested a wide variety of the little used bottomfish and other species for potential food--pollock, skate, rockfishes, smelt, sharks, wolf fish, greenling, starry flounder, arrowtooth flounder, and similar dubious species. Probably our most interesting experience was the work with Pacific sleeper shark and Stellar sea lion. Both proved quite edible in proper form and disguise. Industry tried marketing frozen sleeper shark fillets from Alaska in Chicago with, it's not too surprising, disastrous results. Even in wartime with meat and fish shortages, the consumer still exercised the right to buy something different only once.

Most of the wartime projects terminated in 1946 or soon after; research on vitamin A in fish livers continued until the industry declined drastically in the late 40's with the introduction of synthetic vitamin A. The laboratory needed a research initiative providing funds, and a proposal for a detailed study on utilization of Alaska salmon cannery wastes was funded through the Fisheries Experimental Commission of Alaska. The studies during 1947-48 included sample and data collection, species waste composition, pharmaceutical potentials, food uses for edible portions, edible oil production, and use for salmon hatchery

diets. The reports still provide the basic analytical data for inquiries on salmon wastes after 33 years. The Ketchikan laboratory initiated research on the problem of paralytic shellfish toxin occurrence in butter clams after a problem of product safety developed in this small but important industry in 1946. The studies on freezing and storage of various species were broadened to include Pacific salmon species and a wider range of bottomfish. More emphasis was placed on the factors of pretreatment, packaging, antioxidants, and use of lower storage temperatures to improve keeping quality of frozen products.

In 1947 the laboratory inititated further investigations on the king crab and bottomfish industry in Alaska. Experimental and smallzscale commercial packs of frozen king crab meat and crab sections in the shell were prepared cooperatively aboard the exploratory vessel Alaska in 1947 and aboard the subsidized factory vessel Pacific Explorer in the Bering Sea in 1948. The production of the Pacific Explorer included canned and frozen king crab and frozen fillets of pollock and sole from the Bering Sea. The Explorer operations were hardly successful because of the mediocre quality of the products, the low production levels, and the indifferent market acceptance. Yet it must be counted as a worthwhile endeavor that demonstrated in our product evaluations the process problems and technological pitfalls in factory vessel operations in Alaska.

During the same post-war period, Lowell Wakefield, Bill Suryan, Harry Guffey, Ed Shields, and others were testing their ideas for harvesting and processing king crab aboard vessel. Who led the way most clearly? Certainly the government exploratory studies of the 1940-41 king crab expedition and our laboratory studies of 1947-49 helped sort out the production potentials, quality problems, and the need for process controls at every step. Nevertheless king crab worthy of the name was produced at a profit first and best by Wakefield's. How long did it take? An important question in benefit/cost analyses is always the time from experiment to assured commercial success. Lowell Wakefield once told me that for king crab it was 15 years. Returning to our work in the late 40's on processing frozen pollock and bottomfish of the Bering Sea, it is obvious 30 years later that major problems of using this resource for domestic industry expansion still remain, even though much knowledge of the resource and process alternatives is available.

1951-1961

In the early 1950's, there were several industry developments that were reflected in the technological research program. In the Pacific Northwest and Alaska, salmon canning and halibut freezing were still dominant.

The increased use of freezerships for freezing salmon in Alaska for later canning and the industry problems of increasing costs for Alaska operation indicated that economics and need for better production efficiency were dictating changes. King crab was still on the horizon with less than 1 million pounds frozen meat production as the industry struggled for recognition in eastern markets and higher prices. Frozen fillet production in the Pacific Northwest seemed static around 5 to 6 million pounds; however, the exploratory fishing findings of large stocks of Pacific ocean perch in deeper waters looked promising. Indications

of large populations of pink shrimp off Oregon seemed to point to future expansion of the Northwest shrimp industry.

The California tuna industry was still growing after the post-war expansion and was packing 8 to 9 million cases a year but pilchards (sardines) fell from the biggest production year of 5.3 million cases in 1950-51 to 65 thousand cases in 1953. Tuna was very competitive and striving for a quality image as production climbed.

Back at the Seattle Technological Laboratory, research on utilizing salmon cannery waste, the nutritional significance of fish meals, and freezing and storage studies for several species of fish and shellfish were completed. Studies of the quality changes in freezing and storing salmon for later canning were completed and reviewed with the National Canners' Association and processors. By this time, various studies on quality and processing problems had demonstrated the need to expand the basic data on proximate composition and food values of a wide variety of species of both marine and freshwater origin. This project from 1955 to 1961 provided analyses of most Pacific coast species and proved highly valuable to both industry and nutritionists.

At the Ketchikan laboratory, the 5-year study of the problem of paralytic shellfish poison in butter clams was completed. The results showed that the problem of producing frozen or canned clams in southeastern Alaska required close monitoring of toxin levels prior to processing because of the wide and frequently inconsistent variation in the toxicity of clams from many beaches. This, incidentally, is about where we are 30 years later; however, recent research by the University of Alaska and others suggest we may soon understand the mechanism that accounts for variable toxicity in adjacent clam beds.

A major expansion in the Seattle technological research arrived in 1954 with supplementary funds, from $63,000 initially to over $200,000 by 1960, allotted under the Saltonstall-Kennedy Act of 1954 for fishery development and quality research. Two new major research programs were inititated: (1) Chemical and nutritional characteristics of fish oil and development of new uses for fish oils and (2) Development of voluntary standards of quality for fresh and frozen fish and shellfish for use by the new voluntary inspection program and industry.

The fish oil research included both fundamental and applied research under contract to the top two universities in the fields--California and Minnesota. Industry liaison was a significant part of the research and included oil producers, users, and chemical manufacturers for the studies at the laboratory on chemical derivatives and intermediates. Other research emphasized the significance of the polyunsaturated fish oils and the role of the fatty acids for dietary use in lowering serum cholesterol. Substantial interest and support was shown by nutritionists and physicians in this research because of national concern of the American Heart Association for proper dietary control of the factors causing high serum cholesterol and atherosclerosis in an increasing number of Americans. The research included support of dietary studies with both animals and humans and demonstrated the value of seafoods and fish oils in the diet under long-term comparative conditions. In recent years, new controversies have arisen in

this field because of the complexities of individual health and dietary regimes. It is of special interest to note that pioneering studies of the Seattle heart specialist Dr. Averly Nelson, for whom the technological laboratory provided considerable assistance, showed in a 20-year study of heart patients that when high amounts of oily fish such as salmon were in the diets, 36% of the patients survived over the 20 years; only 8% of the patients who did not use the high fish diet survived. This early work published in 1972 provided the first evidence of the great value oily fish can be for heart patients. Recent workers during the past five years, unaware of Dr. Nelson's earlier results, are now substantiating this role of oily fish and fish oils in connection with heart disease.

The new quality standards program at Seattle emphasized frozen salmon, halibut, sole, cod, and Pacific ocean perch. The measurement of quality in each species was conducted in collaboration with industry groups and included many product cuttings. The validity of the voluntary grade standards and their application for consumer acceptance was thoroughly reviewed and, on occasion challenged, in industry cuttings. This work, for the first time, emphasized the difficulty of defining intrinsic quality in freshness, flavor, and texture of otherwise good quality fish.

The problem was best illustrated in our work with quality grading of frozen halibut steaks and, in a later study, the quality grading of the landed fresh iced halibut. Considerable work on this latter problem was conducted aboard fishing vessels, an interesting assignment that required, in the case of the halibut fishery, a chemist or technologist with good sea legs and a little Scandinavian blood. One of the first facts of fish life that expanded our laboratory views of fresh fish was the finding that halibut of various fishing grounds varied remarkably on occasion in keeping quality and intrinsic acceptability. For example, I can remember selecting in a taste panel a sample of an 18-day-old iced halibut as exemplifying a top quality fresh halibut (i.e., Grade A) in contrast with another sample of halibut from a different ground that was quite edible but appeared to have suffered much quality loss. The poorer sample of halibut was iced for only 5 days. Like melons and fine wines, the environment for fish must be also just right to produce the most desirable quality. In our current quality studies of the cod and pollock of Alaska, we are finding again that all fresh fish are not equal. Our experiments at sea and in the laboratory must recognize the natural variations that affect acceptability and keeping quality of the fish harvested at various times or from different fishing areas.

An important study of quite different problems in the 50's was the quality of canned tuna and the determination of the handling and brine chilling factors aboard vessel that resulted in high salt content, spoilage, and physical damage to yellowfin and skipjack tuna. Research and contract studies at sea were conducted on the quality differences, the problems of brine chilling and freezing tuna, and the factors that contributed to quality losses. The laboratory coordinated the research with the tuna industry technical committee and the National Canners' Association laboratory in California. Results and the final report recommendations emphasized the refrigeration requirements and pinpointed the problem areas. We

recognized, however, that the basic economics dictated a number of the poor practices aboard vessel and this we could not solve.

1961-1971

The 1960's brought some good and poor years for the salmon industry and a feeling of uncertainty about the future as the industry observed the problems of international competition for the prime fishing grounds of the North Pacific. Japanese bottomfish operations appeared in the Bering Sea in 1960 and expanded in 1961. King crab freezing and canning plants at points from the Shumagin Islands to Kodiak and Cordova and southeast Alaska were producing at highest production levels to date in 1961.

By 1966 production of both canned and frozen king crab had tripled in volume from 1961 with landings of 159 million pounds. Pacific shrimp production got off the ground in the late 50's and was producing 155 thousand cases worth $2.5 million by 1961. Alaska bottomfish was still in wraps but halibut and salmon from Alaska and frozen fillets from Puget Sound were tops in the frozen fish business at 72 million pounds total for the Northwest and Alaska. In California, tuna at the beginning of the decade produced a new high of over 15 million cases and continued to grow.

Research on chemistry and nutritional properties of fish oils, development of quality criteria and measurement in fresh and frozen fish and shellfish, and development of voluntary standards for product inspection were major activities as the technological laboratory entered its 4th decade. Included in the fish oil program was the widest range of contract and cooperative research efforts conducted by the laboratory in its history and included such significant problems as oxidative changes, lipid metabolism, fish oil odor chemistry, nutritional properties of oxidized oils, and skin-healing properties of fish oils. In the laboratory, the research on chemical uses, reactions, and derivatives of fish oil developed various class compounds (e.g., nitrogen derivatives of fatty acids, fatty acid esters, and epoxy esters) with potential application in industry as intermediates for chemical synthesis of special industrial products. This research necessitated a close liaison by the chemists with both the fish oil industry and chemical manufacturers to select reactions and compounds of greatest interest and possible application.

The expanded laboratory research on quality criteria in conjunction with the industry cuttings demonstrated the need for better quality measurement. The distinction between freshness and spoilage criteria and the reason for using one or the other had long been a confusing area to fishery technologists. Spoilage, of course, was early assessed by both subjective and objective tests. The study of the more difficult problem of measuring freshness changes with objective methods and simpler methodology was initiated in the 60's and established the Seattle laboratory as a leader in the area. We believe that the application of these studies for quality control in frozen fish production would help assure the high quality needed for today's markets.

Another area studied was texture definition including measuring simple toughness or shear value and the water-binding or drip relations in the flesh. In the early work with Dover sole and

Pacific whiting (hake), the problem of mushy texture in some fish was resolved by the research on the protozoan parasite showing its relation to the proteolytic enzyme causing texture breakdown. In fish fillet plant studies, the importance of washing and minimizing the recontamination of the fillet was shown by conducting microbiological tests on the line in the plant.

As it turned out, this work provided the background for a major study on irradiation pasteurization of fresh fish that was supported most of this decade by the Atomic Energy Commission. The concept of using a chemical-physical means of destroying spoilage bacteria on the surface of fresh chilled fish and thereby extending its keeping quality was hardly a new one. Nevertheless, the extensive chemical, microbiological, and process research with low level gamma irradiation provided the most comprehensive base of knowledge to date on the quality changes that determine consumer acceptability of a fresh product. The extension of storage life of irradiated cod, sole, and other fish was demonstrated repeatedly; however, it seems to me that our most basic contribution lay in detailed studies of the chemistry of the flavor and texture changes in fresh fish that occur in the initial stage of quality loss long before chemical spoilage occurs. The microbiological studies on the irradiated fish first emphasized the detailed life and death story of the bacterial survivors of low level gamma irradiation. Of greatest importance in this work and the research that continues to the present date is the story of Clostridium botulinum, the possible hazard of botulism in partially processed products, and a basic understanding of the factors that determine the growth and toxicity of C. botulinum in such products. This problem more than any other problem, even the hard facts of irradiation economics, was responsible for Food and Drug Administration (FDA) actions that placed irradiation pasteurization of fish on the back burner at the conclusion of the extensive research by the Seattle and other laboratories at the end of the decade.

As a final comment to the fourth decade highlights, we should note that in 1966 Maurice Stansby left the Technological Laboratory after being Director since 1942. The new Director was Dr. Maynard Steinberg, formerly at the Gloucester Technological Laboratory.

1971-1981

In the 1970's, tuna production went out of sight with over 30 million cases valued at over 1 billion dollars. Shrimp became the most valuable landed species, and king and snow crab in Alaska made crab second in value to salmon and made Alaska first in value of U.S. landings. A community in Alaska that most people had never heard of since World War II, Dutch Harbor, became the top U.S. fishing port in value of landings. Pacific shrimp landings zoomed to new highs, then fell off. By 1980, trawl fish landings in the Northwest and Alaska were over 300 million pounds but over 40 percent went to foreign vessels under joint ventures. In 1976, the 200-mile limit became law and development of Alaska bottomfish was a bonanza or a bust depending on whom you asked. At the Seattle Technological laboratory, the Director, Maynard Steinberg, retired in August 1979 and the fourth Director for our 50-year period, John Spinelli, took over in February 1980.

Two developments had occurred in the

60's that shaped much of our technological research for the 1970's. The first was the recognition in the 1960's that the underutilized species of fish and shellfish off our coasts constituted a major food bank for future U.S. fisheries and the consumer. Species off the Northwest and Alaska included Pacific whiting, walleye pollock, and other bottomfish. Off California, anchovy and jack mackerel were included as underutilized resources. International concern for total utilization of fishery resources as food for a hungry world was expressed during the 60's and 70's in fishery conferences sponsored by the Food and Agriculture Organization (FAO) of the United Nations.

The second development was the new federal and state regulations of the 1970's on water quality, habitat protection, and the limitations on disposing of seafood processing wastes in coastal waters. These two developments brought to the industry new potentials for expansion on one hand but costly problems in plant operations on the other. As a result, the policy emphasis in the fifth decade of the technological laboratory included utilization and fishery development and the problems of quality and safety for both new and established processes.

Starting in the early 1960's, some very serious attempts were made to prepare and market relatively pure fish proteins. At that time, the primary efforts on this direction were being made in the United States, Canada, and Sweden. The end-product of this effort was, of course, fish protein concentrate (FPC). Our role in the national FPC program primarily was concerned with technical problems in FPC production at the pilot plant built in Aberdeen, Washington, and operated in 1970-71. FPC never became a viable commercial product and the story needn't be told here. Simply put, FPC was not needed in the industrialized countries and its merits were never demonstrated in third world countries. What about FPC today? It would appear that the technology to produce an inert FPC, solely a protein supplement, is too sophisticated and probably economically unsound. New approaches based on relatively old technology are beginning to show that fish can be used to supplement cereal proteins in a much simpler fashion than preparing a solvent-extracted powder.

The need for tested concepts of total utilization was still standing, of course, when the FPC program was terminated. Our research on Pacific whiting showed that total protein utilization from fishery resources requires various process alternatives for flesh and protein recovery, dehydration, stabilization, and modification of the intermediate dry or frozen product. Incorporation into modern food systems is the last and most important phase. Such concepts have been tested in our studies with Pacific whiting, rockfishes, and walleye pollock and include mechanical production of minced flesh, stabilization (as accomplished in Japanese surimi), and freezing and storage for use as an intermediate product to be used later in a variety of processed foods. The research of FPC and modified proteins has been important in building this base for alternative processing methods that industry can consider as future markets develop. The problems of species, harvest, and processing limitations aboard vessel and at the shore plant have shown that there is no universal panacea like FPC.

Actually, we have learned quite the

opposite. To utilize fully the long-neglected resources and even some of our traditional species, the fishing industry must produce food to the greatest extent practicable, but a variety of processing options must be available. Options should include processing aboard vessel, at a nearby shore plant, and intermediate processing for final production close to the markets. Selection of an option depends on the characteristics and volume of the species and the desired end product. Whether it is frozen, canned, or dried, the product must integrate with modern food production. Price and acceptability are important but also convenience, product image, and nutritive value. In a nutshell, we learned that the fishing industry must join the food industry.

Currently, our most important task is to complete the basic data on the quality, preservation, and food characteristics by species including the utilization options. Most of this has now been accomplished for Pacific whiting. Much more remains for walleye pollock, various rockfishes, flounders, and lesser species of fish and shellfish. An integral part of this technological agenda is the problem of the options for fish waste and by-catch utilization. The economic and energy outlook requires that total utilization concepts are derived also from good engineering and common sense.

CONCLUSION--FUTURE OF UTILIZATION RESEARCH

One common approach when confusion occurs in historical assessments is to gather statistics. For our review of the 48 years of Northwest and Alaska utilization research, the publication output was 615 scientific papers and technical reports, 7 patents, and numerous information reports to industry and the consumer. This sounds impressive but is not easily converted to output value. If we could convert this knowledge or the industry applications over the years to dollars on an objective basis, it would be simple to calculate the benefit/cost ratio for utilization research. How to assure objectivity in such calculations is both difficult and controversial and, for the purposes of this review, benefit/cost speculations do not seem appropriate.

It is difficult because scientific knowlege advances on a broad front and the users of research findings do not bother to give specific credit when those findings are integrated into a revenue-producing device or system. Also there are many instances that we can specifically cite where a research concept or finding lay on the shelf for many years before being rediscovered. Timing is important. Over 40 years ago, Maurice Stansby wrote a research paper on controlled atmosphere for preserving fresh fish. Today, controlled atmosphere has been rediscovered and is the "in" thing. An interesting result of our microbiological research on irradiated fish in the 60's was Dr. Melvin Eklund's knowledge of botulism and his recent finding that botulism in salmonids is responsible for recurring fingerling losses in state hatcheries. This finding will save state and federal hatcheries over 1 million dollars per year. Similarly work on flavor deterioration in irradiated foods by John Spinelli will undoubtedly be used as a quality index for frozen fish and help guarantee its quality. Six years ago, Dr. Lauren Donaldson urged that, in our work on salmonid feeds, we investigate the possibility

of extracting carotenoids from shrimp waste to use as a pigment source for pen-reared salmonids. The results of this work by John Spinelli may well lead to the development of an industry in Louisiana where 18 million pounds of crayfish waste could yield up to 2000 pounds of astaxanthin worth over 1 million dollars. It is difficult, of course, to attach a specific dollar figure on findings such as these even though the feedback shows benefits in dollars for the research.

In looking ahead, I believe Peter Drucker provided a point for management to remember: "Long range planning does not deal with future decisions but with the future of present decisions." Certainly there were major decisions made in fisheries utilization during the 70's that will affect fisheries development for many years. During the five decades of our review, it is clear that we and industry did not select all winners for fishery development; however, the benefits of research and cooperation did produce significant applications. Two important lessons stand out: (1) the need for continuity of utilization research in the basic food processes like freezing and quality measurement and (2) the long time scale for developments and process applications. These place a premium on the collected knowledge of the laboratory and the significance of our industry association for both the past and future of fishery development.

REFERENCES

ANONYMOUS.
1942. The Alaskan king crab. U.S. Fish Wild. Serv., Fish. Market News, May Supplement, 4, 5a. 107 p.

ATWATER, W. O.
1892. The chemical composition and nutritive values of food-fishes and aquatic invertebrates. U.S. Comm. Fish and Fish., Part 16, Rep. Comm. 1888, append 10:679-868.

BUTLER, CHARLES.
1955. The fish liver oil industry. U.S. Fish Wild. Serv. Fish. Leafl. 233, 98 p.

CHAMBERS, JOHN S., and HARRIS W. MAGNUSSON.
1950. Seasonal variations in toxicity of butter clams from selected Alaska beaches. U.S. Fish Wild. Serv., Spec. Sci. Rep. Fish. 53, 19 p.

CLARK, E. D., AND R. W. CLOUGH.
1926. Chemical composition of fish and shellfish. Rep. U.S. Comm. Fish., 1925, append. 10:502-526. (Doc. 1000.)

COULSON, E. J.
1935. The iodine content of some American fishery products. [U.S.] Bur. Fish., Invest. Rep. 25, 7p.

DASSOW, JOHN A.
1950. Freezing and canning king crab. U.S. Fish Wild. Serv., Fish. Leafl. 374, 9 p.

DASSOW, J. A., R. W. NELSON, and W. I. TRETSVEN.
1969. Developing quality standards for fresh dressed fish, Pacific halibut (Hippoglossus stenolepis). In Fish inspection and quality control, p. 34-40. Fishing News (Books), Ltd., London.

EKLUND, M. E., and F. T. POYSKY.
1970. The significance of nonproteoclytic Clostridium botulinum types B, E, and F in the development of radiation-pasteurized fishery products. In Preservation of fish by irradiation, p. 125-148. International Atomic Energy Agency, Vienna, Va.

HAMM, W. S., C. BUTLER, and M. HEERDT, JR.
1944. Food fish dehydrate well. Food Indust., June:445-447, 489-490.

HARRISON, ROGER W., ANDREW W. ANDERSON, ARTHUR D. HOLMES, and MADELINE G. PIGOTT.
1937. Vitamin content of oils from cannery trimmings of salmon from the Columbia River and Puget Sound regions. [U.S.] Bur. Fish., Invest. Rep. 36, 8 p.

HARRISON, ROGER W., ANDREW W. ANDERSON, S. R. POTTINGER, and CHARLES LEE.
1939. Pacific salmon oils. [U.S.] Bur. Fish., Invest. Rep. 40, 21 p.

JARVIS, NORMAN D.
1943. Principles and methods in the canning of fishery products. U.S. Fish Wild. Serv., Res. Rep. 7, 366 p.

JARVIS, NORMAN D.
1950. Curing of fishery products. U.S. Fish Wild. Serv., Res. Rep. 18, 271 p.

KARRICK, NEVA L.
1965. A review of marine oil research conducted and sponsored by the Bureau of Commercial Fisheries of the United States, Fette Seifen Anstrichm. 67(7):489-494.

LEMON, J. M. and C. B. CARLSON.
1948. Freezing fish at sea. Leaflet 278, U.S. Fish Wild. Serv., Fish Leafl. 278, 11 p.

MIYAUCHI, D., J. SPINELLI, G. PELROY, and M. A. STEINBERG.
1967. Radiation preservation of Pacific coast fishery products. Isot. Radiat. Technol. 5(2):136-141.

SPINELLI, J.
1979. Preparation of salmonid diets containing zooplankton and their effect on organoleptic properties of pen-reared salmonids. In John E. Halver and Klaus Tiews (editors), Finfish nutrition and fishfeed technology, Vol. 2, p. 383-392. H. Heeneman GmbH, Verlag, Berlin, Federal Republic of Germany.

SPINELLI, JOHN.
1971. Biochemical basis of fish freshness. Process Biochem. 6(5):36-7, 54.

SPINELLI, J., B. KOURY, H. GRONINGER, and R. MILLER.
1977. Expanded uses for fish protein from underutilized species. Food Technol. 31(5):184-187.

STANSBY, M. E.
1969. Nutritional properties of fish oil. In World review of nutrition and dietetics, Vol. 2, p. 46-105. Karger, Basel/New York.

STANSBY, M. E.
1976. Chemical characteristics of fish caught in the northeast Pacific Ocean. Mar. Fish. Rev. 38(9):1-11.

STANSBY, MAURICE E., and ASSOCIATES.
1953. Utilization of Alaskan salmon cannery waste, Parts 1 and 2. U.S. Fish Wild. Serv., Spec. Sci. Rep. Fish. 109, 107 p.

STANSBY, M. E., and J. A. DASSOW.
1951. Use of frozen salmon for canning. Commer. Fish. Rev. 13(4):20-25.

STANSBY, MAURICE E., and ROGER HARRISON.
1942. Preliminary investigation of methods for freezing and storing fillets of some Pacific Northwest fish. U.S. Fish Wildl. Serv., Spec. Sci. Rep. 15, 25 p.

TAYLOR, HARDEN F.
1927. Refrigeration of fish. Rep. U.S. Comm. Fish., 1926, append. 8:501-633. (Doc. 1016.)

Future Fishery Utilization

James A. Crutchfield [1]

INTRODUCTION

I will deal, not so much with the micro-technical aspects of fishery utilization product development, but rather with the macro-aspects of it: the extent to which we can hope for expansion of the American fishing industry utilizing the resources within our 200-mile zone.

Doing that, however, I would like to express my view, as an economist, of the role of public research and development in fisheries. In the temper of these times, it is very tempting to ask: if research and development benefits an industry, why shouldn't it be carried out by the private sector? In fact, that is being said all over the government in almost every phase of activity. There are some very good reasons why this is not an adequate answer to the problem.

Industry can be expected to invest in research and development only when a number of conditions are met. The benefits have got to be clearly and specifically identifiable; they must be identifiable in such degree that the future value of the benefits, properly discounted, can be compared to the costs and the investment decision appraised. Perhaps most important of all, no individual business firm can be expected to be active in research and development unless it can capture the benefits of that activity itself, and that means excluding other organizations from getting the benefits of the research. It is not surprising then that a lot of research and development activity, particularly the longer run, chancier type, is not undertaken by the private sector-not because it is not competent in research and development, but because it simply does not pay from the standpoint of the individual firm. But it does pay from the standpoint of society.

The research that is needed most in the fisheries field is work that is industry-wide in its application. The results of that work should be available to all participants in the industry; however, we cannot expect such extensive research to be performed within the private sector.

Furthermore, the fishing industry, structurally, is not able to support a large research and development activity. By most American industry standards, the fishing industry is made up of relatively small units, and it has a highly competitive structure; the profit margins involved are never exceptionally great. There simply is neither size nor profit margin available to support the kind of research that is done by the automobile

1/ Natural Resources Consultants, 4055 21st Ave. W., Seattle, WA 98199.

industry or the chemical industry or others (and even these draw very heavily on public research).

There is, then, a proper role for public research and development in fishery development, complementary to and supporting private sector efforts. How many of our now fully utilized conventional fisheries would have reached the state that they have and produced the value that they have, as quickly as they have, without the work of this Center and of other institutions active in similar research and development.

