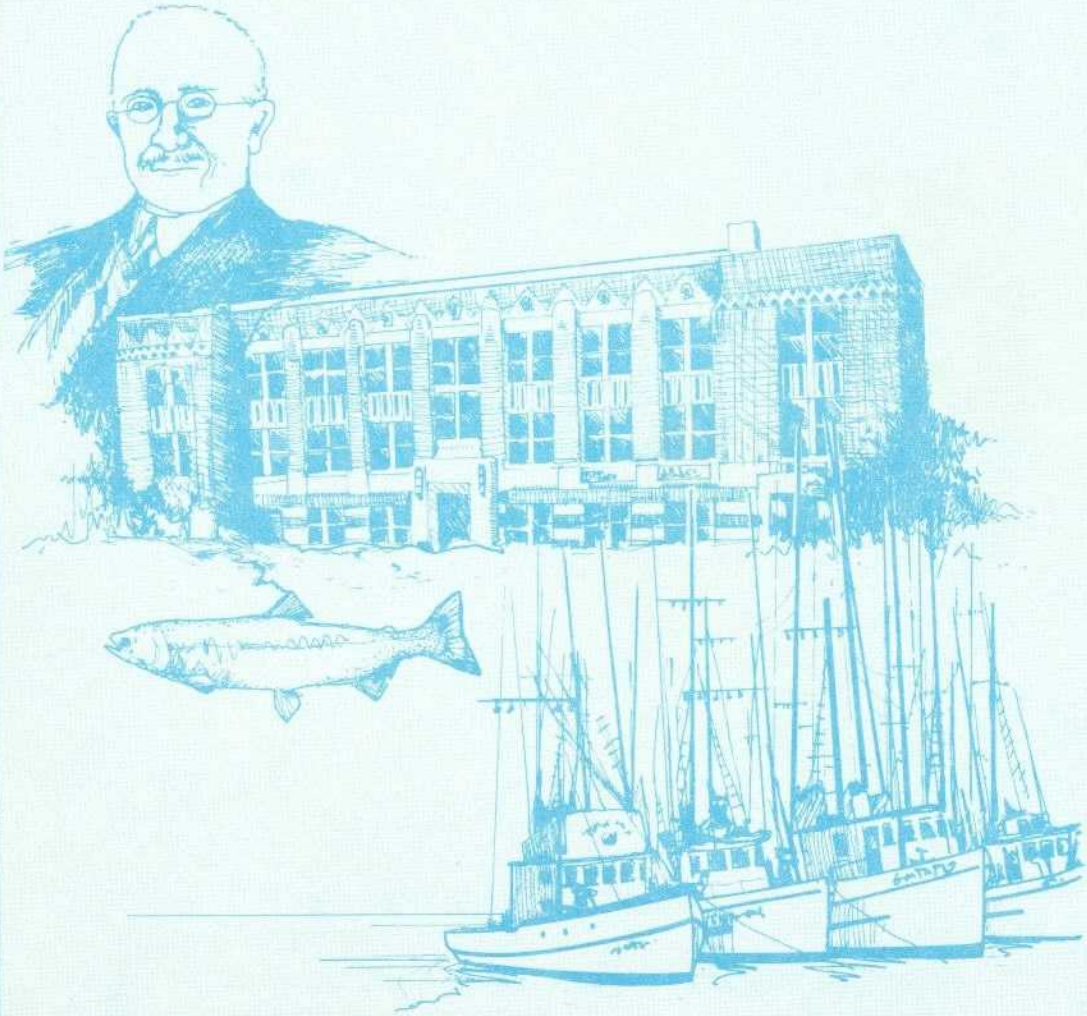
Federal Fishery Research in the Pacific Northwest Preceding Formation of Northwest Fisheries Center



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

Federal Fishery Research in the Pacific Northwest Preceding Formation of Northwest Fisheries Center

Maurice E. Stansby

November 1979

U.S. DEPARTMENT OF COMMERCE
Juanita M. Kreps, Secretary
National Oceanic and Atmospheric Administration
Richard A. Frank, Administrator
National Marine Fisheries Service
Terry L. Leitzell, Assistant Administrator for Fisheries

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 to 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.

CONTENTS

Introduction 1
General activities, 1887-1931 1
Biological research at Seattle, 1931-71 3
  Period of 1931 to 1951 3
  Period of 1952 to 1971 4
Biological research at Auke Bay, 1956-76 9
  Activities 9
  Accomplishments 11
Marine mammal research—1890 to 1971 14
Exploratory fishing and gear development activities 15
  Early work prior to 1949 15
  Work from 1949 through 1971 17
Technological research 20
  Pacific coast prior to 1933 20
  Seattle, 1933-76 20
  Food Science Pioneer Research Laboratory at Seattle 29
  Alaska, 1940-76 30
Formation of Northwest Fisheries Center 32
Sources of information 34
Literature cited 34

Federal Fishery Research in the Pacific Northwest Preceding Formation of Northwest Fisheries Center

MAURICE E. STANSBY[1]

INTRODUCTION

This report traces the historical developments beginning in the late 19th century which led to the establishment in 1971 of the Northwest Fisheries Center (NWFC), now the Northwest and Alaska Fisheries Center (NWAFC). The scientific programs of the various predecessor agencies which eventually came together in 1971 to form NWFC are described from those early beginnings.