FUTURE OF THE INDUSTRY

I will now discuss the future of the industry with respect to fuller utilization of resources within our 200-mile fishery conservation zone. The Magnuson Fishery Conservation and Management Act of 1976 lays down a clear mandate that we are to push ahead, as rapidly as possible, to achieve as near full American utilization of those resources as possible. In a sense, it is a Northwest problem since by far the greatest volume and value of the resources available for American development lie within the region with which we are concerned.

The targets of utilization are fairly clear. As far as traditional species are concerned--salmon, halibut, king crab, and the like--there is obviously not much in terms of increased catch levels, at least in the short run. There are, however, "internal margins" of real importance. One is the development (or, perhaps more appropriately, the application) of improved concepts and practices of fishery management in our so-called fully developed and fully utilized species. In the case of all our resources, it can be argued that we are getting less in output, less in net dollar value, and less in employment than we could get if we were able to put into practice the management concepts that have been developed in the literature, both in the biological and social sciences. There is a lot to be done in rebuilding these stocks to their full productivity.

Even today there is room within these segments of the fishing industry for improved net dollar yield, even from fully utilized stocks. It would be a bold man who would argue that we have done all we can with respect to quality, uniformity of quality, keeping quality over time, and full development of product range from the species that we call fully utilized at the present time.

In the broader sense, however, of increased production, increased employment, and new products, the real challenge lies in the groundfish resources of the Bering Sea and the Gulf of Alaska. The groundfish resource is enormous, depending on whose lies you believe; the resource is somewhere between 2- and 3 million metric tons (less, of course, if we are talking in open Council session where somebody might be listening from overseas). In any event, the resource has an enormous potential, full realization of which would lead practically to a doubling of American fish landings. The groundfish resources are already well utilized by foreign fleets. American harvest capability clearly is rising rapidly, and even at this low state of American participation in the groundfish of the North Pacific, American fishermen have demonstrated, beyond any doubt, their

capability of matching any other nations in terms of productivity and in terms of energy efficiency--the important developmental requirement for the future.

The existing American fleet harvesting Alaska groundfish is surprisingly small. A recent study suggests that no more than about 39 to 40 vessels are actively engaged, most of them in joint venture operations; yet that small number of vessels harvested more groundfish than all the rest of the Pacific Coast groundfish industry put together, including halibut--landing something in the neighborhood of 100,000 tons this year, including the joint venture operations.

As of now, with new construction and conversion capabilities for the king crab and other vessels, a recent study estimated that we are close to being able to harvest 60% of the available yield (or would be in a relatively short period of time, if other constraints were removed). Certainly, then, as far as harvesting capability and capacity are concerned, what we do not have, we could get very quickly.

When we turn to processing capability, it is quite another story. We have practically no shore facilities for handling groundfish taken off Alaska and in the Bering Sea at the present time, and there is a record, unfortunately, of some fairly substantial failures not far behind us. A couple of factory trawler operations are doing fairly well, but only because of a number of special conditions. They are producing a product of exceptionally high quality that commands premium prices on the market (perhaps an indication of the way we are going in the future). They also catch a fairly high proportion of cod in their operations, which raises their returns, and they are utilizing vessels that were purchased on a basis which, if it were to be matched today, would cost them at least twice as much. The prospects, then for a profitable factory trawler operation at the moment, using a new and necessarily American-built hull, would be a lot dimmer than those of the operations that are presently under way.

The most intriguing development in American processing capability, of course, has been the success of joint ventures, which have taken about 100,000 metric tons this year and are limited only by the extent to which new agreements can be reached with the appropriate authorities--the regional councils, the Department of State, and so on within the American government. The success of the joint venture is not due solely to low labor costs aboard the processing vessel, but rather to a whole series of real economic advantages in the operation itself: the fact that so much less time is spent running to and from port; the smaller crew that can be carried by a trawler fishing a joint venture operation; the lack of necessity for carrying ice or other refrigeration equipment; the ability to keep the vessel operating essentially as a tug rather than a fully-equipped fishing vessel; and the ability to dispose of waste at sea safely, without the complications that arise when it has to be handled ashore. These are not, in my opinion, unfair competitive advanges; they are very real economies of operation. Ultimately, I assume that there is no reason why this cannot be accomplished by American-at-sea processors operating in a similar mode.

Obviously we would prefer, other things being equal, that the entire operation be American from beginning to end, but at this stage of the game, joint

ventures would seem to be an extremely useful intermediate step, giving us the opportunity to learn one important part of the game (the fishing and fishing deployment part of it), giving us access to foreign markets which otherwise would be very difficult for us to utilize, and getting us into the game one step at a time. It would be highly desirable that development be continued as long as benefits are realized.

Other than that, it is fair to say that U.S. processing capability is far behind its catching capability, as far as bottomfish operations are concerned, and we do not see any change in the immediate future. What then is holding us back? The fish have been exploited for a very long period of time. The characteristics and ultimate markets for those fish are well established in commerce. Why aren't American fishing vessels and processors doing the job in larger number than at present?

The answer lies in a set of interlocking constraints on U.S. development, no one of which itself is the governing factor, but all of which tie together in making development very difficult. There are some constraints, for example, involved in product characteristics. The catches in the North Pacific will be dominated by walleye pollock and Pacific whiting (hake), both of which raise some problems concerning: 1) parasites and the necessity in the filleting operations of candling individual fillets; 2) the small size of the fish in many of the walleye pollock catches; and 3) the perishability of both of these soft-fleshed fish, relative to the type of firm flesh that we have been used to handling. Obviously, they can market a first-class product, but not without some fairly significant changes in the methods of operation.

The second constraint is transportation. God always sees fit to put fish and people as far apart as possible, and then some poor devil, called a marketing expert, has got to find an answer! Well, the marketing expert looking at western Alaskan fish and at the market lying at the present time primarily in the central and eastern United States is looking at a very high set of transportation costs. Fish are not where Alaska container line terminals are. The high peak-to-average transportation and storage capacity problem is difficult. During the summer months, when conventional species are moving in volume, it is going to be very difficult to integrate around-the-year, high volume, bottomfish operation without substantial new investment in transport facilities. But which comes first? The chicken or the egg? Nobody is going to fish for bottomfish until the industry infrastructure is in existence.

The third constraint is in finance. An industry that must borrow at roughly prime plus 2- or 2-1/2% finds it extraordinarily difficult to put money up front in magnitudes like $10 million or so for a shoreside processing plant of moderate economic capability, between $15 and $20 million for a modern factory trawler built in the United States, or perhaps $300,000 to $500,000 for conversion of the crabbers that we probably would rely on initially.

These are big numbers and in today's financial climate, borrowing at these high interest rates now and in the future is an enormously difficult obstacle. It is not made any easier by the fact that the credit requirements of the fishing industry and the lending practices of conventional commercial

banks simply do not fit together very well. It has been very difficult for the fishing industry to tap financial markets to realize investment requirements, both long term and short term, at rates that would make it possible for it to operate.

Fourth, there are constraints in repair facilities--there are few places in Alaska where a modern high-seas trawling operation can find port facilities with appropriate repair, maintenance, haul-out, supply, and electronic services. That is going to have to develop somewhere before a fully American operation can expect to realize its full technical capabilities. With fuel prices rising the way they are, it simply is not going to be feasible much longer, if it is now, for large trawlers operating in Alaskan waters to come to Puget Sound for any kind of major service. It is also difficult to find in Alaska a port close to major fishing activities where a stable year-round labor supply can be developed, and with that labor supply, facilities for families have got to be there on a 270- to 300-day a year basis. There are a few ports like this, but very few, and they are not close to the major fishing grounds.

Most important of all, there are market constraints. Let me review some of the changes that have taken place in the markets for groundfish in the last 10 years. During the 1970's, there were a number of striking changes. One change was the increase in per capita consumption of fish, which if you break it down, is almost entirely accounted for by increases in consumption of fillets, sticks, and portions. Thus, almost all of the increase was in groundfish with very little else except a modest increase in canned tuna. There have been equally striking changes in market outlets with the advent of what could be called, loosely, the frozen food revolution in American retailing. You now find groundfish products in frozen packaged form, branded, promoted, and very successfully merchandised, in virtually every grocery store that has a freezer. We have a whole new set of outlets in fast food chains, for which controlled portions of groundfish represent an ideal complement to the meat and poultry operation around which they grew up.

There was also a rapid run up in prices. Fish prices rose more rapidly during the period of the 70's than the consumer price index, and more rapidly than either of the major competing product groups of meat and poultry. Fish--particularly groundfish--are no longer the cheapest protein food available. They fall more in the upper or lower middle range than in the very lowest range in terms of price, and that has brought them into an entirely new competitive relationship to meat and poultry.

It is equally striking that the increase in consumption during the 70's was achieved with virtually no contribution from the American fishing industry. Almost all of the increase in per capita consumption was met by imports of frozen blocks and fillets.

Looking to the future, what can we see? Three key factors seem to stand out. None of them is particularly encouraging. Although I don't want to paint too bleak a picture, for the short run they do cast a cloud over development prospects. One is my own belief, which is open to challenge, that the big surge in per capita consumption of fish in the United States has pretty well run its course. The virgin market for packaged frozen fish in the grocery outlets and,

perhaps to a lesser extent, in the fast food outlets, is pretty well worked out. From now on, growth in per capita consumption--if it comes at all--is going to be related much more to changes in income and changes in relative prices of fish as compared to other protein foods.

The second factor is the availability of imported groundfish products at a wide range of quality differentials from extremely high--in the case of Icelandic cod fillets--down to the so-called garbage market at the lower end of the block trade. There is a lot available. We are importing bottomfish products from Canada, Korea, Iceland, Norway, Denmark, Peru, Argentina, Australia, New Zealand, South Africa, and possibly others as well. What it adds up to is a very competitive world market and in the short run, at least, there is not much that can be done in the United States, per se, to influence that world supply or world market situation. We're accustomed to thinking of our Bering Sea and Alaska groundfish resource as really huge and yet in relation to world supplies, the eastern Pacific provides less than about 22- or 23% of the world's pollock, and far less than that of the world's total groundfish supplies. There are a lot of people still willing to sell us groundfish products at any quality level that we want to mention, and they're going to be tough competitors for a considerable time to come.

The third factor and a very important one in this country, is the dominant influence of meat and poultry prices on groundfish prices. Strangely enough, the people to whom I've talked in agricultural economics are forecasting relatively stable real (i.e., inflation-adjusted) prices, for meat and poultry products over the next decade or so, with modest increases in beef prices offset by declining real prices for poultry, pork products, and some others. It's not surprising since the technological advances still going on in poultry and, to a lesser extent in meat, are expected to offset the effect of increased energy and labor costs.

In short, we're operating in the short run with a pretty tight lid over bottomfish prices, set in part by foreign competition and, in part, by the competition of our own murderously efficient suppliers of meat and poultry products. It won't necessarily remain that way indefinitely, but for the near term, at least, we don't look for any very significant price increases in groundfish beyond those that have already taken place. I might point out that inflation-adjusted prices for groundfish products in this country have actually declined every year since 1978 so we are pretty well topped out at that level for the moment.

The longer run outlook is a good deal more encouraging. While there is a clear downward trend, as I am sure a lot of you are aware, in cod landings worldwide, U.S. consumption of groundfish in block, fillet, and stick form is still more than 50% cod. In addition, if and when recovery comes to the Western European economies, which are large consumers of groundfish, there is a good possibility that much of the competition now entering American markets will be diverted to European markets and thus relieve some of the downward pressure on prices that we've been feeling.

Finally, and perhaps most important of all, although I hate to think of it as an encouraging thing, on a world basis there have been very, very small increases in total fish landings for

the last 10 years, and I can see no way in which the supply of groundfish worldwide can continue to keep pace with world demand for groundfish. By the end of the decade then, we may well be reaching a point where groundfish prices will have risen in real terms--inflation-adjusted terms--by the 20- or 25% that probably would be necessary for an all-American operation to develop. A number of analyses of harvesting costs and processing costs have been made, some of them carried on by the Center or under Center auspices, and some by other agencies. Without exception, each has concluded that, at the present level of groundfish prices and given the price the fishermen must have for any kind of an attactive return on their own investments, there simply isn't room for the marketing and processing margin at the present time. We hope that that will come later.

Are there any ways in which we can accelerate that process and speed it up? One, obviously, is to get costs down if we can. I don't think there's any great opportunity for increasing productivity of the American fishing sector faster than it's being done. These are competitive operations by any standard. They are, however, at an enormous disadvantage in being required to purchase vessels built only in the United States. We could buy new vessels at substantially lower costs elsewhere. We could buy excellent used hulls almost anywhere in the world for perhaps half of what we have to pay for new vessels. We're also paying, by contrast with most other countries, very high duties on imports of nets, electronic equipment, and other gear and, while there's been some progress in lowering these duties, they still present a cost barrier to American fishermen.

A second possibility is to improve yields and product ranges. The Center has been engaged in work of this type, and there is much that remains to be done. As has been pointed out repeatedly, it does make you grind your teeth a little to be utilizing roughly 20- or 25% of our bottomfish as fillets and throwing the rest away (or at best, converting it into meal) when a substantial part of what is being thrown away is perfectly usable flesh. Minced flesh and perhaps, with our own research and development or through joint ventures with our Japanese friends, surimi-type products on the American market offer long-term possibilities that cannot be ignored. The fantastic success of the poultry industry makes it clear that American consumers not only can be made to buy, but will eagerly buy, a variety of healthy, low cholesterol, tasty products that can be textured and taste-adjusted to modern American preferences, using technology which is very old in other countries of the world.

We can increase market price and acceptance through better quality control--again a long-term possibility. Possibly we can expand export markets. This is the one that everybody throws up in the air.

Let me simply point out that we do not have a very good fit between what American bottom fishermen can turn out in Alaskan waters and the requirements of the two major export markets in Japan and in the European Economic Community. In Japan, about 75% of the pollock are utilized in surimi and there's no way of interesting an American company in developing the technology, undertaking the heavy investment, and then wading through the morass of trade restrictions in trying to deal in Japan to get into the market. There is a good Japanese

market for the larger pollock but Alaskan (walleye) pollock don't fit that well because they tend to run to sizes below 17 inches. It can be done--unquestionably it will be done. As the Japanese are phased out of quotas within the 200-mile limit, the attractiveness of joint venture and other ways of accessing the Japanese market will increase. But again, it's not something that will come overnight.

The European market is even tougher, although it is a bottomfish-consuming market to a very large degree and is, at the present time, a large deficit area. The United Kingdom alone imported over 200,000 t of cod and cod-like fish last year. But the European Economic Community has embarked on a program of protective barriers, defending local industry in all primary production--in agriculture and fisheries as well. To try to get over a 15% tariff barrier, quotas, and the other obstructions that one finds in the common-market countries when you're 12,000 miles away from the market, is a tough proposition indeed.

Again, it may be done as world prices strengthen, but at the present time, it's not an attractive prospect.

The answer that most people find easiest is simply to slap tariffs and quotas on imports and to equalize costs between American and foreign producers or, if you like, to jack up prices in American markets by raising duties to the point where American producers can become effective as competitors. Neither this administration nor any of the preceding administrations have been very receptive to the idea. There are two real problems with this approach. First, American consumers and taxpayers are being asked to pay the burden for developing a new facet of the American fishery and whatever we may think of the desirability of the jobs and incomes that would be created by doing so, there are a lot of people who are eating and paying for the fish who are going to think otherwise--and their political clout is by no means small.

Second, the studies on groundfish-demand, while they're anything but conclusive at this stage of the game, do suggest strongly that demand for groundfish products is quite sensitive to price. We're likely to find out that in an attempting to raise prices through tariff and quotas, we simply have shifted the fish business over to our competitors in meat and poultry and other protein foods, rather than increasing returns for the product of American fishermen. It's taken a long time to build up per capita consumption of American groundfish to the levels that we now enjoy. It would take a long time to build it up again if we cut it back as a result of artificially high prices. The tariff-quota approach is fraught with all sorts of political difficulties and one with very real economic risks.

It seems to me, and again this is a controversial matter on which there would be disagreement, that the situation that we face may require a basic new approach to industry structure in the northeast Pacific fishing industry. At a risk of exaggerating but to make a point, the idea of having an industry made up of people who bring fish in, other people who decide what to do with the fish that are brought in, other people who market the product that was decided upon, and so on, simply will not wash any longer--not in this kind of highly competitive, high volume, low margin operation. There is an urgent need for much tighter control of quality all the way from the boat up to the final user of the product. There is need for a

much tighter fit among fishing activity, processing, transport and storage, marketing, and distribution, than can be accomplished through the traditional decentralized type of fish marketing that we've depended on. Again, this isn't a matter of being critical of the industry structure as it stands. We simply point out that the successful marketers of groundfish products at low prices and high volumes, in general, have been of this integrated character, and some kind of development along those lines may well come.

SUMMARY

In summary, then, the extension of U.S. operations to utilize fully the groundfish resources of the North Pacific is going to come in the end. The pressure is there, the technical capability is there. Ultimately the economic barriers that I've mentioned will be overcome, but those changes are not going to come quickly, they're not going to come easily, and when they do come, they are going to come as the result of a cooperative and complementary program among industry and the University community and in very strong terms, governmental research and development activity of the type this Center has pioneered.

Structure of the Fisheries of Alaska and the Pacific Northwest and Situations that Lead to Development

William P. Woods, Jr.[1]

INTRODUCTION

I would like to address specifically the existing structure of the fisheries in Alaska and the Pacific Northwest and describe what dictates situations that lead to development. The discussion will emphasize the processor's need. I will conclude this paper with considerations on the appropriate future relationship between industry and government, particularly the Northwest and Alaska Fisheries Center as it enters its second 50 years.

THE STRUCTURE OF THE FISHERIES

The ingredients of a successful business are essentially two-fold; the first is a good quality product that is cost competitive. Good quality can indicate the organoleptic, i.e., the taste and manipulative aspects of the product, and the service with which you deliver to the people that use it. But good quality is essential; the second is being cost competitive, especially in commodity products, large-volume products, and narrow-margin products. If those two ingredients are absent, from a processor's standpoint, the undertaking is a misexercise.

The quality aspect starts at the boat and perhaps even before the fish enters the net. Fishing must take place in the right location, at the right time of year, and at the appropriate point in the fish's life cycle, to give everybody else downstream in that equation a chance to deliver that good quality product to the ultimate buyer. Good quality has to be maintained all the way through the fishing, transfer, receiving, processing, holding, distribution, and marketing functions. That's especially critical in some of the frozen products that are less stable in the latter stages of the distribution chain. People have to work together in an integrated effort on the part of the harvesting sector, the processing sector, and the distribution sector. Without that cooperation, the chance for a successful business equation is missing. Included in the elements of that successful equation are the scientists who study the conditions necessary in the making of a good quality product. The efforts of the Center over the past 50 years have been extremely valuable in this regard.

In terms of being cost competitive, I tried to simplify the scope of the factors that affect the cost competitiveness of any one producer. Competitiveness in production costs is a necessity. These cost factors are items of common sense: labor, fuel,

1/ Castle & Cooke, 130 Merchant St., Honolulu, HI 96813.

packaging, transportation, and production supplies. All those elements of cost to bring the product to market have to be on the same basis as competition: 1) You have to be competitive in production costs. This includes a promotion program, or a branded distribution program at retail; there has to be enough volume to have the cost-per-unit come down to that of the major successful operators. 2) There has to be a distribution and marketing net worth that has equivalent costs with others. 3) There are the financial costs; these are the cost of the investment dollars you put in up front and the interest rates you pay. There are a lot of people who over the last 3 years have gotten a new lesson in the impact of interest costs and financing costs and investment costs on the business equations that are worked out.

These are the three factors that are relatively immutable. They are the givens in an economic situation--the production costs, the marketing costs, and the financing costs.

In a fourth category, these are grouped somewhat apart: the regulatory costs. These are the permits, the tariffs, quotas, the Environmental Protection Agency (EPA) rules, and the Occupational Safety and Health Administration (OSHA) regulations, which can be grouped into the category of "red tape." These are real elements that are definitive factors in all the economic equations processors operate within, and they can't be neglected. They have just as much bearing on those basic factors as the first three that I described.

Now if an operation produces a good quality product, and total production, marketing and financial costs, and regulatory costs are calculated, the total cost has to be within the price range that the ultimate consumer is willing to pay. (And you've got to go all the way down the chain to the person, in the case of the fish product). The difference between the sum of those costs and that net selling price is either the profit or the loss that the investor has gained or lost for having undertaken that business opportunity. An important point in looking at what the margin of the difference between cost and selling price, or revenue, will bring is that as the price drops the volume generally goes up; and in a correlary fashion, if the price goes up the volume will drop--especially in the commodity product from the underutilized species. Rising costs place the volume in jeopardy.

The development for future investment in these businesses depends essentially on two things. Maybe I'm being a little simplistic here, but I'm trying to boil it down to essentially how I look at an equation. An opportunity has to be identified to make a profit, and there has to be some room to run to a little daylight. Now the enthusiasm with which an opportunity is viewed is dictated in large measure by certainty in being able to make the best of that opportunity. Development, therefore, is hampered whenever there's a lack of opportunity because there's nothing to invest in, or when there's a high degree of uncertainty. Remember these two things; a lack of opportunity or a high degree of uncertainty retard development.

Let me address for a moment the type of constraints that limit the opportunities. We in the Alaska and the Pacific Northwest seafood industry see ahead of us two constraints, and here I'd like to try and take a broad perspective. Probably the first constraint is uncertainty about the

resource base. This morning our Dutch Harbor operations group felt a lot of uncertainty about one particular resource--the king crab resource: this year it looks like the total catch from all Alaska will probably be about 45% of what it was last year, and perhaps not even that. The catch last year was about 185 million pounds. The catch this year looks like it may be someplace between 75 and 85 million.

The resource base uncertainty is one that we all have to live with. It starts with the man on the boat first, but it is visited immediately upon the processor and right on into the distribution chain and the market.

Another uncertainty that relates not so much to a problem that is encountered with a specific resource but with a--some would say potential, I think I would say probable--problem in the future: what will be the impact of oil development in the Bering Sea on many of those resources we are currently utilizing fully and on the potential resources that we hope will be harvested for our processing operations in the future. I think most of us who are close to the business and operate in Alaska, see very plainly the strong intent of the petroleum industry to develop the expected, anticipated, and generally highly regarded potential oil supplies to be derived from the Bering Sea. We think it's going to happen. Now the question is, over what period of time and under what circumstances? We need the fuel to run the boats to make sure we've got a supply of fish coming in. If the fishermen can't fish; we the processor (if we're out of fish) are out of business.

We believe there's a fair body of concern on the part of the fishermen and processor alike about the potential impact of oil spills in a cold arctic area like the Bering Sea; we've not been able to identify any clearly executed and recently executed research papers on this subject. We're not really sure how much jeopardy the fisheries resource base is likely to be placed in. So from the standpoint of traditional fisheries we're currently involved in, the uncertainty about the resource--both in the event of failure through a substantial decline, like the king crab resource, and an expected future oil development, in the Bering Sea--those are uncertainties that we'd like to see resolved.

The second area of uncertainty having to do with the traditional fisheries might be about the regulations under which we operate. That's that fourth category I talked about. Some would say "red tape" but it's a very substantial factor in dictating how we set up our operations. I think locally perhaps the best example of a fishery that has operated under uncertainties for a long period of time is the salmon fishery of Puget Sound. Ever since the court decisions in the mid-70's that have changed substantially the allocation of the catch among the harvesting sector, there's been a lot of uncertainty in that fishery that I would put in the area of regulatory uncertainty.

At the present time, perhaps the greatest recent area of uncertainty that's been introduced that affects those of us that operate not only in Alaska, but throughout the United States, is the issue of foreign processors potentially being able to operate inside the internal waters on an invitation system. I would like to describe the nature of the problem. The Magnuson Fishery Conservation and Management Act of 1976 (MFCMA) and its amendments in 1978 incorporated earlier laws and regulations to set up the

three-tier system of resource management. From 3 miles out to 200, there was the ability for foreign operators to come in and both fish and process--if they had satisfied the requirements of the regional Fishery Management Councils and had authorizations from the U.S. Department of Commerce and State to operate within that area. Inside the area from 3 miles into zero miles, which we call the base line in parlance, there was to be no fishing by foreigners and no processing by foreigners. That was a total exclusion inside that area. That sounds like a simple solution, but there is yet another area. That zero mile--that base line--does not define the surf line at the beach as many people think it does. It really identifies the area between headlands from which the 200-mile limit is measured. Inside of that base line, in some areas, such as Bristol Bay, there are substantial bodies of water. I think Puget Sound would qualify for one, San Francisco Bay another, Chesapeake Bay yet another, Narragansett Bay another. Inside that base line, a no-man's land has developed because the federal regulations have been construed to state that there be no foreign fishing, and the federal agencies could not regulate foreign processing inside the base line. The State of Alaska, in undertaking to regulate that activity inside the base line, had a Federal Court strike down its State regulation, saying that it was unconstitutional because it was constraint of international trade that was reserved for federal jurisdiction. This state of affairs shows a serious gap in the regulatory structure in the U.S. fisheries conservation zone (FCZ) and introduces a significant degree of uncertainty, especially to those shoreside processors who were confident that, the MFCMA gave them the same protection against foreign competition right off the dock that the fishermen had inside 3 miles. That was supposedly home turf.

Now if that loophole (if you want to call it that) is not closed in a fashion consistent with the original intent of the Magnuson Fishery Management and Conservation Act of 1976, then certainly that will retard further investment and further development in the shoreside operations in those fisheries by the introduction of significant uncertainty about the ability to operate against foreign competitors. Through lower labor costs and lack of regulations having to do with the "red tape" aspects--the EPA, the OSHA, interest-related costs, tariff barriers that foreign competitors are not subject to while U.S. processors are--it is unlikely that U.S. processors will continue to invest in the existing fisheries.

I now shift from the fully utilized traditional species into the underutilized species. Instead of the use of underutilized species being strictly an issue of concern about uncertainty, it's more an issue of cost competitiveness that will be acting to retard the development of the U.S. industry. Institutional products like these large commodity products have to be cost competitive. There is no doubt about the resource being available. In the last 2 years, I believe, the harvest of walleye pollock in Alaska, for example, was over 1.1 million metric tons. Of the harvest in 1980, over 99% was caught by directed foreign fishing and only 1% was caught by boats either participating in joint venture activity or delivering directly to shoreside operations.

The resource isn't the question; there's plenty of fish there. The

market isn't the question; there's a ready market for that product in the Asian countries in the form that it's now distributed. The principle problem is that the United States at the present time, is not cost competitive in converting that raw product inside the 200-mile FCZ into the form that it can be sold in those markets, primarily in Asia, Japan being the leading consumer.

There are a number of elements in that cost. We talked about labor and I guess I'd have to take issue perhaps with one statement. I think there are processors that do enjoy, in the underdeveloped species, a significant labor advantage vis-a-vis the United States and I'm thinking specifically of North and South Korea. With certain competitors, it's difficult to assign the cost accurately because they have a different system: I'm thinking specifically of the Iron Curtain countries. The USSR and Poland don't have the profit incentive. Their equation is somewhat different and their motivation is not exactly the same, but I think there are a number of processors who do enjoy a labor advantage.

ACCESS TO THE MARKET

Access to the market, in terms of quota and tariff barriers, represent a significant concern to U.S officials and firms anxious to become involved in those fisheries. The financing cost in today's market in particular provides a very significant hurdle for the U.S. boat owner, processor, and others to overcome.

One of the best examples of a successful fishing operation in the Bering Sea this year is a vessel West Germany registered--it cost 4 million dollars to build about 7 or 8 years ago, when it was constructed at an 8% loan cost. That was its cost of capital. A quick and dirty calculation of the financial arrangements shows $320,000 a year cost to amortize the debt, or $1,000 a day, roughly. If a U.S. operation--be it an existing processor, or a group of fishermen, were to go and duplicate that vessel in a U.S. yard today, they'd be talking about a $25 million investment. That's about six times what the Germans have into it, and the rate of interest charged would probably be 19 to 22%; that would be prime plus, and not a lot of enthusiasm from the bankers to provide financing at that. The U.S. operator would have to bear 5 1/2 million a year in interest, and instead of $1,000 a day to amortize the debt it would be $15,000 a day, a heavy load. That's a competitive disadvantage of real magnitude for a product that must be cost competitive. This comparison illustrates significant structural economic issues in the underutilized species that are hampering and will continue to hamper for some time U.S. participation in those fisheries, from the processing standpoint.

On the occasion of the 50th Anniversary, as a representative of the business sector, I would like to request the Center to study how we might operate together in the future. We would like to have Center help in removing uncertainty about the resource. This would be a proper undertaking by an agency such as the Center. We would like help in identifying ways we can become more cost competitive and quality competitive, because those are the two essential elements for that successful business equation.

We would like to reserve to ourselves the ability, the commitment, and the responsibility to make our own economic investment decisions. That's our responsibility to our shareholders, but we would like the support of the Center in those long-term areas of research and development that are best undertaken by a governmental agency.

Economic Aspects of Processing and Marketing the Northwest's Fish Products

John Peterson [1]

INTRODUCTION

The major and most important area of fish production in the United States is in the Pacific Northwest, particularly Alaska. The tuna people and some of the shrimp people perhaps will disagree with that, but that is my opinion. I think it is correct.

The species produced in the Northwest--the five species of salmon, king crab, snow (Tanner) crab, Dungeness crab, shrimp, halibut, and other miscellaneous species such as sablefish, ocean perch, cod, sole, and even herring--have certain unique characteristics. First of all, they are unique to this area. There is salmon production in other parts of the world, but this area is the major source of salmon in the world. They are high priced, including herring, which traditionally or on a worldwide basis, is low priced. Herring is high priced here because of the content of roe and the demand for that product in the Japanese market.

Also the products we produce are of high quality. They must be of high quality because they command high prices in the marketplace. There's been considerable complaint recently especially, from the harvester sector, that we are not going after the worldwide market. Well, of course we're not! We can only sell these high-priced commodities in areas of high per capita income. One of my colleagues said the other day, when we were talking about the problem in the canned salmon business, that we should sell into India, adding "Well, you'd probably have to supply a can opener with each can." These are some of the problems that we look at. The markets we--for the most part--go to are the United States, Japan, Europe (but not all of Europe--only some of it), and Australia. These are high per capita income countries.

HIGH VALUES, HIGH PRICES--CAN WE AFFORD THEM?

But perhaps the high values of these products and the high prices paid to the fishermen have spoiled the industry. Perhaps we are operating in an area of luxury that we cannot afford any longer, and this is with reference to the fishermen and the processors. A prime example of this is one that troubles me greatly and it has to do with the market value of canned pink salmon--"talls." The average wholesale price of the tall can of pink salmon has increased at the rate of about 2% per year for the last 7 or 8 years.

1/ Ocean Beauty Seafoods, Inc., 1100 W. Ewing, Seattle, WA 98199.

The price to the fishermen hasn't improved very much more than that. So here we have a situation where the sales value is increasing at a minimal rate, and the price to the fishermen is increasing at approximately the same rate, but the cost of processing has gone up enormously. The cost to the fishermen has also gone up enormously. How much longer can the fishermen continue to produce pink salmon at current prices? How much longer can we continue to process pink salmon into a canned product at current prices? It seems to me this is one of the major problems facing our industry in marketing at the present time.

I've been talking about the fully utilized species, but I would now like to discuss underutilized species. When the Magnuson Fishery Conservation and Management Act of 1976 was passed, we all approached this tremendous resource with great enthusiasm, and the New England Fish Company became deeply involved at their Gibson Cove plant. This may have been a contributing factor to their bankruptcy. The Icicle Seafoods Company also became involved in a similar operation at Petersburg, Alaska, and I know this was a serious economic problem to them. In my own company, we were involved in an experimental operation in Cordova, Alaska, subsidized by the State of Alaska in the form of funding for chartering vessels to fish experimentally. We spent a lot of money, sending people to Cordova, processing the fish, and learning that it was not economical. Fortunately, one of the fishermen found he could sell the fish to the Koreans for more than we would pay, so the whole exercise stopped prematurely, and I think that was good for us.

So there have been efforts, but the thread that runs through these efforts is--everybody that's tried it has lost money. Business is carried out to make a profit. If there were a profit to be made, you may be sure that the processing industry would be as active as the fishing industry in developing these resources.

But I thought perhaps you might be interested in how I approach and analyze the pollock business, pollock being the major resource in the North Pacific. Without developing that resource, we're not really going to do what should be done. There are two major markets that we can reach. One is the surimi market in Japan. Can we reach it? Not now, but in time we probably could, depending upon a lot of other factors. See Dr. Crutchfield's paper in this symposium on this subject. The other market is the U.S. market for fish blocks. There is another market, of course, and that's the market in the Soviet block nations, but we're never going to touch that. At the moment, then, the only market that is feasible for us to attack and to go after is the market for fish blocks in the United States. This market, as Dr. Crutchfield pointed out, is not a market that is supplied by a unique species of fish, as is salmon or king crab or the products that we have traditionally been working with. It is supplied in enormous quantities from all over the world. So we have no corner on that market, but there is a gap. The gap is between cost and value.

I put together some figures and examined walleye pollock at $.07 a pound to the fishermen, and percentage of recovery from the whole fish. What sort of recovery do we get? We're probably lucky if we get 20% recovery by taking a deep cut to get the fat off so it won't turn rancid. That immediately makes our flesh cost $.35

per pound, nothing else--$.07, 20% recovery, $.35 per pound. To ship that product from Dutch Harbor, Kodiak, or wherever, to the market on the East Coast is another cost factor. In time, perhaps, it will be on the West Coast but presently, realistically, we're looking at an East Coast market. The freight will be $.15 a pound--$.14 a pound, excuse me--I fudged! There are some other costs that can be added to that, such as packing material, interest on pack finance--not plant finance, and sales expense. I've been in the marketing business, I can hammer a broker and make him handle it for a penny a pound. So we would add another $.04 a pound of costs. This brings the cost of that fish to $.53 a pound. Now mind you, we haven't hired anybody and we haven't paid any insurance.

The current market for pollock blocks is between $.75 and $.80 a pound. If we take, say--$.78 as an average, we have a 20-cent-a-pound margin. It's not a margin but that's the difference between those costs and what we can sell it for. But we haven't covered labor costs, we haven't covered the fringes that we have to pay out in labor, and we haven't covered repairs and maintenance in the plant. We've not covered insurance nor depreciation. We've not covered the management costs. We've not covered fuel, water, power, cold storage when necessary, telephone, travel, nor have we covered debt burden. William Woods in these proceedings talked about debt burden on a new processing vessel as costing $25 million and the interest on that, $5-1/2 million a year. I looked at it a little differently. I listed all of these costs and said, "Well, if those costs--for each $1 million of those costs--is $.25 a pound, I must process 20 million pounds of roundfish, and I haven't made a profit yet." That's where the problem is.

THE GAP IS THERE

I don't know how to bridge that gap, but it's there. In my analysis of these things, when I get that much of a gap, there's not really much need to go much further into an analysis. The gap is there. We know what form of fish product is ready for the market. We know where the markets are. We know how to process. We know where the machinery and equipment can be secured, but the development of this industry by U.S. processing companies requires a solution that so far has escaped me. It is, however, in my opinion, an issue of great national importance. I believe it is very much in the best interest of the United States to maintain control of that vast supply of valuable high protein food.

History and Perspective of Exploratory Fishing

Dayton L. Alverson [1]

INTRODUCTION

Working with this Center was one of the real privileges of my life. I look back with a great deal of nostalgia about my involvement and about the topic that we're going to discuss this morning, that is, the history of exploratory fishing and gear research at the Northwest and Alaska Fisheries Center and its predecessor organizations.

Exploratory fishing has a particular element that is somewhat different from the mainstream of biological investigations. The term "exploratory fishing" is used to imply a variety of different types of activities and has different meanings around the world. It reminds me of a story about the young executive who had done extremely well in business and managed to parlay his capital from a very small amount of money into a multimillion dollar corporation. He was thinking about getting into the fisheries business and thought he needed a consultant--a fisheries economist like Jim Crutchfield or a fisheries biologist like Murray Hayes--who knew something about the assessment business or perhaps going with the theme of the day, he thought he should get himself a lawyer. There are, you know, an awful lot of legal issues surrounding the Magnuson Fishery Conservation and Management Act of 1976 (MFCMA). He thought, "I'll call in some of these people and see how they respond to various questions." And so he sent for the economist and he said, "Now tell me--what's two and two?" And the reflected for awhile and said, "Well, if you don't discount for future value, it is probably four." The executive said, "Okay, that's interesting," and called the biologist in and asked the same question. "What's two and two?" The biologist paused and replied "Well, under most circumstances and in the ideal situation, it's likely to be four, but there may be some variation around the mean." The executive said, "Well, that's fine--I understand that," and called in the lawyer and repeated the question, "What's two and two?" The lawyer scratched his head, took off his glasses, and said, "Well, what would you like it to be?"

HISTORY

Let's go back and do a little reminiscing and perhaps be a little bit pejorative about the history of exploratory fishing at the Center. I

1/ Former Director, Northwest and Alaska Fisheries Center; present address: Natural Resources Consultants, 4055 21st Ave. W., Seattle, WA 98199.

looked at the dictionary just to see what they said about "to explore" and it said to "seek for or after, to search for or into, to penetrate or range over for discovery, to examine by means of a probe, to make or conduct a systematic search." I thought those definitions were fairly descriptive of what the whole exploratory fishing process was all about.

If you look back in the history of the North Pacific, which is rich in exploratory activities, and you read your 50th Anniversary history from 1931 to 1981, you'll see that the process really began before there was a formalized exploratory fishing unit at the Center. We have the very early Alaskan crab investigations that went on between 1940 and 1941. I remember the poignant words of an old friend, Lowell Wakefield, who said that the $90,000 that we spent for the early crab surveys was by far the most effective investment the United States ever made in fisheries development--the investment that produced a fishery worth over $50 million annually.

It was the beginning of a search or a probe process. It was indeed a probe, because it was not very systematic or organized. It didn't have all the elements of a sophisticated, well-planned, scientific activity; investigators went to a little known area and searched and gathered information. The results said clearly, "there's more there than we had realized." Obviously fishermen had known these resources were there, but the survey gave new dimensions to a resource which would become one of Alaska's major industries. It was followed by exploratory fishing in the Carl Carlson era (1944), which was called the Alaska Fisheries Exploratory Commission. Carlson began to examine the shrimp resources and to generate concepts for examining the southeastern Alaska pandalid shrimp beyond traditional fishery areas.

We have, of course, the activity aboard the well-known vessel, Pacific Explorer, in 1949. This work can also be categorized as a probe. It was not as well structured as a scientific process or study, but an activity that put a number of people and ideas together and provided the United States with its first real look at the Bering Sea resources and added to the knowledge garnered from foreign explorations.

It wasn't until 1949 that we had the genesis of what would ultimately be called the Exploratory Fishing Group. And at that time, we didn't have a research vessel. There wasn't any fisheries research vessel in the Pacific Northwest capable of offshore work at that time. If you wanted to go out and carry out biological studies you asked permission to go on one of the commercial rigs and if the captain had space on the boat, you brought on a tagging board and measuring equipment, etc., and carried out your studies. The unit formed in 1949 chartered the vessel Deep Sea, followed by a charter of the old vessel Oregon that began to make further probes into the king crab and groundfish resources. Further work was done on the albacore resources of the North Pacific. They were the predecessors of the more formal process that came following the launching of the John N. Cobb, a vessel which (in my view) has a prominent place in the history of marine research.

I was there as a fledgling biologist when the vessel was launched and when she was finally put into commission in the early 1950s. I look back and think about our primitive gear and equipment, but we thought it was the real thing.

We had a 4-foot dredge to look for shrimp in Alaska and we thought that it was the cat's meow in terms of conducting a shrimp investigation. We had two bathythermographs on the boat, both of which were lost when we ran them through the blocks on the second day of the Cobb's operation. We were scared to tell headquarters in Washington, D.C., and Andy Anderson that we lost our investment at that particular point in time.

Money was scarce and equipment was scarcer. The early exploratory group in the Pacific Northwest was built around four individuals, but had its counterparts in the southeastern United States and with the growing operations in the New England area.

It was a new venture. What was this thing--people going out and looking for fish for fishermen? What did that have to do with science? Why did we need that sort of activity? Fishermen could take care of their own surveys. They didn't need somebody looking beyond existing fisheries. There was a "schism" that developed in the old Bureau of Commercial Fisheries (BCF) at that time. Many of you who were around then remember this well--a certain skepticism about this so-called exploratory fishing. Was it really scientifically oriented? Did they really know what they were up to? What did it have to do with the quantitative aspects of the Beverton and Holt model or the Schaefer model? What did it have to do with the logistic growth curve? These were the things respectable biologists worked with. Why are these people going out cataloging resources--information that nobody is using or will use? Why are they looking at the size, distribution, and behavior of fish that nobody really wants?

The "schism" was very strong and the skepticism stronger. In retrospect the criticism had a certain legitimacy. The early exploratory work was not very well structured--not because of a lack of dedication or ability of those involved, not because of the quality of their education--but because the explorers were young, lacked experience, and perhaps were overambitious. Also, few people had given any thought to quantitative resource surveys of unexploited resources. That's looking beyond the boundaries of this convention, looking outside of what was the day-to-day process of the fishery biologist, laying down a heritage of knowledge about resources that at the time nobody was all that interested in. I hark back to Lowell Wakefield's words, "the richest investment ever made was the 90-some thousand dollars spent on a probe of exploratory fishing in western Alaska."

A decade of exploratory fishing and evolution of methodology occurred in the 1950s, led largely by the Seattle group and Harvey Bullis' group in the Gulf of Mexico and Caribbean. The development of methods of exploratory fishing, the acquisition of quantitative techniques, the acquisition of taxonomic capabilities within the group--even the addition of a population dynamics specialist: What was he doing with the young Exploratory Fishing Group?

Mike Tillman was one of the first. He helped that process become more quantitative and improved experimental design and methods. The development of attendant oceanographic observations followed. With maturation of the group came the start of a process of population enumeration and dynamics for latent resources. That took about a decade, a decade needed to develop an

era of legitimacy with our counterparts in other biological fields. At the end of that decade, one began to feel a little more comfortable about the business of exploratory fishing. Letters from Jule Philips came that said the exploratory process evolved in the Pacific Northwest was evolutionary and leading the world. Carl Hubbs wrote that the contribution to the ecological understanding of the resource as the result of the exploratory process had added more to our knowledge than any other activity that had gone on in that particular area. Dr. Keith Ketchen said the summary report on demersal fishes resulting from the exploratory work was better than anything that had preceded it. Finally even Don McKernan caved in and said in the 1960s when we began the renegotiation of the International North Pacific Fishery Commission, "You have the only information on groundfish that's of value in the renegotiation process."

It took on--and I make a point there--an aura of legitimacy with its counterparts. It began to blend with the people in the biological division and the utilization division and integrated their talent in an overall effort to describe and identify the community or resources available. Those trained in the exploratory role took on ever increasing responsibilities in the BCF-NMFS. They were Harvey Bullis, Bill Stevenson (who became a Regional Director and Acting Director of the current NMFS), and our current Assistant Director, Bill Gordon. The exploratory fishing heritage included Don Powell who was involved in the early work and gave a great impetus to the area. Mel Greenwood, Al Pruter, Wally Pereyra (who manages one of the largest fishing companies in terms of fish quantity handled in the United States), Murray Hayes, Ben Jones, Richard McNeely, and Ed Schaefer--all ended up in rather prestigious positions throughout the government system as well as in industry.

When I look back at the early surveys of the group, there were certain frailties in terms of scientific structure, approach, and methodology, but its strength was the ambition of the staff and a willingness to test hypotheses and do the unconventional. Finally the enthusiasm of the young investigators pulled us through.

I remember well when the first albacore survey was initiated and Don Powell was the chief scientist on the project. We poured over oceanographic charts which we knew very little about. We went over and saw old Doc Barnes, who was sort of the oceanographer godfather of the Northwest. We talked about thermal fronts and looked at the historical data base that was available regarding temperature isotherms by month. In addition to our scientific scoping, we added a different dimension--one that probably has played a key role with this Center over the past 20 years. We went and talked to commercial fishermen and told them what we were up to. We asked them questions, how valid were our goals and hypotheses, and what could they tell us about better structuring the work. People like A. K. Larssen, whom I see here today, Gordon White on the Oregon coast, Bill Jensen, Einer Peterson, the Hall brothers, and the Rockums. These along with other industry leaders, the Lokkens, the Yonkers, and the Salitecs, became a part of an information retrieval system for the exploratory program.

What did that early albacore survey show? What was it based on? It was based on a hypothesis that the albacore

move along thermal fronts, foraging along boundary areas. Taking this into account, the explorers set off in the early spring to go some 500 miles to the south and west of Cape Flattery; they felt they would intercept the albacore when they hit the 57-58 isotherm. Albacore were taken within 4 hours of the time they came into the appropriate temperature zone. The results of the survey provided a basic first in thermometric fishing concepts in terms of albacore distribution to lens depth of the surface layer. The survey added a great deal to our knowledge of pelagic fish with which the albacore interface along their northern boundary; eventually the results played a key part in the development of the migratory theory that now is the basis for albacore distribution and behavior off the Pacific Northwest and in the South Pacific. It added a lot more, regarding the community of resources of the oceanic area: information on the abundance of the blue shark and the jack mackerel and the widespread distribution and abundance of pomfret.

The survey added a great dimension in terms of discovery, namely a seamount...Imagine yourself as a young biologist as Don Powell was at that time, in his early 20s, sitting on a boat as chief scientist, and suddenly seeing rising out of the sea an underwater mountain in an area that showed 1800 fathoms. At 400 fathoms it showed up on the echogram, and the trace came up like a submarine, shooting straight up as a solid black streak. As it reached 50 fathoms, even the skipper became nervous; 25 fathoms and the line was still coming up towards the surface. Rather fortunately, the Cobb on that one initial run had come right up on the peak of the Cobb Seamount which later became the subject of considerable inquiry by geologists. In later years scientists would add information in terms of the involvement of seamounts in the distribution of the nekton in the North Pacific.

What about the shrimp explorations? They also began in the 1950s and carried through well into the 1960s. They began in the southeastern Alaska area, with a 4-foot dredge. Later on, because the fishermen in Petersburg got ahold of us and told us what we were doing wrong, we hired a fisherman to come on board and show us how to carry out shrimp surveys. We went to the large beam trawl that had been traditionally used in southeastern Alaska and eventually employed the Gulf shrimp trawl; later a trawl was especially designed for the pandalid shrimp of the area. We surveyed the Washington-Oregon coast and eventually up into southeast and into central Alaska and westward toward the Shumagins looking at the shrimp resources.

This all occurred in the early 1950s and through the early 1960s. You'll find that every major shrimp resource defined by the Cobb and other exploratory vessels has led to a major fishing area for pandalid shrimp. That doesn't mean that fishermen didn't add a tremendous amount of additional knowledge in terms of the resources, or that some fishermen may not have known the shrimp were there in the first place. The systematic exploration and definition of a resource, however, became a usable product in terms of going to the bank for financing, in terms of making an investment, and encouraging entrepreneurs to develop an industry. Of about $150,000 that was spent on the Alaska survey, a $40 million industry developed. The explorers can't take all the credit, that's obvious, but they can take

credit for the initial probe, for initiating interest, for stimulating the concept that there was something there that might be utilized--given the right gear, the right methodology, and the right time in terms of entering into a fishery.

The bottomfish fisheries began also in the first year of the operation of the Cobb. First off, it was in the so-called pinpoint type of trawling, finding little spots on a very difficult shelf and slope among rocky areas where glacial remains made it very difficult to trawl. Off the so-called "spit" area, and down on the Oregon-Washington coast, the knowledge was extended that the enterprising fishermen--the Hall brothers and Gordon White--had uncovered out of Newport an area of Pacific ocean perch abundance. On the first cruise that I went out on we made a set and picked up 20,000 of these critters. I looked it up in the literature and it said, "rare, very few specimens." The survey eventually defined the distribution of a resource that inhabited the whole arc of the North Pacific and was one of the major resource components of the area.

From there, we went north to Alaska through the Gulf. The trawl surveys added a great deal to our understanding of the demersal fish component of the region. They defined every one of the top 10 most abundant species that had been found or utilized in the area. They almost corresponded in their abundance in the exact order now forecast by resource biologists. They added a tremendous wealth in terms of the ecology of other groups of fishes. They extended the distribution and commercial range of sablefish into very deep water, which were later verified by Japanese exploitations. They began to put boundaries on something called the "Pacific hake," which I always called the "McNeely fish." You know, every commercial guy knew how to put the trawl on the bottom and catch hake in the spring and summer along the Washington coast, but we saw this mysterious midwater echo trace and we knew it was something but kept thinking "My God! we must be shooting on plankton." Every time we pulled the net up, we came up "skunked." We didn't have the telemetering techniques at that time, which would have allowed proper positioning of the net, and we were largely guessing. Dick put the system together that allowed us to know where the trawl was in the water column, and lo and behold! When we finally got that system to work we went off the Cape and set on that mysterious echogram that had plagued us. We came up with 40,000 pounds of hake on the first tow. And from that time on, we began to develop the study of the hake (Pacific whiting) resources.

Unfortunately, it is not one that we have yet capitalized on in terms of a totally U.S. fishery, but one in which we are now producing 45,000 metric tons (t) in a joint venture mode.

I should note the work of Frank Fukuhara and Ed Schaefers who went out on the early salmon investigations and found out that there were adult salmon of all species throughout the North Pacific. We had not bothered to read the Japanese literature and were rather surprised by the distributional features and abundance of the resources in the area. This launched the initial study, which was a long and intense survey of the pelagic-anadromous resources across the North Pacific. That, too, was a part of the early exploratory and biological efforts of this Center.

I could go on about the resources of the seamounts, the scallop studies, and

the joint industry bottomfish-clam investigation. I am also reminded to give you just a few words about the old historical Chuckchi venture, which was the time when they were looking at the potential of blasting a harbor near Point Hope in Alaska. About 4 months before the main cruise, we found dry rot in the Cobb. They began picking on the side and the next day there was a hole 4 feet across and suddenly it went across four frames and the center of the boat. We found out that it was just a few of the ribs and stringers that were holding the Cobb together. And it cost us what seems like a trifle amount now, but was a big share of our budget at that time--$40,000 to put it back into the water. We finished 2 days before sailing time. We headed north to go through the Bering Sea and checked the early efforts of the Soviets in that area and then north into the Chukchi Sea.

I am always reminded of that cruise because of one of my own experiences. I had volunteered with Ford Wilke, who used to head the marine mammal group, to go ashore and pick up the mail. The surf did not look that bad to us and we could take the skiff through the surf. We headed in and when we got into the surf, we found the waves were a little bit bigger than we had anticipated. A little chill ran through me. We watched the waves in back of us and forward. We managed to get between two waves and kept the motor going so that we just stayed between them. We knew just how to handle the situation. We hadn't counted on the fact that offshore about 50 feet from the beach there was a berm and we ran onto that going about 20 miles an hour. Both of us went into the surf and the boat came tumbling after. We ended up on the beach, and I looked around for Ford and couldn't see him. He was under the skiff, so I had to get him out from under it.

I could go on about the outer continental studies and works that are reported in the literature under Wally Pereyra, but I think I need to say a little bit about gear research. I have alluded a little to McNeely and the innovation that he put into that particular arena. We had quite a group of gear technologists and gear people looking at various aspects of resource harvest, trying to evolve a reasonable midwater trawl system. The method worked out by Sig Yeager on the sablefish pot system became the main fishing method in the California and southern Oregon fishery. But probably nothing else will stand out greater in terms of the contributions that this particular Center and the exploratory group made to sea research than the tuna-porpoise problem. When that problem came up, Dr. White said to me, "Lee, do you think we have any chance of solving this using new gear to minimize the incidental take of porpoise?" And I said we do, and it rests with Dick McNeely, because there is a guy with a thousand ideas, 990 which are probably bad, but he will eventually come up with the right solution. You can knock him down 15 times and he will pick himself back up and he will find a solution to the problem. I remember the ulcers that Dick generated in trying to solve that problem. About a 4-year effort and a dedicated one, and much a one-man show in terms of looking at selective fishing technology to resolve a major problem confronting an industry. He had rocks hurled at him by both the industry and by the environmental groups and in the end, both of them applauded him and awarded him for his efforts in that area. I think it was an outstanding piece of gear research and the type of work that will be important in the solving of future

fishing problems. That job is finding selective techniques to minimize the impact of harvest activities on other people.

If you look at the literature today, a rich part of it that relates to the living marine resources of the northeast Pacific, had its genesis in the exploratory fishing group and subsequent elements of this group within the Center. They did, indeed, extend the boundaries of knowledge, and they evolved a methodology in terms of assessment that has become a fundamental part of techniques not only in this area, but also in terms of trawl survey and methodology being used throughout the world today.

I have looked at some of the costs involved in all this, particularly in the earlier work. I mentioned western Alaska crab studies. I said $110,000 ultimately generated more than $150 million; $108,000 in the Central area generated more than $200 million. About $150,000 were spent on shrimp surveys in the westward area; in 1 year alone the fishermen there produced close to $20 million worth of fish. I caution you, we are not suggesting that the exploratory fishing group by itself can take the credit which is due the fishermen, investors, and processors, but they did stimulate their imagination and added new information which the entrepreneurs used to develop the fisheries.

CONCLUSION

I conclude by saying exploratory fishing, if properly executed, is a process of systematic search. It is a process of sending out probes. I believe it would be a mistake if the Center were to drop back its boundaries and say "Yes, we know all about fish in the ocean." That is exactly what I was told 30 years ago! All the answers about important resources were available; we knew where all the resources were. It will be a mistake if the Center does not have a group that continues to look beyond, to look at a facet other than assessing conventional species. If that is all you do you will add little in the way of new information for future generations. The last message that I would like to leave with this particular group is that there is a future. Exploratory fishing grew up and became an important part of scientific activity at this Center as well as in the southeastern and northeastern United States, in the Great Lakes area, and on a worldwide basis.

Future of Exploratory Fishing and Gear Research

Steinar Olsen [1]

First of all, we should always consider that we are dealing with dynamic systems of living renewable resources. Renewable also in the wider sense that as the ecosystems change, and not least by the action of man, new resources may very well rise and fall; there are several examples of this. For instance, in the North Sea in the last 10-15 years, after the herring stocks and similar stocks were fished on, there was a fishery for sprats. Fairly large quantities were present which were never there before, certainly not in such quantities. So in that way we got other resources instead of the herring which was fished on.

Secondly, if we look upon the most recent fisheries developments--in the last 10 years or so--you will see that we have a number of examples of new resources that have indeed been identified from time to time, and new explorations have started. In some cases, these have been new discoveries. In others, it has been rediscoveries of what we might call old resources in the sense that some knowledge about them existed, but it is only recent research and explorations that have shown they were exploitable. In other cases, new developments in technology as well as in market conditions have made certain known resources attractive which previously were not commercially exploitable. For example, the blue whiting fishery was developed in the northeast Atlantic since 1971-72 and has turned out to be one of the major fisheries in that part of the world.

It was known before 1971-72 that blue whiting was fairly numerous and that the species usually inhabited deeper parts of the ocean. It was only after the research institutes in the area had determined that this was indeed a very big resource that subsequent exploration, experimental fishing, and gear development laid the basis for a multi-national fishery which has now passed 1 million metric tons in annual catch.

Another perhaps similar example is a recently developed deep slope fishery for blue and white ling off the Norwegian coast. Although both species have long been fished in other localities with longlines, it was not until the deep slopes were fished experimentally with the very efficient monofilament gillnets, that very good catches were obtained, consisting partly of very large fish (which were seldom caught with longlines).

Recently in Norway, we have started a creel or pot fishery for nephrops, a small ocean crayfish. This has come about as a result of exploratory and experimental work over the last 4-5

1/ Director, Institute of Fishery Technology Research, C Sundtsgate 57, Bergen, Norway.

years. The species was taken as a bycatch in our shrimp fisheries, but nobody knew that we had such a large number of localities with this resource (which was also good from the gourmet point of view) in our fjords and off the islands, until we started our trap experiments.

Similarly, to go a bit further afield, off the southwest coast of India an international survey project, set up to explore and assess the sardine and mackerel resources, also resulted in the quite unexpected discovery that indeed the greatest pelagic resource in the area was that of anchovies, which were previously believed to be only of restricted distribution and of minor importance.

And so we could go on quoting examples from different parts of the world, which all suggest that although the amount and perhaps also the rate and the perfection of exploratory activities have greatly increased in recent years, there are still most likely many improperly explored areas and/or depth zones which may contain unidentified resources, and I can see no reason why we have just come to the end of further exploration. Furthermore, in spite of what Dr. Dayton (Lee) Alverson told us this morning, I think it is a fact that the methods and the techniques used in most explorations in the past, which have mainly been done by trawling--of course, there are many notable exceptions--are only applicable and reliable for certain conditions and kinds of fish. In fact, for some types of resources, adequate technology for their proper exploration and subsequent commercial harvesting does not yet exist and can only be developed through research and painstaking experimentation and tests.

Thus, for demersal fish and other creatures inhabiting rough grounds or steep slopes, particularly deep areas that cannot be fished with standard bottom trawl techniques, there are few, if any, expedient methods of reliable exploration which can be readily applied. Similarly, for pelagic, non-schooling quality fish, such as the Spanish mackerel, small tunas, and so on--and not the least, cephalopods--standard exploratory technology is simply not available and will probably have to be tailor-made in each case for specific conditions and target species.

We have a number of examples of explorations which have been carried out around the world with trawls or other gears that are selective with regard to size and species of fish and type of fishing ground or area, and these methods and gears were only suitable for these resources. And, very often the methods and gears were used indiscriminately in the sense that the results obtained were assumed to verify the presence or absence of potential commercial fishing resources. However, without firm knowledge about the efficiency and the selectivity of the gears toward the relevant species, the results were misleading. I think a glorious example of this is one of the first, if not the first, shrimp surveys in the Gulf of Mexico. This failed altogether to show that there were enough shrimp for commercial fishing, and as you all know, in an area where the world's greatest fishery for shrimp subsequently developed. The reason for this failure was that the survey was carried out in the daytime.

Similarly, on the west coast of Africa in the early 1960s, the Guinean Trawl Survey was carried out. It was a major international undertaking, and one of the results was that nowhere could they

find large enough resources of flatfish to be the basis of a commercial fishery. Again, subsequent developments have shown that surely in certain areas off West Africa, there are both soles and other flatfish which can be fished commercially. Here again, the reason was that in this survey, the trawl gear was standardized for roundfish and was inefficient for flatfish.

Now when we get to the pelagic schooling fish off West Africa, the situation was perhaps a bit better. They can usually be relatively easily detected, located, and assessed by means of acoustic methods; with suitable sampling gears, one can obtain necessary samples for identification and biological studies. But, as I mentioned previously, there are many pelagic resources which do not occur in dense concentrations and cannot be easily located with echo sounders and sonar.

Again, to draw an example from the survey off southwest India, with the pelagic trawls and purse seines that we used for sampling, from time to time a few high quality fish, Spanish mackerel, frigate fish, pomfrets, and so on, were caught. These fish were all very high priced in the area, and they were never taken in large quantitites (not considered to be plentiful). While the outcome of this investigation has not resulted in any further exploration or exploitation of the small pelagic fishes, there is now a prolific fishery with 700 vessels, fishing with gillnets, for the larger pelagic fish which we didn't consider numerous enough for commercial fishing.

And so, if we are to answer this first question, through changes in the ecosystems, many of the resources taken now may come and go. We have to accept that. Secondly, new resources have in recent years, continuously more or less, been identified and become exploited. Thirdly, developments in technology in markets make unharvestable resources of yesterday harvestable resources of today and tomorrow. Fourthly, the technology for surveys and exploration often are inadequate to address unharvestable resources and this has hampered results of previous surveys and will probably continue to hamper future work. My conclusion is, all resources of the ocean have most probably not been identified, and accordingly, further explorations can certainly add to our present understanding. In order to do so, we have to know much more about the fishing gears and methods that we are using; we must know, for example, how efficent they are and how selective they are with regard to the species or the creatures we are trying to explore. It follows, therefore, that more exploratory work in the future must be strongly integrated with research and development of gear and methods.

In addition, it is my conviction that such developments must be integrated activities of both technological engineering and investigations of fish behavior; because, if we do not know about the general distribution and behavior of the species, as well as their reactions to various stimuli, we could very well risk the same blunders--like failing to detect the large shrimp resources in the Gulf of Mexico.

Nevertheless, in my view, the main aim of gear research is not to provide resource survey biologists with better tools to explore and assess resources. In my view, this is only a secondary objective of gear research and development. I should like, however, to stress that if in the past some

survey biologists--and I've been one myself--had known more about the fishing gears and methods that they were using and if they had had a better understanding of the needs for evaluating the efficiency and selectivity of the sampling gears, more resources would probably have been identified.

The main objective of gear research and development is to assist in providing the fishing industry with better and more economic methods of harvesting the resources--more economic in the sense of catching efficiency and manpower requirements and not hampered with the present escalating fuel costs and energy requirement. Furthermore, we need better and more efficient methods to harvest the resources in such a way that we take only the wanted species and sizes of fish and we do not destroy young fish and their basis for growth and reproduction in the sea.

And this brings me to another topic that Lee wanted me to touch on, selectivity. There has been a lot of talk about selective fishing and the belief that fishing technologists should indeed aim at developing species selective methods of fishing so that the problems, for instance, in connection with multispecies fishing, can be, if not solved, at least reduced. Now, selective fishing is in my view a paradox or a misnomer because it is reciprocal; non-selective fishing in my view does not really exist because all fishing is in one way or another a matter of choice. While this may sound like splitting hairs, let us now look upon the necessities and the prerequisites for selective fishing. There are two basic requirements which might facilitate selective fishing in the sense that one can choose the kind or size of fish to catch. Either it is required to sort out the fish or sizes of fish after capture, or at some stage or some time or some location to separate the desired fish from others so that they can be fished without a chance of catching anything else. In this case, selection is achieved by choice and time or location but, in order to do that, it is also necessary to know the pattern of distribution or size of target species, so that one can predict where they can be selectively captured or to know methods for instant detection or observation of the desired species.

Now purse seining for schooling species or aimed trawling for aggregations or schools of fish of particular kinds are typical examples of the one type of selective fishing, but quite often the purse seiners also are in for surprises, and here you have a problem with not only fish, but with purposes also. The other alternative is to design and operate a fish capture technology which utilizes the differential behavior and reaction of fish towards the fishing gear. This is simple enough with regard to size and, in some cases, it may be possible to design trawl systems so that they will be efficient for one type or kind of fish.

But, nevertheless, I believe that the prospects for species-selective fishing with active gears are rather dim, except in some cases when selection can be performed by choosing the exact time or location and depth. The basic reason for this pessimistic outlook is that the methods relating to the active types of fishing gear do not depend to a large extent on the actual behavior of fish. You are utilizing, so to speak, the brutal force of technology to catch the fish and, therefore, I sometimes like to call them man-active methods in contrast to the passive, or what I call fish-active methods. Here,

the catching process can exploit what the fish does and not what the man does, and there is a much greater potential for species selective fishing by utilizing the differences in fish.

The progress and development which have occurred in the passive fishing methods have come gradually and as a result of trial and error. Sometimes, they have come from the occasional--maybe not so occasional--bright ideas of fishermen and, in some cases, by suppliers of fishing gear and equipment. We have obtained new materials, synthetics. These materials became available as a result of general technological evolution, but there have been very few systematic studies aimed at the general improvement of the passive fishing methods. As far as I know, with some exceptions, there have been rather few systematic studies anywhere in the world, and the reasons are quite simple. There has seldom been sufficient funding to study these fishing gears. The units of gear are generally small, the volume of their sales is small, and perhaps there are not enough engineering problems to challenge technologists. Furthermore, it requires detailed studies of fish behavior and reaction to make progress; technology alone is not enough, and so far, most of the gear work has been ruled by the engineers.

In contrast, the trawl and purse seine fisheries generally consist of large, expensive capital intensive units. In these fisheries, there are large sales of gear and equipment and also challenging engineering problems. Accordingly, in the past, millions of dollars, rubles, marks, kroner, or yen have been used to develop the technology of the active fishing methods, while in the case of the passive methods, the corresponding efforts can probably be better measured in cents, pfennigs, or kopeks.

In general, therefore, the state of the art today is that the active--or as I call them man-active methods of fishing--have been developed to a level of performance where the potential for further improvements, at least with regard to engineering of the gear itself, is pretty low--pretty limited. Take demersal otter trawling; further gear work is probably needed, and a lot of work is being done in various places in the world, to reduce towing resistance. Introduction of the large-mesh technique, which has been so efficient in pelagic towing, can (I believe) be tried extensively also for bottom trawls. There are also improvements to be made with regard to trawl doors; new types are available which are economically better than most of those in use today. It's perhaps a matter of more economic production, and we can see that towing resistance can be reduced but probably not reduced more than 25% today, because contact with the ground is necessary to catch any fish. And similarly, we may witness a new development in net handling which will improve the operational ease on board the trawlers. But perhaps the greatest break-through in increasing efficiency of trawling is introduction of pair trawling, because here the herding area is increased without increasing power or energy requirements. Nevertheless, the potentials for improvement of the trawl fisheries, in my belief, can be counted in tens of percent. In purse seining, the actual capture process has been brought to a very high level; I believe that future prospects are mainly on the operational side. Maybe sometime in the future a purse seine system will be available which can fish deeper, be well-balanced, and can sink, and depth will not be as limiting or restricting as in current seines. But we have to

remember that this is the type of gear which is suitable only for schools of fish, but there are limitations here also. When we get to the passive, or fish-active methods, the situation is different. Here, because of the lack of study and development, I'd say that these methods are still largely in their infancy. The methods of capture themselves give room for probably very great improvement. To back this up, I shall relate some information on the studies which have been carried out in recent years by our institute.

In our longlining investigations, we quickly deduced that probably the hooking efficiency of the normal Norwegian cod longline is not very high. We discovered this from detailed fishing behavior studies--studies of how the fish actually attacks the baited hook. These were done both in tanks and with underwater TV on the fishing grounds, and it confirmed quantitatively how inefficient the normal longline really is.

Permit me to go a little bit into detail. When the fish attacks a baited hook, it will suddenly open its mouth, suck in the bait, and then if it doesn't spit it out right away--because it's displeased--it will rush to get away with the bait it has taken. Of course, the fish is stopped by the snood or branchline. The snood trails beyond the fish, along the body, but the hook actually is just in the mouth, and when the fish is stopped, it may after some time, stop and shake the head vigorously and try to swim away again or spit it out. The fish is not hooked. To get the point of the hook to penetrate the tissue, the mesh line has to be at an angle to the body of the fish; with a normal straight hook, where the hook is parallel to the shaft, this doesn't happen so easily. In data of studies I've been given, estimates of the hooking efficiency indicate that of 100 fish that do attack and take a baited hook only about 20 or perhaps 25 are caught. This immediately showed us that here is a very great potential for improvement, and it is not only in tens of percent, but in hundreds of percent.

The same fish may attack the same bait several times or go to another one. Probably it feels the point and/or the barb of the hook and experiences some discomfort; after several attempts, it probably learns that something is wrong. When this experience is associated with a visual picture such as the picture of the traditional heavy lines in front of it, the learning process is relatively quick. And we have found that if transparent monofilament lines are used, the fish probably sees practically nothing except the bait itself and will continue for a much longer time to attack the bait--to try again. In comparison with traditional lines, we have found that monofilament transparent lines fish three to four times better, catching 300 to 400% more fish. Not only that, we have found that on the monofilament transparent lines, not only are there more fish, but also the bait is still on the hook. In comparison to traditional lines, there is still a lot of bait intact, but on the monofilament line, the fish apparently continue to attack the bait until they are finally hooked or manage to steal the bait. The main outcome of the behavior studies is that they have given us a lead towards better hook designs that will increase hooking efficiency. The detailed studies of how a fish attacks the bait gave us the idea that the chance of hooking will be better if the hook is formed in such a way that the pull of the snood--the branchline--is really an extension of the point. There are such hooks

already, such as the Mustad Wide Gap type. They are also like the ones which are used by the Japanese for tuna fishing; we have tried those and found they immediately give an increase in catch rate of about 30%, compared to the standard flat hook which is used by the Norwegian longline fishermen.

We have also demonstrated that the traditional hook spacing used in Norway is too narrow to give the highest relative catch rate, and it's better to cover as large an area as possible than to put out many hooks in a restricted locality, but this is, however, a function of fish density. Similarly, we found that increasing the snood length, which in Norwegian longlines is about 50 centimeters (18-20 inches) long, to 70-80 centimeters gives a higher catch rate.

We also looked into the bait and hook size. Bait is one of the major expenses in longlining; and, in Norway, the government is subsidizing the bait to the fishermen to the tune of some 40-50 million Norwegian kroner a year, which is 2-1/2 times the budget of our institute, and we thought that we might be able to reduce the bait size somewhat without significantly reducing the catch rate. In the first experiment, we tried by comparing standard bait sizes and sizes of hooks with half bait. The result was, to our great astonishment, that we hooked about 40% more fish on half baits. We have repeated this in other fisheries and this has been confirmed--not that you get 40% more, but that you get at least the same catch rate and slightly better with a reduced bait size. So there's a considerable potential for economic savings here.

And of course, on top of this, comes the results of the many promising efforts of mechanizing and automizing the gear handling and other operations in longline fishing, which are being conducted not only in my country, but certainly also here in North America. In general, we have found that there is a very great potential for increasing the catching efficiency of these methods, as well as for economical improvements. We also found this with regard to other types of passive fishing methods--gillnetting, for instance.

The catching efficiency of the traditional gear in Norway is certainly not optimal; for instance, by a better matching of the mesh size used in a gillnet fishery to correspond with the available size of the fish, we could make improvements. One year we could show that by simply a better mesh size, you could have 60% increase in the catch with the same number of nets--the same effort, really, and probably the nets would be cheaper because it had larger meshes. Further, you could improve the gillnets by modifications of hanging ratio; by improved net geometry; and by changes in operational methods; and by better gear handling, equipment, and deck layouts.

Gillnet fishing is often blamed for bad quality of fish because the mortality it generates is much more than what is really landed. And, in addition, lost nets ghost fish, killing a lot of fish. I believe that these are problems which in all probability can be satisfactorily solved.

These are the general conclusions from all our work in recent years, but the potentials can only be realized by research and systematic technological development in other places as well. I should like to make the point that while in the fisheries where there is big money where the big units and great sales are, such research and

development may very well be undertaken by the industry itself. They can afford it; and, in some countries, the economic and political system promotes research. In others, it is public money which supports that kind of research and development; but, in the small fisheries, at least in the beginning, it will not. The necessary money for gear and research and development will not be available from the industry itself to carry out development in a systematic, orderly fashion; consequently, it is only research and development based on public funding which can realistically bring these methods of fishing up to what they could and should be. In Norway we can clearly see now that because our stocks have been fished down and our fuel costs are escalating, we may soon be approaching the time when we have to develop modern efficient longlining and gillnetting in order to be able to harvest some of our native resources. I believe that no modern fishing nation can continue to survive without the support of research and technological development; the fishing technologists in the other parts of the world, I believe, are now eagerly waiting for the time when this challenge will also catch more of the attention of the tremendous potential force of research and development in the United States.

Fisheries Management: A Historical Overview

Clinton E. Atkinson[1]

INTRODUCTION

This afternoon we complete the series of talks given at this 50th Anniversary of the Montlake laboratory. We have heard accounts of the role of the laboratory in studies of the resource and its environment, fishing and fishing methods, and utilization of the catch. Now we come to the final session, namely, the management of the fishery and marine mammal resources. If we examine the history of these management practices, we can recognize at least three stages of development or goals: 1) to stop the decline and simply maintain the existing level of yield, 2) to determine, theoretically or empirically at least, the maximum sustainable biological yield and, most recently, 3) to extend the maximum biological yield to include the economic and social benefits as well. Each of these steps, in their time, were considered complex but are gradually being overcome through experience and the development of scientific knowledge. Yet to be resolved, however, are the added difficulties imposed by political pressure groups and legal decisions, all too frequently divorced from scientific fact or reason, and now broadly included within the concept of "social benefits" of the present goal of management.

Management of fisheries in the United States is quite different from that followed by most other countries: Here we have always considered that management of fisheries was a State's right and the jurisdiction of the Federal Government has been generally limited to Territories, the high seas, and management under international treaty and/or administration and, in the case of salmon and certain other freshwater fishes, access and protection of fish in navigable waters. Needless to say, this fragmentation of management authority over fish and fisheries that share the waters of the several States or go beyond their coastal zones has been the source of innumerable conflicts between the States or between the States and the Federal Government.

The United States Commission of Fish and Fisheries was established by law in 1871 with Dr. Spencer Baird of the Smithsonian Institution as its first Commissioner. By far, the greatest emphasis of the work of the Commission during its first years was directed towards the artificial propagation of food and game fish, especially for the

1/ Former Director, Seattle Biological Laboratory, Bureau of Commercial Fisheries, U.S. Fish and Wildlife Service; present address: 4055 21st Ave. W., Seattle, WA 98199.

marine species along the New England coast. Billions of eggs were collected each year, incubated, and the young released in an effort to maintain the important fisheries of the United States. There were massive transplants made in those early years of American shad and striped bass from the Atlantic to the Pacific coasts and, conversely, salmon and trout from the west coast to the eastern streams. The scientific work of the Commission at that time generally centered around studies "to determine the best methods to be pursued in fish-culture, to ascertain the results of fish propagation and to study the habits, migrations, growth, food, enemies, and diseases of fish" (Brice 1898, page 138).

Although much of our early information on the fisheries of the Pacific coast came from the first surveys of the various salmon streams in a search for suitable locations for hatcheries, the Smithsonian Institution and the U.S. Commission of Fish and Fisheries undertook a comprehensive survey of the fish and fisheries of the United States, directed by Congress as a part of the 10th census (1880). The series of reports generated by the survey still provide a wealth of information on the histories of the various fisheries, their records of exploitation, and the early efforts at management. Dr. David Starr Jordan, who was then President of Indiana University, was among the 19 scientists and experts chosen as associate authors for this survey by Drs. Spencer Baird of the Commission and George Goode of the Smithsonian: these two and Jordan, along with Charles H. Gilbert, conducted the survey of "The Salmon Fishing and Canning Interests of the Pacific Coast" (Jordan and Gilbert 1887). Soon afterwards, Leland Stanford University was founded at Palo Alto , California, and Dr. David Starr Jordan was appointed its first President. For nearly the next 50 years, the scientific investigations and the management activities of the U.S. Commission of Fish and Fisheries (and later, the U.S. Bureau of Fisheries) on the Pacific coast centered around Dr. Jordan, his faculty, and students at Stanford University.

The fishery research vessel Albatross, built by the U.S. Commission of Fish and Fisheries in 1882, initially for surveys along the Atlantic coast, was transferred in 1887 to the Pacific coast and for the next 25 years was engaged in a wide variety of assignments extending across the North Pacific Ocean from California, Oregon, and Washington to the coasts of Japan and Russia and from the Pribilof Islands in the Bering Sea to the Hawaiian Islands.

It should be pointed out that the U.S. Commission of Fish and Fisheries (established in 1871) had little time to become actively involved in the management of the fisheries of the States of California (granted statehood in 1850) and Oregon (granted statehood in 1859), but the situation in Washington (granted statehood in 1889) was a little different: The salmon fishery began in 1877 while Washington was still a territory and almost from the very beginning of the salmon fishery, there was conflict between U.S. and Canadian fishermen over the U.S. catch of sockeye salmon that passed through U.S. waters on their way to spawn in the Fraser River which is almost completely within the Province of British Columbia. The first attempt to resolve the conflict was through the International Joint Commission (United States and Canada), and the U.S. Commission of Fish and Fisheries was called upon to provide the joint

commission with the appropriate background information and statistics. The U.S. Commission of Fish and Fisheries and its subsequent U.S. fishery agencies have continued to be plagued with the problems of international management of salmon fisheries for almost 100 years; and, although the organization of the Internaional Pacific Salmon Fisheries Commission in 1937 took the pressure off the Fraser River sockeye and pink salmon fisheries, conflicts over the other salmon species and areas continue to be a subject of negotiation between the two countries even at the present time!

Alaska was purchased from Russia in 1867 and Hawaii was annexed in 1900. Both remained Territories until statehood. While the coastal fisheries of Hawaii were of little importance, management of the fisheries of Alaska, however, was a completely different story. At the time of purchase, the United States inherited a very rich and developed fur seal industry--a resource that had provided the chief source of revenue to the Russian-American Company in Alaska, but the annual yield of which was already showing signs or serious depletion due to excessive kill. After about 2 years of private commercial sealing, the United States declared the Pribilof Islands a national preserve and the Federal Government assumed management of the fur seal resource in 1870.

The salmon fisheries began to show depletion within 20 years of the establishment of the first cannery in Alaska at Klawok (1877). The halibut fisheries began to decline in the early 1900s and the herring fisheries in the 1930s.

These were the important fisheries of Alaska until statehood in 1959, and all have been the subject of a series of studies and recommendations, first by select groups of scientists from Stanford University, then by the organized research programs (such as the Pacific Fishery Investigations) at Stanford University and later at the Montlake laboratory, by the State agencies and universities and by international fishery commissions.

Although the Federal Government was relieved of its fishery management responsibilities for Alaska and Hawaii in 1959, the recently enacted Marine Mammals Protection Act, the Endangered Species Act, and the Magnuson Fishery Management and Conservation Act of 1976 have placed broader and, in many ways, more difficult responsibilities within the Federal Government's fishery laboratories and management organizations. It is the staff of the Northwest and Alaska Fisheries Center, with the heritage gained from the biological research conducted at the Seattle and Auke Bay Laboratories, that must now develop the scientific basis for policy and plans in the management of the fisheries within the 200-mile fishery conservation zones of the Pacific Northwest and Alaska, in other waters of the United States, and far beyond in response to international treaties and understandings.

MANAGEMENT OF FUR SEALS OF THE PRIBILOF ISLANDS

The fur seal resource of the Pribilof Islands provides one of the earliest examples of successful management of an aquatic resource, especially in international management. It is an extremely valuable resource, attracting the attention of the early explorers from Russia, and the annual harvest

provided the chief source of revenue for the Russian colonial government and the Russian-American Company during the 18th and 19th centuries. Its history provides many examples of overkills and waste, the effects of severe environmental conditions, e.g., the extended ice conditions reported in 1834, etc., problems of pelagic sealing and attempts at protection of the fur seals and international arbitration and, finally, the first international fishery management treaty by the United States.

The author has taken the liberty of reprinting here, verbatim, the very excellent description of the history of fur sealing prepared by Ralph C. Baker, Ford Wilke, and Howard C. Baltzo and published by the U.S. Bureau of Commercial Fisheries in 1970 (Baker et al. 1970, pages 2 to 4, 14 to 17).

"In 1742 Georg Wilhelm Steller drew up the first scientific description of the fur seal after he had survived the wreck of the vessel commanded by Vitus Bering off what is now called Bering Island in the Commander Islands, U.S.S.R. These islands are one of the three principal breeding grounds of the northern fur seal.

"In 1783 Gerassim Pribilof, navigator in the service of Imperial Russia, joined the search for other breeding grounds of the North Pacific fur seals. The Russians originally came to this area in search of sea otters, and here they found fur seals as well. Each spring the seals were seen to swim northward through the passes of the Aleutian Islands and disappear into the fog and mist of the Bering Sea. In 1786, 3 years after his search began, Pribilof came upon the islands that now bear his name and found fur seals along the beaches in seemingly uncountable numbers. Almost immediately the teeming rookeries became a source of sealskins for the fur markets of the world, at about the time the 13 colonies on the Atlantic coast of North America were forming a new nation. Today northern fur seals breed on the Pribilof Islands, St. Paul and St. George, in the eastern Bering Sea, the Commander Islands, Bering and Tuyleni, in the western Bering Sea, and on Robben Island off Sakhalin Island. Small colonies have become established in the Kuril Islands between Kamchatka and Hokkaido and on San Miguel Island off California.

"Two years before the discovery of the Pribilof Islands, adventurous skippers from New England and Europe had discovered commercial possibilities in the great herds of fur seals along south American coasts, in Antarctica and off South Africa. Even though the Spaniards expelled British sealers from the Falkland Islands in 1770, the United States' first experimental cargo of 13,000 pelts from the Southern Hemisphere appears to have been taken at the Falklands in 1784 by the crew of the American vessel States from Boston.

"In the 50 years that followed, the fur seal rookeries on Islo Alejandro Selkirk (formerly Mas Afuera), Juan Fernandez, the South Shetlands, Prince Edward, the Antipodes, and many other islands were destroyed as fast as they were discovered. Literally millions of pelts were taken to the Canton market to trade for tea, silks, and other products of China. The populations of fur seals south of the equator were rapidly decimated. Some herds survived, however, and still live off the coasts of South Africa, South America, Australia, New Zealand, the Galapagos Islands, and some of the subantarctic islands.

"The exploitation of the Alaska herd at first followed the same destructive methods as those pursued by sealers in the southern seas. Twice during the Russian administration the herd on the Pribilof Islands was threatened by annihilation: first, through failure to restrict the numbers of seals killed, and later by failure to give the females adequate protection. Russia forbade the killing of females after 1834, but according to H. W. Elliott the ruling was not enforced until 1847. Elliott was told about a wall of ice that prevented the females from landing on St. Paul Island and forced them to bring forth their pups in the water of the storm-tossed surf, which killed many of the mothers and most of the pups. The truth about this catastrophe and the condition of the seal population in 1836 cannot be verified. By 1867, when Alaska was purchased, the seal herd was reported to be thriving.

"After the purchase of Alaska by the United States, Congress passed legislation to protect the future seals of the Pribilof Islands from reckless slaughter. A number of independent companies had begun sealing on the islands and had taken about 300,000 skins the first season. To prevent this destruction, an Act of Congress of 27 July 1868 prohibited the killing of fur seals, and on 3 March 1869 the islands were set aside by the U.S. Government as a special reservation for the protection of the animals. Only local natives were allowed to kill fur seals, and then only for food. A year later the U.S. Treasury Department was authorized to lease exclusive rights to take seals on the islands, with the stipulation that no females were to be taken. Further legislation in 1874 authorized the Secretary of the Treasury to establish catch quotas and open seasons for the lessee.

"Fur seals are vulnerable to capture while at sea as well as on land. Pelagic sealing, or taking of fur seals at sea, began to develop on a commercial scale about 1879. As practiced extensively by American, Canadian, and Japanese sealers in the North Pacific, pelagic sealing resulted in the indiscriminate killing of the seals, without regard to age, sex, or the number taken. The pelagic take of sealskins reached a peak of 61,838 in 1894.

"In 1870 the Alaska Commercial Company, composed of several sealing competitors who had compromised in 1868 to gain control of the resource, was awarded the United States' first 20-year contract to seal on the Pribilof Islands. Under the first 20-year lease, the Alaska Commercial Company took 1,977,377 sealskins. Under a second 20-year lease (to the North American Commercial Company), only 342,651 sealskins were taken in the period ending in 1909. The leasing system was discontinued in 1910, and since then the Alaska fur seal herd has been under the management of the Federal Government, first by the Secretary of Commerce through the former Bureau of Fisheries and now by the Secretary of the Interior through the Bureau of Commercial Fisheries of the U.S. Fish and Wildlife Service.

"Early pelagic sealing had a devastating effect upon the fur seal herd. Almost a million skins were taken on the high seas from 1879 to 1909, and many of the seals shot or speared in the open sea were not recovered. The effect on the Alaska herd was disastrous, because females made up 60 to 80 percent of the pelagic catch. In 1912, when the first complete census was taken by David Starr Jordan and George A Clark, 215,900 seals were counted or estimated

on the Pribilof Islands. Although scientists believe this estimate was too low, the Pribilof herd had undoubtedly been reduced severely, and the smaller herds off the Pacific Asian coast were faced with extinction.

"After extended diplomatic negotiations and a long series of ineffectual bilateral agreements, the United States, Great Britain (for Canada), Japan, and Russia concluded a Convention on 7 July 1911, for the protection of the fur seals of the North Pacific. Pelagic sealing was prohibited except by aborigines with primitive weapons. Each country with fur seal rookeries agreed to share 30 percent of its annual take of sealskins--Canada and Japan each to receive 15 percent of the sealskins from the Pribilof Islands and the 15 percent of those from the Commander Islands; and Canada, Russia, and the United States each to receive 10 percent of the pelts from Robben Island.

"Worldwide political events affected the international agreements protecting the fur seals. The convention of 1911 provided for the first time a sound basis for the management of the North Pacific fur seals. It remained in force for 30 years, until terminated by Japan on 23 October 1941. From 1942 to 1957 the Pribilof herd was protected by a provisional agreement between Canada and the United States, which reserved to Canada 20 percent of the skins taken each summer on the Pribilof Islands. As a result of World War II, control of Robben Island and the Kuril Islands passed from Japan to the Soviet Union, giving the U.S.S.R. complete control of all fur seal rookeries off the Asian coast.

"On 9 February 1957, a new interim North Pacific Fur Seal Convention was concluded by Canada, Japan, the Union of Soviet Socialist Republics, and the United States, similar in form to the 1911 Convention. The new convention, as amended by a protocol in 1963, has as its principal objective the achievement of maximum sustainable yields of fur seals in the North Pacific. It provides for a Fur Seal Commission comprised of representatives of the four Governments to coordinate research and management for the northern fur seal. It also provides that Canada and Japan each shall receive 15 percent of the sealskins taken commercially by the United Staes and the U.S.S.R.

"The Fur Seal Act of 1966 (Public Law 89-702) puts into effect domestically the international convention. It provides for the conservation and protection of the fur seal and sea otter and for the administration of the Pribilof Islands.

"Under international protection and rational management, the Alaska fur seal herd has increased from the low point of about 216,000 animals in 1912 to its present level of over 1 1/4 million animals. From 1940 to 1967 the herd has provided an average 59,758 male sealskins. Since 1958, over 738,000 have been harvested or taken for research under management policies approved by the North Pacific Fur Seal Commission."(Pages 2 to 4)

"Fur seal habits are such that a program of wise utilization is readily devised; however, the success of the program depends on international cooperation because the seals live much of the time outside territorial waters. In Alaska, with few exceptions, fur seals come ashore only on the Pribilof Islands, always about the same date each year. Because seals are highly polygamous and the sexes are born in

equal numbers, it is possible to take many males without adversely affecting the productivity of the herd. The young males, whose pelts are most valuable, habitually haul out on the islands apart from the breeding animals in the harems, so they are easily obtained.

"Seal measurements guide biologists in selecting seals to harvest. Harvesting of the seals is limited for the most part to the 3-and 4-year-old males. In 1918, the U.S. Government determined age-length relation from measurements of seals of known age, branded as pups in 1912. Until recently this age-length relation has served as the basis for selecting animals that are now classified into age categories by counting the annular ridges on canine teeth from a 20- to 30-percent sample. Also the overlap of lengths between ages is better understood through extensive recent measurements of tagged seals.

"The number of seals killed each year has varied for a number of reasons. From 1911 to 1917, seals were killed only by the residents of the Pribilof Islands to use as food. Commercial killing for skins was resumed in 1918 after the 1-year cessation. From 1918 to 1922, harvests of seals were high in relation to population size because of the accumulation of males. The kill declined after the excess males were removed, but thereafter steadily increased until 1940. From 1940 to 1955 it averaged about 66,000 males annually. Since then, the kill of males has varied from a high of 96,000 in 1956 to a low of 30,000 in 1959. Part of the difference between these extremes resulted from an extended season in 1956 which made available a larger proportion of the 3-year-old group, but recent fluctuations are caused primarily by variations in year class survival.

"In managing the fur seal herd, the Federal Government has adhered to a policy of taking pelts from seals considered surplus to breeding requirements. From 1923 to 1932, a minimum yearly breeding reserve of several thousand bachelors was provided by marking them with a brand or by shearing a patch of fur, then permitting them to return to the sea. This precaution may not have been necessary but it ensured that the number of males escaping the kill would be adequate.

"From 1932 to 1955, a sufficient breeding stock was assured by limiting the killing season each year to a period from about the middle of June to the end of July. Only the male seals 41 to 45 inches (104-114 cm) long were taken as they appeared in the daily drives on the islands during the sealing season. From one-half to two-thirds of the animals in this group are 3 years old, and most of the remainder are 4 years old; a small number of 2- and 5-year-old males are included. The proportion of 3- and 4-year-old animals taken depends on the relative survival of year classes.

"In recent years Bureau of Commercial Fisheries managers have adjusted the sealing season to the number of young males that are available and to some extent to the age and size of seals that they wish to harvest. Early seasons produce a larger proportion of 4-year-old seals and later seasons a larger proportion of 3-year-old seals, because the older ones arrive earlier. The season for male seals now begins in late June and ends on 31 July. Close cropping of 3-year-old seals during a late season leaves relatively few 4-year-old males

to be taken early in the following year. Forecasts of year class strength made before the 3-year-old seals appear in the kill are still in the process of development. The forecasts are based largely on averages. They give usefully accurate information in an average year but have not been satisfactory on a very strong or weak year class.

"Biologists consider the number of males that have been escaping the kill more than adequate, and, as a result, the upper size limit of harvestable male seals has been increased recently. This change permits closer cropping by taking animals that would have been rejected solely because of size under the former limit even though they had skins of good quality." (pages 14 to 16)

"On their respective islands the United States and the U.S.S.R. carry on research programs that emphasize population dynamics. Tagging, tag recovery, kill records by age and sex, and studies of mortality and reproduction are all essential for understanding fur seal populations. In addition, research on growth, pelage and other anatomical features, behavior, and parasitism and other infections are underway or completed. As knowledge of population dynamics accumulates, the probability increases that we can successfully forecast year class survival and the resulting harvest.

"Canada, Japan, the U.S.S.R., and the United States cooperate in a widespread investigation of the ocean life of fur seals. The distribution, ocean abundance, food habits, and intermingling of seals of different origins are studied. Most of the investigations aid management; in addition, certain broad principles of animal populations are being tested and zoological knowledge of marine mammals is being increased.

"Many seals are now held and studied in captivity. Studies are expanding on specialized aspects of seal biology. Scientists not employed by the Federal Government are expanding their specialized studies on seals." (pages 16 to 17)

MANAGEMENT OF THE THREE IMPORTANT FISHERIES

Most of the history associated with the development of fishery management and research along the Pacific coast has been confined to salmon, halibut, and herring. In the very early years of the Pacific coast fisheries, Pacific cod was probably the target species that soon evolved into the halibut fishery. In more recent years, we have seen the development of very important shrimp, king crab, and snow (Tanner) crab fisheries in Alaska. There are numerous local, coastal fisheries which are important to certain communities or to a State but lack either the history or the volume and value of salmon, halibut, and herring.

Furthermore, the general pattern of development of the salmon, halibut, and herring fisheries is similar and can be divided into the four characteristic periods described below:

Pre-1850

Subsistence fisheries, using primitive methods of fishing and preservation were limited to certain rivers and streams and to the immediate coastal waters. During this period, we see the

first probes into the commercialization of the fisheries: There was barter for salmon between the Indian nations and tribes and between the early trading posts and settlers along the Fraser, Columbia, and other rivers in the Pacific Northwest. Near the end of this period, we also find the beginning of the export trade in salt salmon from Sitka to Moscow and western Russia and from Fort Langley (Fraser River) and the San Juan Islands (Puget Sound) to the Hawaiian Islands and the growing imports of salt needed to process the fish. The Russian-American Company at Sitka also depended upon fresh/salt herring and on halibut as part of their subsistence diet.

Although fishing rights at certain favorite places were recognized and the source of frequent intertribal conflict during periods of scarcity (and there were periods of scarcity of fish as well as famine), management per se was not practiced during this early period.

1850-1880

Exploration of our fisheries associated with the discovery of gold in California, the rapid growth of the population in California, Oregon, and Washington and the purchase of Alaska from Russia. To satisfy the demand for food, numerous salteries for salmon and other fish were established along the Pacific coast. The first salmon canneries were started on the Sacramento River in 1858, on the Columbia River in 1866, and in southeastern Alaska in 1877 or 1878. The first U.S. deep-sea fishery in the North Pacific for cod and halibut began operating out of San Francisco in 1857 and, at about the same time, the United States negotiated with Russia on its first international fishery treaty in the Pacific area which provided for landing rights in the Aleutian Islands for its cod vessels and whalers operating in the area. Attempts were also made during this period to ship fresh halibut from Victoria, British Columbia, to San Francisco (but this was not too successful).

California was granted statehood in 1850 and Oregon in 1859. Soon thereafter, the first legislation was passed by these states to manage their fisheries, generally aimed at protecting the runs of salmon during their migration up the rivers and on the spawning grounds.

It was during this period that the United States established the Commission of Fish and Fisheries (1871) and, in 1875, established the first Pacific salmon hatchery on the McCloud River in California. The laws also encouraged the establishment of private hatcheries on the Clackamas River (1877) and the Rogue River (1878)--both were operated originally by the Oregon-Washington Propagation Company under contract to the Oregon Fish Commission. Some of the first information on the salmon and other fisheries along the Pacific coast was found in the reports of the early investigators searching for suitable hatchery sites in the various areas.

1880-1919

Exploitation of the salmon, halibut, and herring fisheries along the Pacific coast states and Alaska and the growth of these fisheries is illustrated in Figure 1.

The beginning of this period is marked by the first comprehensive survey of the fisheries of the United States as part of the 1880 census. The number of salmon canneries grew from

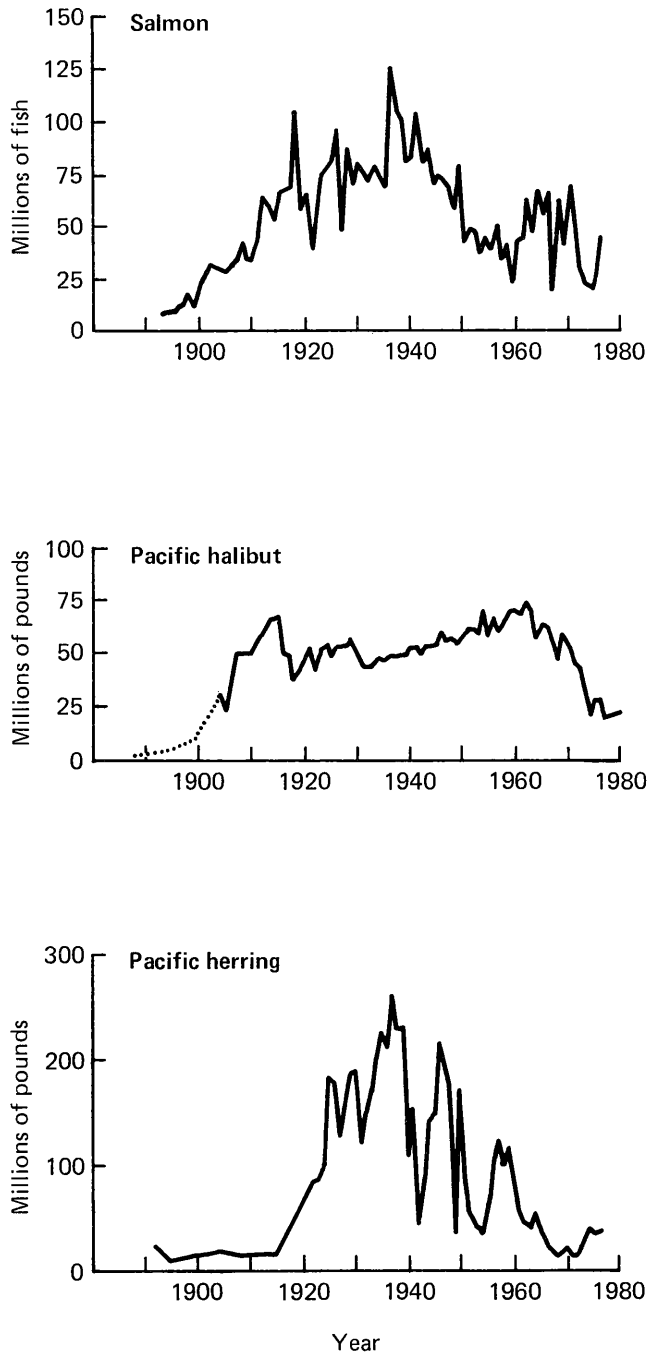


Figure 1
Annual catch of salmon (Alaska only), Pacific halibut (United States and Canada), and Pacific herring.

approximately 40 canneries in 1880 to a near maximum number of 189 in 1919, and a maximum pack of canned salmon of 8.5 million cases were filled in 1917. The commercial halibut fishery began about 1888 with three boats and increased to a maximum number of 18 "steamers" by 1913, then declined to 9 in 1919; the catch reached a peak of 68.8 million pounds in 1915 (United States and Canadian vessels) and fell to 38.0 and 40.5 million pounds in 1918 and 1919, respectively. The first information on the extent of the commercial herring fisheries along the Pacific coast appeared in 1882, amounting to a little more than 3 million pounds for that year, increasing to and fluctuating between about 6 and 32 million pounds, until the development of the popular "scotch cure" method of preservation in 1917. There was an increase in landings to 48 and 38 million pounds in 1918 and 1919, respectively, and a rapid rise in catches in the years thereafter.

The rapid development of the fisheries during this period is related to: 1) the growth in population along the Pacific coast and 2) the introduction of a number of technological improvements into the fishing industry. For example, in the State of Washington the population in this period grew from about 75,000 in 1880 to about 1,400,000 in 1920--a 20-fold increase in the 40 year period. Much of the growth in population and the resulting commerce was associated with the completion of the transcontinental railroads: the Canadian Pacific in 1885, the Northern Pacific in 1887/1888, the Great Northern in 1893, and other railroads that followed. Gold was discovered in Alaska in 1889, firmly establishing Seattle as the "Gateway to Alaska," and many businesses operating in Alaska worked out of Seattle.

With the growth in population came the effects of industrialization, especially upon the salmon streams of California, Oregon, and Washington. Many of the runs were destroyed by destructive logging and mining practices, frequently blocking the migration of salmon by dams along with the scouring or silting of the spawning areas. Similarly, the first hydroelectric and irrigation projects were completed during this period and many streams were further blocked by the dumping of rocks from road and railroad construction into their channels. Salmon were rarely considered in the development of the various water-use projects--after all, what's one stream among the hundreds that were available to salmon at that time--yet now, when you add them all up, the cumulative losses must have caused a very serious reduction in the salmon fisheries in these states.

There was considerable destruction of the herring runs in California, Oregon, and Washington due to the loss of spawning beaches but fortunately in Alaska, both the salmon and herring fisheries generally escaped the effects of industry and population growth during this period. Halibut, of course, live in the ocean far from shore and would not be affected by these kinds of land-based activities.

There was little change during this period in the methods used to fish for salmon. The fishery in the Sacramento River used gill nets fishing from sail or row boats: It is interesting to note that the salmon fishery of Bristol Bay, Alaska, depended for many years upon fishermen from the San Francisco area and the same type of fishery was used up until the mid- or late 1950s. Pile-driven traps were introduced into the Columbia River and Puget Sound salmon fisheries in 1879-80; soon afterwards, in 1885, pile-driven traps were introduced into Cook Inlet, Alaska--followed in 1907 by the development of a floating trap. Both the pile-driven and floating traps were found to be efficient types of gear and remained the dominant fishery throughout this period.

Halibut were taken by baited long-line, setting the gear from dories--a method introduced from the east coast. However, in 1889 the first halibut was shipped to the east coast by rail and as the market developed and the demand grew, the fishery, which was originally confined to the coastal and inside waters of British Columbia and southeastern Alaska, began to gradually expand farther offshore. The extension of the fishery was closely associated with: 1) a shift from the sailing schooners to "steamers," 2) the availabilty of ice and cold storage plants (1892 to about 1905), especially in Alaska, and 3) the depletion of the halibut stocks in the coastal waters. The year 1910 is generally recognized as the birth date of the deep-sea halibut fishery (Thompson and Freeman 1930).

The early herring fishery employed a Norwegian method of seining from oar-propelled seine boats, but in the early 1900s, the western-style purse seine was first used in the herring fishery and gradually replaced the Norwegian-style gear, totaling 6 or 8 vessels in southeastern Alaska by 1919 and about 10 vessels in Prince William Sound. The growth of the herring fishery in Alaska is due to the European demand for edible herring during World War I and the introduction of the "salt cure" method of processing to meet that demand (note that in 1917, the U.S. Bureau of Fisheries sent Aug. H. D. Klie and several assistants (including Clarence Anderson) to Alaska

to introduce the Scottish method of curing herring) (Rounsefell 1931; Rounsefell and Dahlgren 1932).

The first efforts at the management of the fisheries occurred during this period. First, of course, Oregon and California were already states and, in 1889, statehood was granted to Washington; appropriate agencies were later established in the state governments to manage their fisheries.

In 1888, U.S. legislation was enacted providing for the U.S. Commissioner of Fish and Fisheries to be a salaried officer (instead of on-loan from the Smithsonian Institution) and restating the duties of the commission, namely: survey the aquatic resources of the United States; describe and develop methods of fishing; collect statistics of the fisheries; and engage in artificial propagation of fish to maintain the fishery resources. In the next year (1889), the Alaska Salmon Fisheries Act was passed to protect the salmon fisheries of Alaska. At that time, a favorite method of taking salmon in Alaska was to place a weir or other barricade in the stream (a method commonly used by Indians) which prevented the salmon from reaching their spawning grounds. The Act specifically prohibited the erection of dams or other obstructions on salmon streams and directed the Commissioner to further investigate the salmon fisheries of Alaska. As a result of the investigations, the Act was amended in 1896 and again in 1900, prohibiting fishing in streams above tidewater and providing for closed areas, fishing seasons, and gear restrictions (but only after public hearings) and provided for fines or other penalties for violations.

In 1900, the Act of 1896 was further amended to require that each sockeye salmon cannery in Alaska establish and operate a salmon hatchery, releasing each year, four times the number of young as were taken as adults from the stream the previous year, i.e., brood year. The law was a disaster in many ways: There was no effective way to enforce the law nor to verify the accuracy of the "plants" made by most of the canneries, but perhaps most tragic was that most of the young sockeye salmon were generally released directly into the saltwater bays or lagoons when the life history of the species (but unknown at the time) requires that all juveniles spend at least 1 year in a freshwater lake before migrating to sea. Thus even for those canneries that were trying to satisfy the law (such as the one at Karluk) the returns were nil.

In 1903, the Department of Commerce was established and the functions of the U.S. Commission of Fish and Fisheries were transferred from the Treasury Department to the Bureau of Fisheries. Shortly before this reorganization, however, a Special Commission was appointed by the President to investigate the condition of the Alaskan salmon fisheries and to make appropriate recommendations for management of the fisheries. Dr. David Starr Jordan was appointed to head this study.

The recommendations from the Special Commission only reiterated the position of the Commission of Fish and Fisheries adopted almost at the time of its inception in 1871: namely, the need for artificial propagation as the primary means of maintaining the various fisheries of the United States. Thus, an Act was approved in March 1905 establishing one or more federal salmon hatcheries in Alaska: A hatchery was established that same year at Yes Bay (McDonald Lake) in southeastern Alaska

and in 1907, a second hatchery began operating near Litnik Bay on Afognak Island. In addition to these two federal hatcheries, 6 private hatcheries operated in Alaska, and 44 operated in California, Oregon, Washington, and Alaska. By 1915, the total number of salmon hatcheries along the Pacific coast (including Alaska) was 62.

The report sparked several other actions by Congress. The Alaska Salmon Fisheries Act of 1906 established the first license tax on salmon landings but, perhaps more important, the Act also provided for a tax rebate to those companies operating salmon hatcheries and if anything, only aggravated that damage that was already being inflicted upon the salmon runs where hatcheries had been established by the local canneries. Other legislation was enacted to prohibit aliens from fishing in Alaska; this was the aftermath of an attempt by a Japanese company to establish salmon salteries on Attu or Agattu Islands in the early 1900s.

As we review the history of fishery management during this period, we are impressed by the direction of the work by some of the most qualified people of that time--scientists like Drs. Baird, Goode, and Bean from the Smithsonian or the National Museum; Drs. Jordan, Gilbert, Evermann, and Snyder from Stanford University; and Cobb (who later established the College of Fisheries at the University of Washington)--but their recommendations and decisions were generally based upon "common sense" theory and not fact and were frequently marked by disaster because of the lack of knowledge. The scientists knew this and thus, in the early 1900s, we find the beginning of biological studies directly related to problems of management.

Fred Chamberlain of the Bureau of Fisheries undertook the first marking experiments on salmon in 1903 in southeastern Alaska. Here, both ventral fins were removed in order to determine the age and place of return of the marked fish. Most of the fish came back at ages 4, 5, and 6, but some returns were reported from Karluk and other distant areas, apparently from fish with "naturally" missing fins. In addition to the initial studies by Chamberlain, a similar marking study was made at Klawak cannery/hatchery in 1907, at Quadra Hatchery in 1911, and no doubt there were others. A notice was issued in 1908 requiring written permission of the U.S. Commissioner of Fish and Fisheries or his agent in Alaska before a company released marked salmon from their hatcheries.

The scientists who were engaged in the studies and management of the Alaskan salmon fisheries were soon to recognize the need to know the desired ratio between catch and escapement, i.e., how many salmon should be reserved from the run to assure that the future runs of salmon might be maintained and expanded. In 1908, the Wood and Nushagak Rivers were closed to commercial fisheries and a joint investigation was begun by the U.S. Bureau of Fisheries, the Alaska Packers Association, and the Alaska-Portland Packers Association with a controlled catch and a weir to count the number of sockeye salmon escaping into the Wood River system and to get estimates of the numbers of salmon that entered the Snake and Igushik Rivers. The results of these studies indicated that in the Nushagak, at least, the fishery normally took an average of 69% of the total run (a range of 64 to 75%). Thus, an escapement of 50% of the run to the spawning areas should be reasonably sufficient to rebuild the depleted salmon runs and to maintain

them. This was the concept later adopted in the White Act (1924).

These studies were continued until 1919 when Dr. Charles H. Gilbert, who had been in charge of the Alaskan studies since about 1909, decided that additional information would be desirable from other areas, and the work was transferred to Chignik and Karluk.

The other important series of studies begun during this period were the determination of the age of salmon by Gilbert (Gilbert 1913); he first used the scales of fish collected from the Columbia and Fraser Rivers. Within the next few years he and his assistants expanded the collections to included the various runs of sockeye salmon in Alaska as well. The age determination techniques developed by Gilbert were soon adopted by other scientists working on Pacific salmon and provided an understanding of the cyclic patterns of the returns of salmon and a major advance in the management of the fisheries.

There was little interest by the government agencies either in the management or research on the herring fisheries of Alaska and probably elsewhere along the Pacific coast as well.

The story was different, however, for the halibut fisheries. In 1915, W. F. Thompson, one of Jordan's students from Stanford University, began his investigations of the halibut fisheries of the North Pacific (Thompson 1916a, 1916b, and 1917); one of his reports dealt with the life history of the halibut, one with the statistics of the fishery, and the third with protective measures needed to maintain the fisheries. Although there had been previous investigations of the salmon fisheries of Alaska and the Pacific coast, these studies on the halibut were, in many ways, the first scientific studies made on a Pacific coast fisheries aimed at management of the fisheries. They showed quite conclusively that there was a serious decline in the abundance of halibut with a shift in the fisheries away from the coastal areas to maintain their catches. The studies supported the efforts by the industry for a 3-month closure of the fishery in winter during the spawning period and pointed out that such a closure was not really sufficient to stop the decline and other conservation measures were necessary (Thompson and Freeman 1930).

There followed the introduction of U.S. legislation providing for both the closed season and for a nursery area, to become effective upon similar action by the Canadian Government. It failed to pass the House.

Shortly thereafter (in 1918), the problems of international management of the halibut fisheries (along with similar problems of management of the Fraser River sockeye salmon fisheries in Puget Sound/Gulf of Georgia) were submitted to a joint commission. The action, taken as a wartime agreement, facilitated the entry of United States and Canadian vessels into the ports of both countries, but offered no provisions for conservation of the halibut fisheries. The agreement was terminated in 1921.

1920-1945

In this period, the following events took place: expansion of the salmon and herring fisheries and all-time record catches of 1936 and subsequent declines; recovery of the halibut fisheries under international

management; elimination of salmon traps on the Columbia River and in Puget Sound; inititation of the comprehensive water development projects on the Columbia and Sacramento Rivers; establishment of fishery research programs and initiation of fishery management programs based on the results of research; boom years of the 1920s; Big Depression of the 1930s; and World War II.

During this period, the catch of salmon in the Pacific coast states and Alaska increased from about 50 million fish in 1921, to a peak of 139 million in 1936, and a subsequent decline to a level of 75 to 90 million fish during the war years of 1942-45. Over 90% of the catch was made in Alaska: during the same period, the number of canneries increased from about 127 in 1921 to a peak of 202 in Alaska, Puget Sound, and the Columbia River in 1929, and then declined to an average of 109 during the war years of 1942-45.

The halibut landings increased from 46.9 million pounds in 1920 to a peak of 56.9 million pounds in the "crash" year of 1929 followed by a sharp decline to 44.2 million pounds as the fishery came under international regulation and a gradual recovery to some 53.9 million pounds in 1945; the first accurate information on the number of regular halibut vessels fishing appeared in 1930 with a total of 378 vessels plus 100 to 125 "small" boats. By 1945, the number had increased to 591 regular vessels and about 400 to 500 "small" boats.

The catch from the herring fishery increased from a low of 37.7 million pounds in 1921 to 263.2 million pounds in 1937 and then declined to only 46.3 million pounds in 1942 and a recovery to 153.7 million pounds in 1945--again, similar to the salmon fisheries; almost all of the herring was taken in Alaska, mainly southeastern and central. The number of vessels operating in the fishery increased during this period from about 16 in 1921-22 to 80 in 1927 and then declined to only 15 in 1942 (the early years of World War II) and a subsequent recovery to 38 in 1945. Much of the fluctuation in catch is believed to be due to the wide variation in survival of herring, especially in the earlier stages of life, and not closely related to fishing effort.

The most significant change in the method of fishing for salmon occurred in 1935 with the passage of Initiative 77 by the Washington State Legislature which eliminated all fixed gear, i.e., traps and set nets, from State waters and divided the Puget Sound fishing area into two areas--an inner area mainly reserved for gill nets and the outer area for all remaing legal gear, i.e., purse seines, etc. Shortly thereafter, the expected happened: the numbers of both gill nets and purse seines immediately increased as a replacement for the traps.

The herring fishery remained predominantly purse seine and the halibut fishery, set line. This period is also marked by a rapid expansion of the motorization of the fleets. For example, diesel power which was introduced into the fishing fleet near the end of the previous period had not been very successful, and it was not until after World War II that diesel engines became common in the various fishing fleets, providing the necessary power for the large herring purse seiners and the range and efficiency necessary for the distant-water halibut fishery.

Although there had been a number of attempts towards management of the

fisheries along the Pacific coast, these efforts were generally not as successful; this was attributed to the lack of knowledge about the life histories of the fish and the relative abundance of the various stocks of those fish. However, at the beginning of this period, the research that had been started some 10 or 15 years earlier began to mature and provide a basis for what we might now call "scientific fishery management."

In 1922, action was taken by Presidential Executive Order to create fishery reservations on the Alaska Peninsula and in southwestern Alaska, to: define districts and zones within these reservations and to issue permits to operate with limitations on the size and mesh of the gear operated, the number of operations, and the size of the pack. Steven Pennoyer points out that this action was strongly opposed by the Alaskan residents as the salmon fisheries at that time were basically controlled by the canneries (with their own boats and permits) and the only way in which an "outsider" could enter the fishery was to become a tenant of the cannery (Pennoyer 1979).

The White Act of 1924 (an Act for the Protection of the Fisheries of Alaska, and for Other Purposes [6 June 1924]) was perhaps the most significant development in the management of the salmon fisheries of Alaska during this period. This Act provided, in part that: 1) all salmon streams in Alaska would be weired, or adapted by some other means, in such a manner that the number of salmon migrating upstream could be counted with accuracy and that an escapement of at least 50% of the total run must be attained, 2) no salmon would be taken by the commercial fisheries during a 36 hour week-end closure (except for personal use), 3) violators of this Act or of the Act of 1906 would be punished by a fine not exceeding $5,000 or jailed for 90 days, or both, and 4) designated employees of the Bureau of Fisheries enforce the provisions of the Act, in addition to the U.S. Marshals. Although the prescribed escapements were based upon the recommendations of Gilbert's experiences at the Wood River weir site and the Act did provide for greater means of enforcement and heavier penalties, it was soon found that the Act was impossible to enforce, especially the necessary escapement counts to define the 50% level. Nevertheless, this policy remained basically in effect until statehood in 1959.

Even though the total catch of salmon continued to increase until after the peak of 1936, it became increasingly apparent that many of the individual stocks were disappearing because of overfishing or other causes and there was increasing pressure from the industry for more effective management of the salmon fisheries in Alaska. In 1939, the Commissioner of Fisheries resigned. The Bureau of Fisheries was transferred to the Department of the Interior and merged with the Biological Survey to form the Fish and Wildlife Service.

All of the salmon management problems, however, were not confined to Alaska. Since the late 1800s, there had been a series of disputes between U.S. and Canadian fishermen over the regulation of the catch of sockeye salmon returning to the Fraser River of British Columbia by the fisheries in Puget Sound and the Gulf of Georgia. This was an international problem which involved a decrease in the production from this run of some 2.4 million sockeye salmon in 1913 to only 0.2 million salmon in the cycle year of 1933. The Treaty was negotiated

between Canada and the United States in 1930 but was not ratified by the two countries until 1937. The Treaty provided for an international scientific staff to make the necessary studies and 8 years of investigation before the Commission could begin regulation of the fishery. It is of interest to note that the Commission soon found that the cause of decline was not overfishing but an obstruction caused by the residue from a massive rock slide at Hell's Gate in the Fraser River canyon during construction of the Canadian National Railroad in 1911.

A similar crisis arose in the salmon fisheries of the Columbia River from the construction of the Rock Island Dam near Wenatchee by a private utility company (fishways completed in 1932) and from the development of plans by the U.S. Army Corps of Engineers for the construction of 10 multipurpose dams on the river that were presented in their "308 Report" (1932). These were the depression years and the first two dams, at Bonneville and Grand Coulee, were started late in 1933 as Public Works Administration projects and completed in about 1938. In one sense, Bonneville Dam was most critical since it was the first major obstruction to the passage of salmon on the Columbia River, and ways had to be found to successfully pass salmon over the dam, or the very valuable salmon fisheries of the Columbia would be virtually lost. In other ways, the problems at Grand Coulee Dam were equally difficult: the dam would be about 350 feet in height and believed to be too high to even consider ways to pass salmon over the dam, and thus the very extensive "up-river runs" that were blocked by the dam had to be collected and transplanted to new "home streams" below the dam. Both of these projects were firsts in the management of the salmon fisheries and placed new and important responsibilities on the State and Government management agencies.

If we examine the management of fisheries (excluding fur seals as a different type of management problem), the first and probably the best example of marine fishery management by any agency is found in the work of the International Fisheries Commission (later, the International Pacific Halibut Commission). There was, of course, a decline in the fishery throughout the early 1900s and a growing concern for the fishery by U.S. and Canadian fishermen who shared the remaining profitable fishing grounds in the more and more distant waters from port. Key elements, however, in the eventual management of the fishery, as pointed out in the previous section, were the results of the early studies by W. F. Thompson--one of Jordan's students from Stanford University.

The first efforts at international control in 1919 failed to be approved by the two countries but in 1922, a second draft which confined the work of the Commission to investigations and limited regulation of the halibut fisheries was finally ratified in October 1923. It provided for the formation of a Commission with a Director of Investigations and an international scientific staff as well as regulation of a 3-month winter closure and incidental catch taken by other fisheries during this closed season.

The permanent and continuing programs of research and biolgical studies that related to management of the salmon fisheries began in about 1908-09 at Stanford University and started to mature soon after the end of World War I (beginning of this period). Because of the previous studies by Gilbert on

Bristol Bay's Wood River and the subsequent provisions of the White Act, one weir was established and operated at Karluk in 1921, and other weirs were operated at Karluk and Chignik in 1922. Four weirs were used in Alaska in 1923 and the numbers increased until they reached a peak of 28 in 1931; they then declined to seven in 1945. These weirs provided a series of sites for extensive research into the life histories and survival of the various species of salmon, although they were never quite adequate enough to fulfill the intent of the White Act.

Other studies were made on the Copper River, in southeastern Alaska, and elsewhere; beginning in 1922, there was a series of tagging experiments which continued through 1930 and after in Bristol Bay, along the Alaska Peninsula, around Kodiak Island, in Cook Inlet, in Prince William Sound, and in southeastern Alaska. The description of the life history of the sockeye salmon at Karluk Lake was published by Gilbert and Rich in 1927, and a limnological study was conducted as part of the Karluk studies, by Juday, Rich, Kemmerer, and Mann between 1926 and 1930.

It was also during the mid-1920s that studies of the herring fisheries of Alaska were begun with considerable attention given to the identification and interrelation of the various stocks of herring in southeastern Alaska and Prince William Sound.

All of the above research was initated by the U.S. Bureau of Fisheries research unit stationed at Stanford University and reflected the role of that University in the development of fishery management in the Pacific Northwest and Alaska in those early years.

In 1931, the Bureau's research was transferred to the newly completed fishery laboratory on Montlake Boulevard in Seattle where the work in southeastern Alaska and in Bristol Bay was expanded considerably to obtain a better understanding of the life histories and survivals of salmon and herring in Alaska and contributed much to the management of fisheries during this period (Detail of this work is given in the first section of these Proceedings and is not reviewed further in this paper.)

Of even greater significance at the time were the studies on the life history, movements, and abundance of halibut conducted by the staff of the International Fisheries Commission beginning about 1923. It was here that the concept of the theory of fishing was refined and developed, based on theory advanced by the Russian scientist Fedor I. Baranov in 1918, and applied to the successful management of the halibut fisheries. The International Fisheries Commission was also a part of the Montlake Laboratory from 1931 to 1936 and an integral part of its heritage.

1946-1976

Notable during this period were: Post-World War II adjustment in the fisheries with declines in the yield; effect of foreign fisheries and some recovery; statehood for Alaska and transfer of management authority from the federal government; elimination of traps in Alaska and shift from sailing gill-net boats to power in Bristol Bay; development of the quantitative sciences and their application to fishery management; and studies on the effect of the ocean environment regarding the distribution and survival of salmon and other fish.

During this period the catch of salmon decreased from about 17.8 and 26.4 million fish in 1946 and 1947, respectively, to 10.8 and 18.2 million fish in 1951 and 1952, respectively, followed by a further decline to an all-time low of 7.1 million fish in 1973. The Japanese high-seas salmon fishery, operating west of 155°W and which during some years took as many as one-third of the total run of Bristol Bay sockeye salmon, was a major factor contributing to the lower catches between 1952 and the early 1970s. The catch by the sports fisheries (especially in Washington, Oregon, and California) increased markedly during this same period--from about 300,000 salmon in 1946 to 1.6 million in 1976.

The halibut catch averaged about 56 million pounds in 1945-49, increased to more than 70 million pounds in 1962, and then fell to less than 25 million pounds by 1974. The decline has been attributed to the following three factors: 1) an increase in the effectiveness of the set-line gear, 2) an increase in the incidental catches of halibut by the trawl fisheries--both domestic and foreign, and 3) unfavorable environmental conditions in the nursery areas of the young halibut.

The catch of herring also suffered a severe decline during this period, decreasing from about 218.2 million pounds in 1946 to about 12.8 million pounds in 1968 with a recovery to about 36 million pounds in 1976. The increased catches in 1974, 1975, and 1976 were due to a growing demand for herring and herring roe in Japan and the curtailment of the foreign fisheries for herring in the eastern Bering Sea.

The salmon fishery in Bristol Bay has an interesting history. The fishery has traditionally been by gill nets operated from a sailboat--a type of fishery that was common in the San Francisco Bay area, and many of the fishermen still come from that area. For many years, this was the only type of gear allowed to fish in the Bay. The boats were difficult to operate and the cause of many deaths due to sudden storms, and were about as inefficient as any gear used in the salmon fisheries. In 1952, in response to growing pressure from the fishermen and the industry, the regulations were modified to allow motor boats to replace sailboats.

In 1959, with the granting of statehood in Alaska, action was taken by the State to eliminate traps in the salmon fishery that had traditionally operated in southeastern Alaska, Prince William Sound, Cook Inlet, Kodiak Island, and along the Alaska Peninsula--a total of about 250 floating and pile driven traps. Only those on the Metlatakla Indian Reserve in southeastern Alaska were allowed to continue fishing. As would be expected, there was almost an immediate increase in both gill-net and purse-seine vessels in the fishery.

There were also a number of improvements in fishing gear and technology that appeared after World War II. Perhaps most revolutionary was the introduction of synthetic (nylon) netting, both lighter and stronger than the traditional natural fiber nets, and development at about the same time of the power block by Mario Puretic and the MARCO company, which completely changed the purse-seine fisheries. The seine and gill-net drum method of fishing also appeared during this period and there were a number of minor modifications in fishing, such as increasing the distance between hooks in the halibut set line. Also, there

was the gradual introduction of various new sonic and radar instruments--all of which made fishing safer and more profitable. All in all, the greatest changes in fishing and fishing technology in the Pacific coast fisheries occurred during this period.

On 30 June 1940, in accordance with the President's Reorganization Plan No. III, the Bureau of Fisheries and the Biological Survey were merged to form the Fish and Wildlife Service in the Department of the Interior; the reorganization also provided for the establishment of five Regional Offices in the various sections of the United States. It was not until 1950 that the sixth Regional Office was established in Alaska with a primary function of facilitating the administration of Alaska's fisheries. At this time, the installation and operation of weirs and other similar activities were made the responsibility of the Regional Office under "management biology," which separated them from the research programs originally developed at Stanford and later at the Montlake laboratory in Seattle. Although there was close cooperation between the two units, repetitive questions arose as to what is "fishery research" and "management biology" and there was some fragmentation of effort.

In the meantime, the salmon fisheries of Alaska continued to decline. Increasing pressure and criticism was leveled against the Fish and Wildlife Service by the fishing industry, and a virtual rebellion occurred among many of the fishermen making enforcement difficult. It was during this same period, with concern for the resource and a desire for local control of fisheries, that the Alaska Fisheries Board and the Department of Fisheries were formed in 1949 as well as the establishment earlier of the Institute of Fisheries Research at the University of Washington under contracts with the Alaska salmon industry.

Finally, in 1952, Alaskans voted in a referendum (20,500 to 5,500) to request Congress to give them control over their fisheries. This growing opposition was sparked by the desire of many Alaskans for future statehood; provisions were generated within the Fish and Wildlife Act of 1956 for reorganization of the administration of Alaska's fisheries. An Office of the Administrator of Fisheries was established in Juneau with increased authority over the management of the fisheries of Alaska, and all research relating to the Alaskan fisheries (except the research being conducted for the International North Pacific Commission) was transferred from the Montlake laboratory to Alaska. At that time or shortly thereafter, one of the primary functions of the Administrator of Fisheries was to prepare for the orderly transfer of management functions of the federal government to the State of Alaska.

Statehood was granted to Alaska in 1959; in 1960, management of Alaska's commercial fisheries was turned over to the Alaska Board of Fish and Game and to the Alaska Department of Fish and Game. Although there have been good years and bad, the State has been able to stabilize the catches of salmon during the following years, and now, after three-quarters of a century of effort to maintain and rebuild the salmon fisheries of Alaska, the State, with its flexibility of regulations based on an accumulation of scientific fact and experience, has been able to restore the yields from this very important resource.

The role of the International Pacific Salmon Fisheries Commission served as

an example of good salmon fishery management practice. The Commission, established by treaty between the United States and Canada in 1937 and after establishing and remedying the cause of decline in the salmon fisheries at Hell's Gate in the Fraser River Canyon, began to manage the sockeye salmon fisheries in 1946. Not only did their program include the voluminous collections of statistics on catch and escapement but the commission undertook studies of the movement of the sockeye salmon through the fisheries and on upstream to their spawning grounds. In addition, the hydrological conditions that affected the migration of the salmon were considered as well as the various environmental factors that affected their survival in fresh water, in estuaries, and at sea. Steps were intitated that would restore once productive but now barren salmon spawning and nursery areas. Management of the pink salmon fisheries of the Fraser River was added in a new Convention in 1957. The success of the Commission's program is found in the history of the sockeye catches: A low of 443 thousand in 1947 reached a peak of 10.5 million fish in 1958 and averaged about 2.0 million fish in the 4-year cycle of 1973-76. The Commission, however, would be the first to point out the need for additional biological studies and information. There is growing political pressure between U.S. and Canadian interests and between the Indian and the non-Indian fishermen--the job of the Commission has not been an easy one.

A valuable lesson was also learned from the experience of management of the halibut fisheries by the International Pacific Halibut Commission. From the time of the beginning of regulation in about 1932, the catch and catch per unit effort of the halibut fisheries had increased rather consistently from year to year, with over 90% of the catch being taken by the regular long-line fleet and with little change in the fishing methods or in the vessels. As noted by the International Pacific Halibut Commission (1978, page 41), "Since 1960, important changes have occurred including increases in: 1) the effectiveness of the set line gear; 2) the proportion of the catch taken by small, set line vessels and salmon trollers, particularly in British Columbia and southeastern Alaska; 3) the incidental catch in domestic (and Canada) trawl and pot fisheries; and 4) the incidental catch by foreign vessels (Japan, Korea, and USSR). Further, environmental factors apparently have contributed to the decline in abundance of young halibut." The precipitous decline appears to have been stopped in the early 1970s (see Figure 2) and now begins the task of once again rebuilding the stocks of halibut to the estimated level of maximum sustainable yield--a combined total of 70 million fish for Areas 2 and 3.

The herring fisheries posed quite a different management problem. Although there were brief peaks in the catches of herring after World War II (1946-50) and again in 1957-60, the general trend of the catches has been downward, reaching a low of about 5,800 metric tons (t) in 1968. From the evidence available, this decline was not due to overfishing but to: 1) the depressed market conditions for herring products, i.e., economic conditions and 2) strong political pressure to reserve the herring as a food organism for other fish, mainly salmon. The analysis required by the International North Pacific Fisheries Commission, for herring to qualify for abstention from the Japanese high-seas fisheries, failed to show that these stocks were

either being fully utilized or being managed to obtain the maximum sustainable yield. Thus, this species was removed from the list of abstention species. The conditions changed suddenly in 1974 with an increased demand for herring roe in Japan, and the U.S. catch jumped to about 17,000 t; this amount more than tripled in 1978 after the enactment of the Magnuson Fishery Management and Conservation Act of 1976 and the establishment of the 200-mile fishery conservation zone.

This period is also marked by the trend towards greater cooperation between the various fishery agencies of the States and between the States and the Federal Government. In 1947, an interstate compact was approved by the States and the Federal Government, creating the Pacific Marine Fisheries Commisssion for the purpose of: 1) conserving the coastal-offshore fisheries of interest to the citizens of the Pacific coast states, 2) agreeing upon uniform regulations for such conservation, 3) agreeing upon uniform legislation (if required) to be presented to each legislature for such regulation, 4) agreeing upon means of enforcing uniform regulations, and 5) developing a program on the various species of marine life and deciding how such a program should be carried out. The Commission has served as an invaluable medium for the discussion and evaluation of the current fishery developments along the Pacific coast and the planning and coordination of a number of research programs dealing with multistate fisheries. The Commission has not been particularly effective in the development of uniform regulations for management.

There were a number of other coordinating groups established during this period, mainly to determine the needs of the fishery management agencies and to plan and to review the results of research. Some examples are the Technical Committee of the U.S. Army Corps of Engineers, the Inter-Agency Fishery Research Coordinating Committee, the First and Second Governor's Conferences, and others.

Research and investigations in fishery management continued to expand during this period. The biological research programs conducted at the Montlake laboratory are described in some detail in the first section of these Proceedings. Most significant, however, were their accomplishments in the studies of freshwater survival of salmon in the Sacramento and Columbia Rivers and in Alaska; the outstanding work on passage and guidance of salmon at dams; on separation of the Asian and North American salmon in the high-seas catches of the Japanese; and on the life history and populations of king crab in the eastern Bering Sea.

Of direct application to management, however, were the studies undertaken at the Montlake laboratory for the International North Pacific Fisheries Commission applying to the criteria established by the treaty for Japanese (and in some cases, Canadian) abstention from fishing our stocks of salmon, halibut, and herring. The major requirement was proof that the stocks were being fully utilized by our fisheries and perhaps more difficult, that these stocks were being managed to provide the maximum sustainable yield from the resources. Although conceptually, the fishery management agencies were attempting to obtain the maximum sustainable yield from their fisheries--to prove that to the Commission was another story. The cases that were prepared by the scientists at the Montlake laboratory, the International Pacific Halibut

Commission, and in other agencies very pointedly demonstrated a general lack of adequate and sufficiently precise information for "scientific" fisheries management.

Also important to fishery management was the creation of the Fisheries Research Institute at the University of Washington, financed initially by contract with the Alaska salmon industry. Its work, beginning with a series of comprehensive studies on salmon in Alaska, has expanded into almost every area of fisheries science--most, if not all, have been directly applicable to management problems.

The contributions to fishery management made by the several universities along the Pacific coast should also be recognized. Soon after the end of World War II, perhaps in the early 1950s, the universities offering curricula in fisheries added courses in population dynamics of fishery stocks with direct application to management problems, and those courses were generally made a required part of a student's training program.

As we review the events in fishery management that have occurred since World War II, we cannot help but be impressed by the increasing dependence of fishery agencies on the results of research and scientific analysis as a basis for their regulations. There have been successes and failures as well as mistakes in judgment, the misapplication of theory, and the continuing need for new information and study; but the success--the results of work by the International Pacific Halibut Commission, the International Pacific Salmon Fisheries Commission, the Alaska salmon story, and other examples--well demonstrate that the modern principles of fishery management can work when based upon the collection of adequate observations and data and an understanding of the biology and environment of the particular species.

1977-present

Enactment of the Magnuson Fishery Conservation and Management Act of 1976 and jurisdiction over fisheries within the 200-mile fishery conservation zone; joint state-federal management of the fisheries within the 200-mile zone by regional management councils; development of coordinated management research programs; and regulation of domestic and foreign fisheries based on the determination of the maximum sustainable biological yield, the optimum yield, and similar population parameters.

The enactment of the Magnuson Fishery Conservation and Management Act of 1976 has established a completely new organizational structure for the management of the offshore marine and anadromous fisheries and has overcome the previous difficulties and political resistance in regulating both the "interstate" fisheries and the foreign fisheries off the coasts of the United States. The Act established six regions to be administered by regional councils composed of representatives of state and federal fishery agencies, the industry, and the public. The councils in turn, appoint various advisory and scientific committees to assist in developing the various management programs and in determining the conditions of the various stocks of fish and the appropriate levels of catch that should be allowed. The councils provide for extensive hearing schedules to allow for the expression of opinion from the industry, fishermen, and the public; they coordinate many of their regulations

with those of the state agencies responsible for the fisheries in the coastal areas. The councils take necessary action to protect the operation and development of the U.S. fisheries within the 200-mile zone and give particular attention to the effect of the foreign fisheries on the domestic catch.

The North Pacific Fishery Management Council, which controls the fisheries in the 200-mile zone off Alaska, has been greatly assisted by the experience gained by the programs of the International Pacific Salmon Fisheries Commission, the International Pacific Halibut Commisiion, and the International North Pacific Fisheries Commission--all of which are aimed at management of the several fisheries by determining the levels of maximum sustainable yield. Many of the fisheries, e.g., the groundfish fisheries, lacked this background of information and experience and have required much effort to be able to provide even approximate levels of catch and of population.

Although it is still too early to try to evaluate the success of management of the resources within the 200-mile fishery conservation zone, the administration to date by the North Pacific Fishery Management Council, although at times cumbersome, is working and there is every indication their efforts will be a success.

REFERENCES

BAKER, RALPH C., FORD WILKE, and C. HOWARD BALTZO.
1970. The northern fur seal. U.S. Fish Wildl. Serv., Circ. 336, 19 p.

BRICE, JOHN J.
1898. The work of the United States Fish Commission from December 1, 1896, to November 3, 1897. Bull. U.S. Fish. Comm., 1897, 17:135-139.

GILBERT, CHARLES H.
1913. The salmon of Swiftsure Bank and the Fraser River sockeye run of 1912. Prov. Br. Columb., Rep. Comm. Fish., 1912, p. 14-24.

INTERNATIONAL PACIFIC HALIBUT COMMISSION.
1978. The Pacific halibut: biology, fishery, and management. Int. Pac. Halibut Comm., Seattle, Wash., Tech. Rep. 16, 56 p.

JORDAN, DAVID STARR, and CHARLES H. GILBERT.
1887. The salmon fishing and canning interests of the Pacific coast. In George Brown Goode et al., The fisheries and fishery industries of the United States, Section 5, Volume 1, p. 729-753. U.S. Gov. Print. Off., Washington, D.C.

PENNOYER, STEVEN.
1979. Development of management of Alaska's fisheries. In Brenda R. Melteff (editor), Alaska fisheries: 200 years and 200 miles of change, Proceedings of the 29th Alaska Science Conference, p. 17-25. Univ. Alaska, Fairbanks, Alaska Sea Grant Program, Sea Grant Rep. 79-6.

ROUNSEFELL, GEORGE A.
1931. Fluctuations in the supply of herring (Clupea pallasii) in southeastern Alaska. Bull. [U.S.] Bur. Fish. 47:15-56.

ROUNSEFELL, GEORGE A., and EDWIN H. DAHLGREN.
1932. Fluctuations in the supply of herring, Clupea pallasii, in Prince William Sound, Alaska. Bull. [U.S.] Bur. Fish. 47:263-291.

THOMPSON, W. F.
1916a. The problem of the halibut. Prov. Br. Colomb., Rep. Comm. Fish., 1915, p. 130-140.

THOMPSON, W. F.
1916b. Statistics of the halibut fishery in the Pacific: their bearing on the biology of the species and the conditions of the banks. Prov. Br. Colomb., Rep. Comm. Fish., 1915, p. 16-126.

THOMPSON, W. F.
1917. The regulation of the halibut fishery of the Pacific. Prov. Br. Colomb., Rep. Comm. Fish., 1916, p. 28-34.

THOMPSON, WILLIAM F., and NORMAN L. FREEMAN.
1930. History of the Pacific halibut fishery. Rep. Int. Fish. Comm., No. 5, 61 p.

Future of Fisheries Management or the Diverging Paths of Theory and Practice

Peter A. Larkin [1]

INTRODUCTION

This paper is essentially a commentary on the future of fisheries management with particular reference to the Pacific Northwest. For my text I have chosen a few lines from Plutarch (Discourses: Chapter 26):

> In theory, there is nothing to hinder our following what we are taught; but in life there are many things to draw us aside.

For the purpose of developing my text, I have chosen three topics of contemporary fisheries management which I think will substantially shape the future of research. The three topics are

1. How to evaluate the effects of exploitation on the genetics of fish populations.

2. How to manage multispecies assemblages of fishes.

3. How to clarify the concept of optimum sustained yield.

As is usually the case with current concerns, these three topics are interrelated in that the answer to the first poses part of the problem of the second, which in turn poses part of the problem of the third.

THE EFFECTS OF EXPLOITATION ON THE GENETICS OF FISH POPULATIONS

It has long been suspected that the intense selection imposed by a fishery might have effects on the genetics of a population of fish. Arguing from first principles, it would certainly be expected that rates of exploitation that commonly exceed 80 or 90% would have selective effects even for populations that are spatially and temporally homogeneous. The idea of stocks is a very old one in fisheries biology, and there is abundant evidence to corroborate the thinking of populations as subdivided into groups that occupy spatial and temporal niches. It is also a modern-day commonplace that some stocks are subject to much higher rates of exploitation than others. In consequence, it is common to observe that particular stocks may be virtually decimated (while others persist): the genetic diversity of the species population ostensibly is also reduced. Papers in the recent publication of the Stock Concept International Symposium in the Canadian Journal of Fisheries

1/ Institute of Animal Resource Ecology, University of British Columbia, Vancouver, B.C. V6T 1W5.

and Aquatic Sciences provide ample evidence of the phenomenon in salmonid populations. There is a current flurry of controversy concerning the existence of tuna stocks and their relevance in management. The existence of stocks in herring populations is well known and has given rise to speculation about whether it is desirable that they be harvested on a highly local basis.

It is my guess that these examples will be multiplied many times over and that the next 20 years will give us a much better understanding of the genetics of fish populations. It is also my guess that it will become known that some species populations are more diversified than others and that most stocks of most species retain a large potential for diversification. We will come to appreciate, I believe, that a large proportion of the genetic diversity among stocks is nonadaptive (or neutral), and we will develop considerable talent at transplanting stocks where it is necessary to do so for the purposes of rehabilitation. Where the diversity of stocks is adaptive, we will also have a significant capacity for restoring them, even if they have become virtually nonexistent. It has already been demonstrated that fish can be cloned and, for some species, sex can be manipulated (Streisinger et al. 1981). With the development of more sophisticated rearing and holding techniques, it should be possible to increase the numbers of depleted stocks to a level sufficient to ensure their perpetuation.

It is my view, then, that as we gain more knowledge we will worry rather more efficiently than we do now about the effects of exploitation on fish population genetics, and we may even have the capacity to improve on natural populations for our own purposes. It is certainly a field of endeavor for which this Seattle Laboratory already has a notable record of achievement that deserves vigorous future support.

It also seems likely that within the next two decades there will be substantial development of theories about how best to manage populations of mixed genetic structure. The pros and cons of various kinds of tradeoffs, of the type suggested for Pacific salmon by the work of Ricker (1958) and Paulik et al. (1967), will be exhaustively discussed--to some extent in the context of r and K selection and in the context of the necessity for retaining genetic diversity as insurance against environmental change.

However, virtually none of this theory will be used as a basis for day-to-day regulation of fisheries, even that for Pacific salmon, for which it might be seen to be more applicable than for most other species of fish. What I think will happen is this: we will be aware that mixed stocks are harvested together and that this will probably lead to virtual decimation of some stocks; but rather than attempt to harvest so as to avoid the consequences, we will resort to our technical bag of genetic tricks to attempt to redress any harmful effects. Day-to-day regulation will continue to be as clumsy as it is at present.

There are some fairly basic reasons for making such an assessment. In a forthcoming edition of Rothschild's book on world fisheries policy (Rothschild 1971), I have asked the question: "How much research and management is enough?" The answer is essentially that anything that is too complicated will cost more than its worth and won't work anyway. As I see it, managing fish populations so as to preserve or manipulate their genetic

structure is not the sort of thing that can be done with cost effectiveness. Redressing obvious genetic wrongs probably would be justifiable economically, and that's what we will probably do. Imagine, for example, what is necessary to assess precisely just which fish of which races are being caught at what rates on a day-to-day or perhaps even an hour-to-hour basis. For a national fishery involving only one kind of gear and concentrated in only one area, it is just barely conceivable that a very well organized and efficient team might regulate a fishery so as to preserve or manipulate the natural genetic structure. For an international fishery that involves more than one kind of gear and that is spread over a large area, the mind boggles at the cost of what would perforce be an Olympic technological performance, even assuming a high measure of international collaboration. It seems to be far easier, cheaper, and more practical to observe what happens and then to patch it up.

A related topic of great theoretical interest will be the genetic structure of communities of fishes and even, perhaps, of all the organisms in natural ecosystems. Presumably, the genetic characteristics of various stocks of a species are shaped in part by environment and in part by interactions with other species. Exploitation will have effects not only on the genetic structure of the target species but on all of the species with which it interacts, which will in turn have ramifications on all of the species with which they interact. This line of reasoning is developed by Ryder et al. (1981) and raises a great many difficult questions. Again, the elaboration of this problem, except for expanding potential awareness, will not contribute to the practice of management for a long, long time, if ever. Can you imagine what research would be needed to assess the changes in the genetic structure that were induced in all of the organisms in the Bering Sea as a consequence of the simultaneous fisheries on walleye pollock and salmon? And can you imagine management on that basis? I can't. It would be tough enough to do it in an aquarium for guppies and Artemia.

To summarize the fascinating future of population genetics of fish, there is every prospect of some exciting research that will make management more knowledgeable and better able to cope with its mistakes, but it will be no less ham-handed. Theory and practice will diverge, theory advancing but practice being much as it is today.

MANAGEMENT OF MULTISPECIES ASSEMBLAGES

This discussion leads logically to the second challenge of contemporary management: how to manage multispecies assemblages of fishes. It is first necessary to suppose that as time goes by we will gain a better understanding of how species of fish interact and of how fishermen behave in deciding how to allocate their efforts. There are some consolations for temperate zone fisheries biologists in that there are fewer species of fish and fewer and better educated fishermen than in many tropical fisheries. Even for the polar fisheries, there are more than enough species and more than enough contrary fishermen to make the multispecies problem extremely difficult.

The first steps in the solution of the problem are the simultaneous developments of theoretical models and

greater understandings of the biology of the fish and the behavior of the fishermen. The modelling work at present is largely centered on conceptualizations that are either too simple or too complex.

The simple models in the Lotka-Volterra tradition were used by Marten (1979) for Lake Victoria and developed by Pope (1979) and subsequently tested by Larkin and Gazey (in press) for the assessment of the recent history of the trawl fisheries of the Gulf of Thailand. Though the results in both cases (Lake Victoria and Gulf of Thailand) would seem to have some potential where there is a long enough data series, the interpretation of the parameters is as mysterious as it always has been for these models. Moreover, their unrealistic assumption of fixed interaction coefficients that operate on the products of abundance (or biomass) is a major deviation from the way things happen naturally. For example, predators "switch" to more abundant prey rather than eat all that are available in proportion to their abundance (Murdoch 1969). In a similar vein, the assumption that predators have a fixed diet, regardless of the relative abundance of prey, is a major weakness of the simple model of Riffenburgh (1969).

At the other extreme, the complex models of Andersen and Ursin (1977) and of Laevastu and Favorite (1977) are so demanding of information, so involved in their construction, and so potentially flexible in their application, that though they are great for expanding awareness and have been important as pathfinders, they are virtually useless for management (for a detailed discussion, see Larkin and Gazey, in press). Give any good mathematician 25 variables and, albeit with some difficulty, he can mimic virtually anything--give him 400 variables and it only becomes a tedious chore to sort out the many thousands of combinations of parameter values that will all do the job of mimicking with equal utility (or futility!).

It seems likely, then, that future development of theoretical modelling for the multispecies problem will focus on the middle ground between these extremes. Among the potentially promising current developments are the extended cohort analysis of Pope and Knights (in press) which moves from the simple toward the complex and the grouped species approach, typified by the model of Larkin and Gazey, which moves from the complex toward the simple. Perhaps most appealing is the approach of Steele and Frost (1977) for models of zooplankton communities in which the trophic level of interest is depicted in greater detail than those above and below. Similarly for fish communities, models that provide a broad brush treatment of the setting and a substantial degree of detail and resolution for target species of interest may well be worth pursuing.

Leaving aside the technical details, it seems likely that there will be rapid development of many kinds of models for the biological side of the multispecies riddle. And again, the Center having been a leader in the past, should be a leader in the future. It might also be hoped that by reversing the trend of the past, the future will see much more attention devoted to models of the behavior of fishermen. There have been some useful contributions in this field. (For example, see Haley 1981, the report of the North Atlantic Treaty Organization's [NATO] symposium on applied Operations Research in Fishing). Mendelssohn (R. Mendelssohn, Pacific Environmental Group, National Marine Fisheries Service, NOAA, c/o.

Fleet Numerical Oceanography Center, Monterey, California. Pers. commun.) has recently demonstrated that fishermen who have access to several species perform so as to maximize their economic returns, which seems sensible, and which is reminiscent of the long-forgotten work of Taylor (1951) who had faith that economic factors were sufficient for regulation of the fisheries of Maryland. There have been other contributions as well, but in contrast to models of fish interactions, models of fishermen's behavior both on the micro- and macro-scales have been few and far between.

The eventual answer to the multispecies harvesting question lies in a marriage of models for the two interacting systems--that of the fishes and that of the fishery. This is the challenge for the future, which no doubt will be met head on by the younger generation who have been trained to much higher levels of mathematical literacy.

In these pursuits it will be important to remember that modelling should not be done in isolation from experience, observation, and experiment, for otherwise it can become an intellectual "glass bead game." For example, in the matter of experience, I recently had occasion to remind one of my younger colleagues that one of the cyclical lows that was central to his theme of species interaction was in fact a year in which the catch was low because the fishermen went on strike. It always pays to be familiar with the material you are modelling.

It also pays to have colleagues who are making the traditional types of observations that provide the grist for the modelling mill and the occasional bit of sand for its gears. Years ago, Dr. Dayton Alverson liked to tell the story about some of his colleagues here at the Seattle Laboratory who were discussing how to control dogfish. One said it was a lost cause because they laid thousands of eggs, to which the other replied that that was not so--they laid only a few eggs in capsules at the bottom of the sea. I wouldn't wish to be classed as being an ichthyologist, but as an amateur modeller I would underline that, to my mind, a modeller with limited biological knowledge is a more dangerous breed of cat than a biologist with a limited modelling knowledge. Better to be nailed to the ground than hanging from a cloud.

Finally, of course, it pays to put one's multispecies models to the test, to use them as a basis for prediction or for experimental management which is aimed at discrediting them. Inasmuch as our existing arsenal of models has not been notable for its successes in prediction and there is very little to show in the way of experimental management, it is hard to be optimistic about the future. As I said elsewhere, the fisheries part of fisheries science is not a hard science like physics or molecular biology. It is more akin to the softer sciences such as political science or what are generally called the social sciences, in which various firmly held views are essentially quasi-religious interpretations of what was and what could be, with little foundation in rigorous experiment. This is especially true of contemporary multispecies models. In brief, they are much like contemporary economic models, which Leontiff has complained of as being constructed on "unobservable facts."

To summarize, multispecies modelling will no doubt be a titillating subject for research for the next two decades. We will probably gain some important

new concepts of how the natural world is put together. The successful models will probably be of the kind that Steele and Frost have suggested, wherein the trophic levels of interest and certain target species within them are dealt with in detail and are embedded in a sandwich that deals quite grossly with the trophic levels below and the fishery above.

Regardless of the nature of the conceptualization or of the technique, it will be a far cry from practice. To manipulate where, when, and how which fishermen will harvest which species will be seen as a challenge beyond the capacities of managers. Instead, the fisheries will be observed, the statistics will be interpreted in quasi-religious ways, perhaps very convincingly, and after much discussion not too much will happen in the way of regulation except in the most drastic circumstances, and then it will be largely on the old fashioned single species basis. The reasons why nothing more complex will be done will stem not only from the difficulty of confidently predicting the ecological impact of regulation but also from the apprehension that there might be social and economic impacts on the fishermen and the fishing industry. This leads me, of course, directly to my third topic.

CLARIFYING THE CONCEPT OF OPTIMUM SUSTAINABLE YIELD

There are two ways in which scholars try to clarify fuzzy concepts. One way is to make simplified assumptions; the other is to consider wider contexts. I fully expect that the next two decades will produce several tons of literature that use these approaches to develop the present fuzzy concept of optimum sustained yield (OSY).

On the simplified side, there is already a considerable literature on what is optimum from a strictly biological point of view. For example, optimum may be seen as taking sufficiently less than maximum sustainable yield (MSY) so as to ensure sustained recruitment in times of environmental adversity. The question of what kind of genetic profile might be appropriate for harvested populations is also being explored (for example, Caswell 1980). These sorts of approaches will be progressively developed for single stocks, mixed stocks, and multispecies, and will no doubt provide the basis for a large number of PhD theses, all of which will be concerned with what one would do if populations were to be harvested with biological elegance.

Indeed, that is what we have been doing for several decades. At one time there was widespread enthusiasm for the idea that MSY was optimum, and several variations on the MSY theme are still the prevailing wisdom among fisheries biologists throughout the world. It might be expected that simple single species models will prevail in the fantasies of fisheries managers, at least until my generation is gone and probably much longer than that, wherever simple minds prevail. Where the more sophisticated reside, such as at the Center, the simple single species models have long since been abandoned, at least from a philosophical point of view. In future this trend will continue: profound thinkers and analysts will generate highly elegant single and multispecies models describing the population biology of fishes. But however simple or elegant, these kinds of models will not be descriptive of what actually

happens; they very rarely have been in the past, and they won't be in the future. They are, and will be, models of how biologists might suppose fish should be harvested.

Much the same can be said of the approaches that economists may take in clarifying the concept of OSY. The most simpleminded concepts identify optimum with maximum economic return. Even these creations can generate substantial complexities when they include such realities as capital investment and discount rates in the circumstances of fluctuating availability and abundance of fish. Unfortunately, even for single species, unforeseen variations in the costs of fishing and the prices for which fish can be sold render much of this analysis of more theoretical than practical interest. Nevertheless, it is only a matter of time before these analyses will be extended and developed for the much more complex multispecies situations. The elasticity of prices of fish, the varying strategems of fishermen and fishing companies, the economic interrelations among different fisheries, will all be considered in the pursuit of the optimum way to harvest fish stocks. The extensive work of Clark (1976) and the recent manuscript of Pearse (1980) are typical forays into the future of economic modelling of fisheries.

Meanwhile sociology, which is either a nondiscipline or a half a dozen emerging disciplines all grouped together under one flag, will be taking increasingly more searching looks at the social structures of fisheries. While it may be a bit much to expect sociology of this kind ever to develop mathematical models that are precise and tractable, it seems certain that it could lead to much more profound appreciation of why fisheries are prosecuted as they are, how they came to be that way and, most to the point, what are the realistic options for restructuring. But again, taken by itself, sociology isn't likely to produce a useful paradigm for fisheries management.

It is my contention that all of this discipline-oriented research is not going to have much bearing on how fisheries are regulated, nor what are the main thrusts of government economic and social policy. In the first place, it will all be seen as too one-sided and therefore out of context with reality; in the second place it will suggest solutions that are either too complicated or too politically hazardous to apply.

One of the morals that might be drawn is that there is need for "multidisciplinary research" on what should be meant by optimum sustained yield, but I would hasten to assure you that it isn't a moral I would draw. I see the phrase "multidisciplinary research" as a contradiction in terms. If it is research, then it is disciplinary: if it is multidisciplinary, it is either a project, an assessment, a synthesis, or a report. To be sure, there will be many projects, assessments, syntheses, and reports that will contain references to the views of several disciplines. To some extent these reports may help decision makers to appreciate the dimensions of their problems. But all this will happen without any need to encourage it and even if there are active attempts to discourage it.

Moreover, in the future, as I see it, the actual practices in fisheries management will stem much more from the day-to-day politics of the resource users than from the grandiose

conceptions of the academics or bureaucrats. There is an old saying to the effect that young radicals become old conservatives: you can only appreciate that saying as you get older. I grew up in the dustbowl during the Depression and certainly had many radical and idealistic views about how to organize the world so that it would run properly. As I grew a bit older, I became a bit more reasonable and shared the not uncommon view that though government shouldn't run everything, it should at least organize, coordinate, and regulate to ensure such things as best use of publicly-owned resources. The older I get, the less need I see for government to exercise these roles, doing so on their assumption that I am essentially irresponsible and doing so at my personal expense as a taxpayer. My confidence is steadily shifting from the ideals of paternalistic government to the processes of responsible participatory citizenship.

For this reason, I strongly endorse the development of regional fishery councils in the United States and strongly advocate similar bodies, on an even more local scale, for Canada. For all of their hilarious inconsistency and amateurism, they are a better bet in the long term for accomplishing optimum sustained yield than any amount of government intervention. In brief, it is the process that is important, not any monolithic vision of what is optimum and where the compromises should be made. Theory and practice will not only diverge, but that is how it has been and should be.

MORALS FOR MONTLAKE

You might expect from the foregoing that since whatever the Center does won't be used anyway, they might as well close up tomorrow. Let me hasten to correct that impression, if that is the impression I've created.

As I see the real value of research, it is to provide better understanding of the consequences of pursuing various courses of management action, rather than to prescribe what should be done by management. Thus, if regional councils are to conduct their business of social and economic trading off, they should do it against an informed background of the likely results of their decisions. For example, if they decide that it is more important to catch more fish now than seems prudent from a biological point of view, they should have good economic or social reasons for risking future livelihoods and life styles. There are many variations of this theme. The essence of all of them is that knowledge is essential to good management. In fact, the most important contribution of highly sophisticated studies will be to show that simple and cheap techniques of management are 90% as effective as costly and complex regimes. That is the real gap to close between theory and practice.

I thus see the future role of the Center much as I see its past--conducting studies of both long-term and short-term significance that are aimed at providing a wider base of knowledge and a greater depth of understanding of the biology, economics, and sociology of fisheries. In that role the Center will no doubt continue for many years to come to be a leader in the future of resource management.

POSTSCRIPT

As a personal postcript to these remarks, I'd like to add a comment or two about what might be called "institutional" matters. One of the great advantages of locating a government laboratory close to a university campus is to ensure that both may enjoy the benefits of close association. But it is one thing to have a close association and another to be doing each other's jobs. As I see it, and I admit to being old-fashioned, it is the job of universities to train the next generation; it is the job of government research laboratories to perform a professional research role in the long-term public interest. The increasing practice of contracting more and more research from government laboratories to universities steadily erodes the difference in the role of the two institutions. If I could give only one piece of gratuitous advice for the future of the Center, it would be to contract with universities only when it can't be done elsewhere and only when there is clear educational value. I hope you notice that I am implying that I favor grants for universities and the building of continuing research strengths in government laboratories.

Not satisfied with just one bit of gratuitous advice, I will offer another, which is related to the foregoing. There is a trend in Canada, at least, and perhaps in the United States, not only to homogenize the sectors, but also the spectrum of long-term research, short-term research, and management. In consequence, we are finding that our long-term research is becoming curtailed in the hope that quicker routes can be found to cope with immediate problems. At the same time, management personnel are becoming increasingly bewildered in their attempts to immediately apply lessons which are not adequately understood. In short, the scientist who is an intermediate shade of grey, who may attempt to perform in all arenas at once, is very likely to be a bust in all of them.

The moral is that laboratories should appreciate the need to distinguish between long-term researchers, short-term researchers, and managers; and give each group an appropriate mandate and freedom to pursue it. That is not to say that some individuals should not move from one group to another from time to time. What they should not be asked to do is wear several hats at the same time or to be a uniform shade of grey. Coordination of functions is preferable to integration of functions. Even coordination can get to be too much of a good thing. Some of my best friends in the Canadian Fisheries and Oceans Department are coordinated into a state of virtual paralysis. After finding out what everyone else is doing, they have no time left to do their own jobs.

In my view, the constant pressure for every actor to be all things to all men at all times has been a major impediment to gaining better understanding in the past and could well be one of the major impediments to the future.

With these few concluding remarks, I wish the Center's Seattle Laboratory a happy 50th birthday, a happy next 50 years in a blissful state of contractless, coordinated, cooperative commitment and the reminder from Plutarch: "In theory, there is nothing to hinder our following what we are taught; but in life there are many things to draw us aside."

REFERENCES

ANDERSEN, K. P., and ERICK URSIN.
1977. A multispecies extension to the Beverton and Holt theory of fishing, with accounts of phosphorous circulation and primary production. Meddr. Dan. Fisk. Havunders. 7:319-435.

CASWELL, HAL.
1980. On the equivalence of maximizing reproductive value and maximizing fitness. Ecology 61:19-24.

CLARK, COLIN W.
1976. Mathematical bioeconomics: the optimal management of renewable resources. Wiley Interscience, New York, 352 p.

HALEY, K. BRIAN (editor).
1981. Applied operations research in fishing. Proc. NATO Symposium. Trondheim, 1979. Plenum Press, New York, 430 p.

LAEVASTU, TAIVO, and FELIX FAVORITE.
1977. Preliminary report on dynamical numerical marine ecosystem model (DYNUMES II) for eastern Bering Sea. Processed Rep., 81 p. Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

LARKIN, P. A., and W. GAZEY.
In press. Applications of ecological simulation models to management of tropical multispecies fisheries. International Center for Living Aquatic Resource Management/Commonwealth Scientific and Industrial Research Organization (ICLARM/CISRO) Workshop on Theory and Management of Multispecies Stocks, Cronulla, Australia, January 1981.

MARTEN, G. G.
1979. Impact of fishing on the inshore fishery of Lake Victoria (East Africa). J. Fish. Res. Board Can. 36:891-900.

MURDOCH, WILLIAM W.
1969. Switching in general predators: experiments on predator specificity and stability of prey populations. Ecol. Monog. 39:335-354.

PAULIK, G. J., A. S. HOURSTON, and P. A. LARKIN.
1967. Exploitation of multiple stocks by a common fishery. J. Fish. Res. Board Can. 24:2527-2537.

PEARSE, PETER H.
1980. Property rights and the regulation of commercial fisheries. In Peter N. Nemetz (editor), Resource policy: international perspectives. Institute for Research on Public Policy, Montreal, Que., 371 p.

POPE, J. G.
1979. Stock assessment in multispecies fisheries with special reference to the trawl fisheries in the Gulf of Thailand. Food Agric. Organ. U.N., South China Seas Fish. Dev. Coord. Programme, SCS/DEV/79/19, 106 p.

POPE, J. G., and B. J. KNIGHTS.
In press. Simple models of predation in multiage multispecies fisheries for considering the estimation of fishing mortality and its effects. Can. J. Fish. Aquat. Sci.

RICKER, W. E.
1958. Maximum sustained yields from fluctuating environments and mixed stocks. J. Fish. Res. Board Can. 15:991-1006.

RIFFENBURGH, R. H.
1969. A stochastic model of interpopulation dynamics in marine ecology. J. Fish. Res. Board Can. 26:2843-2879.

ROTHSCHILD, B.
1971. World fisheries policy: multidisciplinary views. Univ. Wash. Press, Seattle, 272 p.

RYDER, R. A., S. R. KERR, W. W. TAYLOR, and P. A. LARKIN.
1981. Community consequences of fish stock diversity. Can. J. Fish. Aquat. Sci. 38:1856-1866.

STEELE, J. H., and B. W. FROST.
1977. The structure of plankton communities. Phil. Trans. Roy. Soc. Lond. 280:485-534.

STREISINGER, G., C. WALKER, N. DOWER, D. KNAUBER, and F. SINGER.
1981. Production of clones of homozygous diploid zebra fish (Brachydanio rerio). Nature (London) 291:293-296.

TAYLOR, H. F.
1951. Survey of marine fisheries of North Carolina. Univ. North Carolina Press, Chapel Hill.

Banquet and Luncheon Speeches

A Review of the Northwest Fisheries in Relation to the Northwest and Alaska Fisheries Center[1]

John V. Byrne[2]

It's a pleasure to be here. It's a pleasure to be here on this occasion for a number of reasons. To begin with, it's my first opportunity to get back to the Pacific Northwest after leaving Oregon State University; furthermore, it's particularly gratifying at this time because it's not often that we have the opportunity to recognize 50 years of success. There's no question that the 50th Anniversary of the Northwest and Alaska Fisheries Center is really a testimony to the success of many of the people in this room. I surmise that there are several reasons why it has been a success.

First, there were people who had the wisdom 50 or more years ago to recognize the need for a research center that devoted its activities to fisheries of the oceans--specifically, fisheries in this particular part of the ocean. Another element leading to success was the application of the scientific approach to the fisheries. Clearly there was wise management and, as I look around, some of the wise managers are in this room tonight. More important, some of these people had the wonderful talent for selecting dedicated and competent scientists to work at the Center. That's the key--the people who did the work. All of these demands have come together because we're here, 50 years later after remarkable successes in learning about the fisheries.

I think it's important to acknowledge that this particular Center has been successful. We now recognize the importance of the fisheries that lie off the northwest coast of North America, both for recreational and for commercial purposes. These are relatively new, rich fisheries; all you have to do is to compare them with some of the fisheries that have been exploited in the Atlantic which are depleted.

We're still in a pioneering period. Certainly we have a number of pioneers in this room tonight whom we would all recognize, but there are also some here whom we wouldn't recognize--the younger staff who maybe have just come to the Center. We are still in a very early stage of the pioneering period with respect to the fisheries off Oregon, Washington, and Alaska. Think about some of the changes that have taken place during the last 10 years; these changes demonstrate that we are in a very early stage.

For the first time in the history of

1/ Speech presented at a banquet on 27 October 1981 at the Westin Hotel, Seattle, Washington.

2/ Administrator, National Oceanic and Atmospheric Administration, Rockville, MD 20852.

the United States we're attempting to manage the fisheries. The Magnuson Fisheries Conservation and Management Act of 1976 gave us an opportunity to do things we've never been able to do before; it was set up for a number of purposes which you all know much better than I do. A new quasi-government agency was set up called regional fishery managment councils; it's too early in my judgment to really decide whether these have been a success or a failure. I don't think the score is in yet.

It is obvious, however, from our experience over the last few years that we do need to make some changes. We need to fine tune the system. We need to make some adjustments that will improve it for all of us, not only for the managers but also for those of you who go out and harvest the fish from the ocean. There are some significant changes that are needed before we can claim that this mechanism, this particular type of government, is going to be a success.

Let me share a few comments with you with respect to fisheries in general and, specifically, with respect to fisheries here in the Northwest. Coming to NOAA as a new member of the government, as a newcomer from a University, I've been very impressed by the way the fisheries people have been organized.

I have learned through interaction with some of the fisherfolk who come to my office in droves and tell me what should be done about fisheries management in the United States. One of the things I've learned is how different fisheries problems are as you go from one part of the country to another. The problems that exist in the New England fishery really do appear to be different from those that occur in the southwest or the Gulf of Mexico or the Northwest. And so I think the regional approach that's been adopted really makes great sense, particularly when you look at the waters off the Northwest region.

The laboratory here at Seattle has developed in a way parallel to the development of the fisheries in this region. It has provided many answers needed to unlock some of the secrets of the fisheries to enhance fishing activities. At lunch today Bill Gordon mentioned the importance of the Northwest region with respect to the fisheries of the world.

First of all, I think this particular area may have the greatest potential for development of all the fisheries of the United States. You folks realize that much more than I do. Statistics show us that from 1977 to 1980, 19% of the U.S. domestic catch and 92% of the foreign catch took place in this area. When you average these out, you come up with the result that indicates slightly less than half of all of the fish taken in U.S. waters within the 200-mile limit came from this particular region: clearly, the region is very important. If you want to measure in terms of dollars, 41% of the dollar value of fish taken was produced from this area. The fish were taken by 37% of the fisherfolk from 27% of the fishing craft that we operate from the United States--you used to be able to say fishermen but not anymore--you have to say fisherfolk. Bill Gordon mentioned that the total potential for groundfish in this area was estimated at about 2-1/2 million metric tons, but the total U.S. catch in 1980 was only slightly more than 100,000 metric tons. If our assessment of the potential is correct, we have a long way to go. We have a bright future ahead of us in terms of harvesting fish in this area.

The data are impressive, but as the poet once said, "The best is yet to be."

In the United States, I think we're obligated to manage this magnificent resource as wisely as we can. To do this, we have to understand it--and that, of course, is the reason for carrying out research. I think the scientists of the Northwest and Alaska Fisheries Center will help us do that.

I would like to share with you just a few examples of some of the research that has taken place at the Center over the last 50 years. It's clear that much of the research which has taken place here has been very meaningful in terms of fisheries development. This has been research in fisheries biology, chemical contaminates, marine mammals, food technology, gear development, and assessment of fish stocks. As I cite the examples, you may think "Hey, that's pretty routine stuff." But it wasn't routine when it was done the first time. It was revolutionary, it was unusual, it was new. It was innovative, and the fact that it has become routine simply indicates that it was done properly and that it was right. Right now we couldn't conceive of doing population dynamics or stock assessments without really understanding statistical factors. And you should know that a statistical analyst was added to the staff here in 1933: this was one of the first applications of statistics to the development of understanding fisheries.

A few years later some studies of Puget Sound sockeye salmon were made in this laboratory. These studies played a significant role in working out an agreement with the Canadian government after a period of something like 50 years of controversy between fisherfolk of the United States and Canada.

In 1938 we saw the first major expansion of the Alaskan fishery research program here with a study of salmon runs in Bristol Bay. Although you may not realize it, this was the first real study in the United States of the ocean life history of salmon. Lots of work was performed on salmon, of course, because we all know how magical salmon are for people in this part of the country. Based on studies of the scales on salmon, it was noted that there were salmon of different continental origins in the North Pacific; salmon which were being caught far away in the mid-Aleutians were, in fact, coming from Bristol Bay. This had an impact on international fisheries agreements. Because so much data were being collected as part of the salmon program, it became obvious that it was very difficult to work with the data. So someone--and this was in the mid-50s--had the idea, "Perhaps we can use one of those new, fancy electrical devices called computers." We live with computers today, but those of you who were doing research in the mid-1950s can remember the old mechanical Monroe calculators. You would punch data into them and they would whine and rumble for a few minutes. After you had punched in some numbers you would get an answer. This laboratory was the first to acquire a computer and use it in fisheries biological research. That's routine now, but in 1955, that was true innovation.

There were other research products and projects. Before 1956 almost nothing was known of the biology and populations of king crab in the eastern Bering Sea and elsewhere off Alaska; within an 8-year period, from 1956 to 1964, the complete story--life history, rate of growth, migration, survival, numbers of crab in an area and so on--

was all worked out by the scientists here at the Center.

Bill Gordon mentioned some of the directions that studies of chemical contaminates have taken. I won't go into those. On marine mammal research the estimate of the numbers of seals in the Pribilof Islands was something like 3-1/2 million; it turned out that in fact, on the basis of scientific observations, there was something on the order of half that number.

In 1948, a scientist at this Center took 36 teeth from a freshly killed sea lion for photographic dentician studies. He noticed that there were faint ridges circling the root of each tooth, and he thought maybe each of those ridges represented 1 year of life. He was proven correct and from that we developed the technique to ascertain the ages of seals and sea lions and other pinnipeds.

Food technology is another area of accomplishment at the Center. Some of you may recall that in the early days when salmon was being canned, frequently it would dry in the can because there wasn't sufficient oil; it was discovered that by taking oil from some of the inedible parts, you could put it in the can and keep the salmon in the can fresh and moist and so on. That process was developed here. In the years after World War II, initial research was performed on the fractionation of fish oils and preparation of chemical derivatives.

We all went through the mercury scare--some of the early measurements of mercury in fish were carried out at this laboratory. Now we know that man isn't entirely responsible for that. There are tons of mercury being added to the sea through hydrothermal vents in the sea floor every year. In those days we were blaming ourselves.

A long line of successes in terms of developing new equipment and fishing methods came from this laboratory--such things as the tangle net power roller. I don't even know what that is, but the tension block was used to temper the shock of an albacore tuna hitting a fast troll lure. Open sea floating salmon traps, tags for tuna, salmon, shrimp, and so on were used. All of these contributed to our understanding of, and our ability to improve, the fishing in this region.

And finally, I should mention again the point that Bill Gordon made about stock assessment. This is fundamental information that we need to properly manage the fisheries resource.

The foregoing are simply examples. They're examples which came from a long list provided me. I found them intriguing. I'm sure each of you can think of your own pet examples of work done at this laboratory. The point to remember, however, is that the research that was carried out here was of high quality, and is still of high quality. This has become the hallmark of the Northwest and Alaska Fisheries Center. We expect high quality research to come from this laboratory because of the excellence of the administrators and the excellence of the workers. From the precedent established here, it's clear that the concept of regional centers in support of regional directors and management of fisheries is important. This center is important to both the commercial and the recreational fishermen.

Now what about the future? Those of us who are in Washington right now clearly see that there are some changes ahead and I suspect that most of you see this as well. As I look at it, it is clear

that we need to develop what I refer to as a U.S. strategy for the oceans. We have too many laws and regulations that are in conflict with each other. We lack a coherent policy pertaining to use of the oceans. We certainly appear to lack a plan to achieve whatever policy we think we may have and we need some program of action. If we look at the development of an ocean strategy, there are a number of components that it must have. We need to work together to bring all of the talents we have to bear on important problems and to avoid as much duplication as possible; furthermore, as we go through a period where the budget seems to be on most people's minds--at least in Washington--it's clear that duplication must go. We need to be sure that whatever policy and plan we develop, we maintain the health and vitality of renewable resources. We need to be sure that we preserve our security as a nation. We need to be sure that our strategy will focus on the world ocean rather than just the ocean off our shore. We need to focus on the development of those resources which are available to us. As I see the development of ocean activities, and that includes fisheries activity, I think we're moving into an era of resource development--an era in which we'll see more activity on the basis of the private sector, free enterprise.

NOAA has acknowledged and plans to take the lead in this. We plan to make this the era of ocean resource development; however I should point out that we don't anticipate sacrificing our concerns about the environment. We plan to enhance the activities that will assist industry in the exploitation of the resources that are available. We'll pay more attention to industry--not just fisheries, but all of the industries at work in the ocean. At the same time, we're going to expect more of industry. We're going to expect industry to take on those things which it can do best--to become independent where that is possible, to focus on product development and marketing, for example, which seem to be natural for industry to take on.

Those of us in government will try to develop an optimum environment for these kinds of activities. In the case of fisheries, we want to help you folks move into the 21st century. In order to do this we need to put decisions close to where the action is; we need to stop making decisions from Washington, D.C., when they can better be made in the local or regional area; and we need to give more responsibility to local and regional managers. The drive for that responsibility is accountability. That means that as long as things work fine, there'll be no problem, but if they don't accountability will show where we're lacking and changes will have to be made.

With respect to fisheries, we anticipate that the regional councils will be given more authority. But that also is at a price; that price is a more statesmanlike approach to fisheries problems on the part of the Councils. I envision the authority and the responsibilities of Regional Directors increasing; these people have among the hardest jobs in government. Major decisions should be made by Regional Directors in the area.

Finally, we have to cut back on regulations--particularly what I think of as the second and third order regulations. These are the regulations which regulate the regulations, and we have a lot of them.

More specifically, and perhaps I'm too naive in this, I think it's time to

revise the Magnuson Fishery Conservation and Management Act of 1976 (MFCMA). I think we need different approaches by other agencies to some of the collateral activities that are covered under the MFCMA. Bill Gordon mentioned the use of a parallel approach rather than a serial approach to approvals. I'd like to see us move more in the direction where more and more of the plans that come to Washington, D.C., are almost automatically accepted because they have been worked out so well at the regional level and those that are rejected or turned back are the exceptions--rare exceptions. I'd like to see us come to a situation where a new fisheries management plan can be implemented within 60 days; perhaps the way to do this is to give the federal government 60 days to reject a plan and, if it's not rejected, to automatically accept it.

Clearly, if we can pull these things off, we will have created a significant change and I think we can, but in order to do it we have to work together. We have to look at the facts, we have to plan together, and we have to act together.

In conclusion, I would like to leave you with three laws: a law of observation, a law of planning, and a law of action. Those of you who have heard me speak before have probably heard these three laws. The first is the law of observation. It comes from a rather well-known 20th Century observer, a philosopher--a man named Yogi Berra who was at one time the catcher for the New York Yankees and subsequent to that was the manager of the New York Mets. Just to digress for a few moments before I give you Berra's law of observation, the year after the Mets won the pennant Yogi Berra had exactly the same team, but they came in fourth. Someone asked him, "Yogi, what happened?" and he said, "Well, this year we just made the wrong mistakes." Berra's law of observation: you can observe a lot just by watching.

Observation by itself doesn't give you very much, so you really need a plan and for the law of planning you go to somebody named Peter. Most of you know him for Peter's Principle which is the law of incompetence. You know--you rise to your level of incompetence, but we're not talking about that tonight. Peter's law of planning says, "If you don't know where you're going, you're likely to end up somewhere else."

And finally we need a law of action and this goes back a little bit. In fact, it goes back to around the time this laboratory here at Montlake got started. It goes back to a man that some of you may remember--Will Rogers. I call this Roger's Law of Action: "Even if you're on the right track, if you're not moving, you'll probably get run over."

Those of us at NOAA Headquarters look forward to working with you, we look forward to observing together, to planning together, and to acting together to have us live up to the potential that the oceans in this particular part of the world really offer us. Thank you very much.

The Challenges of Being Administrator of the National Marine Fisheries Service[1]

William G. Gordon[2]

INTRODUCTION

The work at the Northwest and Alaska Fisheries Center for the past 50 years has caused it to be recognized as a leader in fisheries research. For example, in 1932, the movements and migrations of herring in southeastern Alaska were studied using a belly tag made of metal and recovered with a magnetic reflection system in the processing plants. To my knowledge that work became a basis for the largest tagging effort in the world; it was used to track millions of Atlantic menhaden in their movements up and down the Atlantic coast.

Clearly the history of this Laboratory in salmon research is unequaled, forming the basis for international management, for domestic management, and for enhancement efforts that are going on in many areas along the northwestern United States. I might add that some of the work that has been carried out has received wide recognition, and some of the people that were trained here or had experience here have, in fact, become the world's experts in fish passage studies and in addition their services have been sought all over the United States, as well.

The mortality caused by passage of young fish over the dams and through the turbines was a unique problem which led to activities that improved survival rates of downstream migrants.

The salmon aquaculture program, now stationed in Manchester, brought about the commercial development where salmon are grown rapidly to pan size in pens; we now have thriving commercial enterprises, not only on the West Coast but several enterprises have started on the East coast--again based on that work done here.

RESEARCH AND EXPLORATION

In research on effects of chemical pollutants, some of the early work done here has formed a basis for understanding the uptake and discharge of pollutants by marine organisms. That work will form the basis for, I'm sure, many more achievements that will be carried out here as offshore oil development takes place.

The marine mammal studies that originated here are well recognized and

1/ Speech presented at a luncheon on 27 October 1981 at the Seattle Yacht Club, Seattle, Washington.

2/ Assistant Administrator of NOAA for Fisheries, National Marine Fisheries Service, Washington, D.C. 20235.

as we continue to manage the fur seal population on the Pribilofs, that work will stand the test of time.

In food technology a lot of research was performed here as well. As an example, the commercial use of fish oil was first worked out at the Center.

Shrimp explorations in southeastern Alaska and, of course, Oregon also led to the development of a thriving industry. I could name a host of fishery methods and equipment that were designed and tested at the Center and turned over to the industry; many of these have become a part of the way industry operates today. The industry has taken prototypes developed at the Center, and built on top of them and achieved even more striking developments. Of the many modern vessels and equipment you see today, the fundamental designs for many of these were conceived here in those earlier days.

FISHERIES POTENTIAL

If we turn to the fisheries potential, of the Pacific Northwest we should first note that the implementation of the 200-mile limit by the Magnuson Fishery Conservation and Management Act of 1976, initiated a very startling change in the way the world's ocean resources and particularly those contiguous to the shorelines of the various nations around the world will be managed. The United States certainly took on a fantastic task, one that at the moment is very poorly understood: we achieved the moral and legal responsibility for 17 to 20% of the world's harvestable fisheries resources.

But yet here in the Pacific Northwest, we see the greatest potential for growth in the U.S. fisheries in the immediate future because of the tremendous resources off Alaska and off the Washington, Oregon, and California coasts. In 1980, the Center estimated the groundfish population potential at 2-1/2 million metric tons and yet the U.S. catch in 1980 was just a fraction over 100,000 metric tons. Flatfish resources have a potential of around 320,000 metric tons, yet the U.S. catch was a low 13,000 metric tons. For Pacific hake with a potential of about 175,000 metric tons, the U.S. catch was 28,000 metric tons. These resource potentials represent a tremendous opportunity for the industry to expand into.

I think it's very critical that this nation embark on a course of continued growth of its fisheries. Much to my chagrin, Dr. Byrne, on a trip to our laboratory in Gloucester, was told by the Laboratory Director that fish is the number 3 product in our balance of trade deficit beginning first with oil and cars. Yet we talk about these tremendous potentials that are available to us. The question is whether or not we'll be able to harvest and market fishery products in competition with the imported product or harvest, process, and market those products in the world market. That there is a world market is certain, or why else would the foreigners pay the fees and face the prospects of higher fees and continue to come here and fish for these resources.

All in all, the Center has contributed a tremendous amount of information to the Pacific (and North Pacific) Fishery Managment Councils, to the states, to us within the National Marine Fisheries Service, to the Marine Mammal Commission, and to other international

bodies and, soon, to representatives at bilateral meetings with Canada on salmon. One of the principal and substantial areas of the Center's contributions is in the stock assessment area; many people look upon this area as perhaps a biologist's dream. Stock assessment is basic not only to fisheries management, it is a basis for industry involvement and expansion. Such information is the capital upon which management decisions are made, not only in terms of how we manage the fishery but how industry manages its investment decision and marketing strategies and the like.

Another factor that doesn't seem to be too well understood among the general public is the tremendous variability in fish populations that takes place, whether a man-induced factor is there or not (such as a fishery). It is one of the common laws of nature that these levels of recruitment change and they can vary in orders of magnitude. For example, some of the survey work of the Center in the eastern North Pacific over a 5-year period indicated that the biomass index for Pacific cod changed from 100,000 metric tons in 1975 to nearly a million metric tons in 1980. The mechanism that brought about that change, of course, is very poorly understood, but it's that sort of work that provides a basis for: 1) the regional fishery management councils to take action, 2) for the industry to follow up, and 3) for fisheries managers to allocate the resources.

I would like to discuss some of the Center's plans in the future. They're going to continue their surveys by ship to assess or verify stock conditions on a wide range of resources. They will be managing the observer program that places the observers on foreign fishing vessels in the U.S. fishery conservation zone; observers provide a wealth of information to the computer bank at the Center which in turn is processed and passed on to the various users. I don't think we've completely tapped the ability to gain information about the foreign fishing fleet. The harvesting technology, some electronics, the processing technology, the economics of fishing, in addition to biological data, can be obtained by appropriate observers on those foreign fishing fleets. As long as these fleets are here, I hope that we continue to gather maximum information from them.

The Center will continue the bio-economic analysis on important commercial/recreational species, complete the research on the quality and processing characteristics of Pacific whiting for domestic use, and complete the studies on maintaining the quality and extension of the shelf life of fillets of some rockfish. The results of these studies were practically applied within the industry in a very short period.

The National Marine Mammal Laboratory must continue their field activities on bowhead whales and other marine mammals, including fur seals. The Center staff will be doing a considerable amount of work on the ecosystem model of the Bering Sea to predict the impact of commercial fisheries on marine mammal stocks. All of these activities will eventually provide information to the responsible managers.

I will summarize some of the areas I am committed to. I think our human resources are a most valuable asset and we ought to do our best to provide an opportunity for people to grow. I would like to enhance the National Marine Fisheries Service as an agency which provides opportunities for

development of challenging professional careers.

We must maintain a strong scientific base to provide timely information for fisheries, monitor management, and develop habitat protection programs (including enhancement as well as mitigation activities). I think we have to use that knowledge to achieve equity in the management of the recreational/commercial fisheries.

Because of the austere budget, it may be required that we focus only on those fisheries within the fishery conservation zone that are in need of regulation.

I would like to achieve greater realization of the fishery management process and plan implementation. We should integrate fisheries management and fisheries development. They go hand in hand and one can lead the other. We have to strengthen cooperation with all segments of the fishing industry; at the same time, we must strengthen our relationship with our state counterparts, for without them we cannot carry out our task.

We will enhance our relationships with other agencies that affect the National Marine Fisheries Service in the Department of Commerce and with other federal agencies at the state and local levels.

I am confident that the leadership and staff at this Center will continue to make contributions to knowledge such as those I have briefly covered in my remarks. I am proud of our past accomplishments and will be even more proud of those under my leadership. Good luck and best wishes for the future.

Acknowledgments

Recognition is due the many persons who planned, prepared, and participated in the celebration of the Center's Golden Anniversary. Center Director, Dr. William Aron, and Deputy Center Director, H. Heyamoto, initiated the activities; and a Steering Committee, selected by Dr. Aron, met at intervals from October 1980 to August 1981 to assist in formulating plans for the celebration. The committee consisted of Clinton Atkinson, former Director of the Seattle Biological Laboratory and U.S. Department of State Fishery Attache to Japan, who acted as Chairman; and the following members: Dr. Dayton Alverson, former Center Director and now with Natural Resources Consultants, Seattle; Dr. Donald Bevan, Associate Dean, College of Fisheries, University of Washington, Seattle; Neva Karrick, former Deputy Director of Environmental Conservation Division, Northwest and Alaska Fisheries Center, Seattle; Harold Lokken, Fishing Vessel Owners Association, Seattle; Robert Schoning, National Marine Fisheries Service and Oregon State University, Corvallis, Oregon; Maurice Stansby, Scientific Consultant, Northwest and Alaska Fisheries Center, Seattle; John Wedin, Chief, Fisheries Development Division, Regional Office, National Marine Fisheries Service, Seattle.

The full Steering Committee first met on 27 October 1980 setting up informal guidelines for planning for the celebration. During the next 5 months an unofficial group consisting of those members of the Steering Committee on the staff on the Northwest and Alaska Fisheries Center plus Heyamoto and Atkinson, Steering Committee Chairman, worked together to implement the plans.

Robin Waxman, detailed from the NMFS Washington Office, acted as coordinator for much of the planning. She and Mary Galer, Heyamoto's secretary, and Eleanor DiMarco, Dr. Aron's secretary, worked closely with the Steering Committee and the unofficial working group of the Center.

The historical section of this book was written by current and former employees of the Center. Stansby, and Atkinson, directed the project, and assisted the authors in culling long-buried facts and lore which led to the creation of the history.

A 2-day Open House preceded the Symposium at the Montlake laboratory. The event was highlighted by an exhibit on the "History of Fishing on Puget Sound," kindly loaned to the Center by the Whatcom Museum of History and Art in Bellingham, Washington. The Open House was coordinated by Charles Gill. All graphic work for the Open House, other commemorative activities, and this book were undertaken by the Center's Graphic Unit, headed by James Peacock, assisted by unit members Carol Hastings, Melody Tune, and Robert Radek. Camera-ready copy for this book was typed by Eleanor Uhlinger.

The 2-day Symposium beginning on 26 October featured speakers from the Center and others. Dr. Steinar Olsen arrived from Norway, Dr. Peter Larkin from Canada, and John Gottshalk from Washington, D.C. Local speakers included Dr. Alverson and Dr. James Crutchfield of the University of Washington. William Woods and John Peterson represented the fishing industry. The industry panel was moderated by Walter Yonker.

On the first day of the Symposium, a luncheon was held on the Montlake grounds honoring the Center employees. Smoked halibut was prepared by the Halibut Fishermen's Wives Association, led by Gretta Strom. The luncheon was sponsored by the Fishing Vessel Owners

Association, the North Pacific Fishing Vessel Owners Association, the Northwest Fisheries Association, and the Pacific Seafood Processors Association. On the second, and last, day of the Symposium, William Gordon, Assistant Administrator of NOAA for Fisheries, was the feature speaker at a luncheon at the Seattle Yacht Club.

The final event of the anniversary celebration was a banquet at the Westin Hotel in downtown Seattle on the evening of 27 October. The banquet honored old timers and friends. The keynote speaker was Dr. John Byrne, NOAA Administrator.