GENERAL ACTIVITIES, 1887-1931

The initial Federal scientific fishery work on the North Pacific coast can be considered to have started in 1888 when the U.S. Fish Commission vessel, *Albatross*, arrived in San Francisco. This vessel had been constructed for the use of the U.S. Fish Commission and was launched in 1882. It was an iron hull, twin-screw vessel of 1,034 tons displacement (registered net tonnage 384 tons), was 234 feet long, and was built at a cost of $145,000. For its first 5 years it was based at Woods Hole, Mass., making voyages on the North Atlantic.

The *Albatross* left Woods Hole on 19 October 1887 and arrived in San Francisco on 15 May 1888 after having collected many marine samples during its voyage around South America. Its first voyage into the North Pacific area began when it left San Francisco 4 July 1888 bound for the Aleutian Islands and the Alaska Peninsula. The voyage was undertaken primarily to collect a wide variety of marine samples and to observe fish and other aquatic life. The following year a similar trip was made off the coasts of Washington and Oregon in the spring and another, shorter, trip made in the late summer along the coast from Cape Flattery to Cape Mendocino. In 1890 the *Albatross* made a trip to the Bering Sea where special attention was paid to cod and incidental observations were made on other species.

From 1891 through 1895, trips were made each year to the Pribilof Islands to obtain information on the life history of seals. These voyages were made first in connection with the need for evidence for use in arbitration before the Paris Tribunal which met to settle the dispute among several nations taking seals in that area. During the last several years of this period the *Albatross* acted as a patrol vessel to enforce sealing regulations.

After a lapse of several years, when the *Albatross* made voyages to the Hawaiian Islands and the South Seas, work was resumed in 1903 at which time Congress had authorized research to investigate apparent declines in salmon in Alaska. Trips were made for this purpose from 1903 to 1906.

During many of these *Albatross* voyages, Charles Gilbert, Professor of Biology after 1890 at Stanford, accompanied the vessel often as field leader for the scientific work. Gilbert had been on the academic biological staff of the University of Indiana and University of Cincinnati, and he was a former student of David Starr Jordan, who was then the President of the University of Indiana. When Stanford was first opened as a new, fully staffed university, David Starr Jordan was appointed

Charles Gilbert, Professor of Biology at Stanford University, was active from 1880 to 1927 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.

[1]Northwest and Alaska Fisheries Center, 2725 Montlake Boulevard East, Seattle, WA 98112.

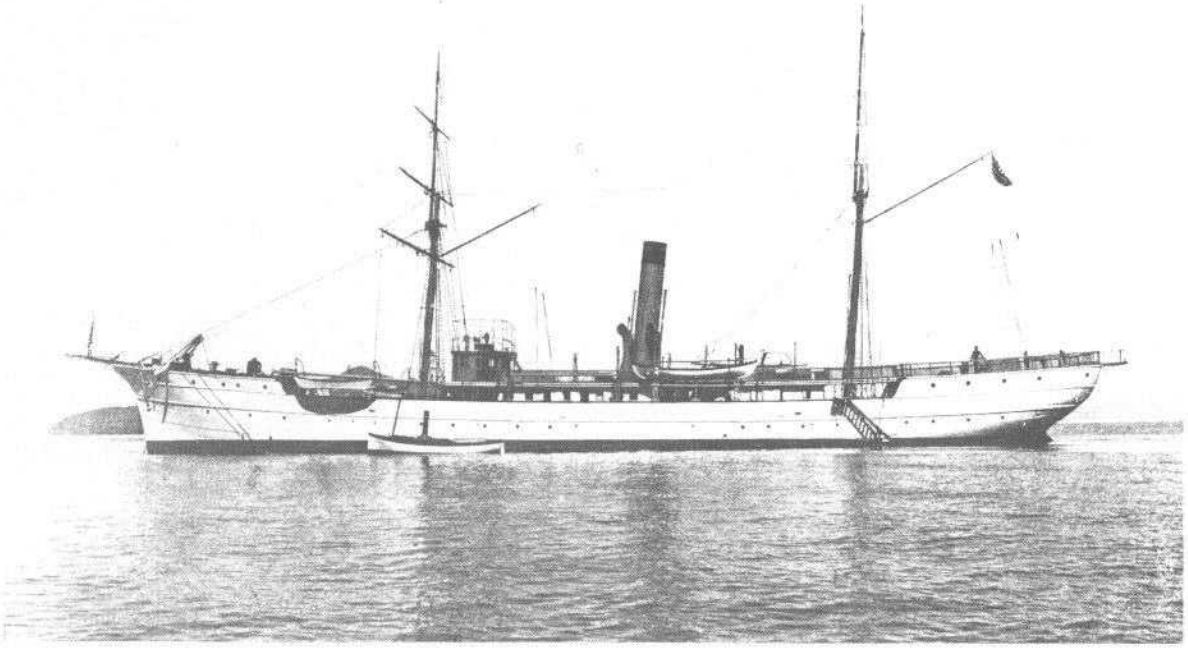
President and he brought Gilbert with him to head the biology department at the new university. Within a few years the biology department at Stanford had become one of the leading ones in the United States.

In 1909, Charles Gilbert was appointed by the Bureau of Fisheries as Scientist in Charge of all the fishery investigations being performed along the Pacific coast. Because of his long association with voyages on the Pacific Ocean on the *Albatross*, he was at that time the leading authority on fishery biology of Pacific coast fish. During the early years up into the 1920's, the biology department of Stanford University served also as a field station of the Bureau of Fisheries since during this period the Bureau of Fisheries had no permanent facility anywhere on the Pacific coast. In 1914, however, the Bureau established in Seattle a small, one-man administrative office, located in the Smith Tower, as a focal point for statistical and general administrative matters for its Pacific coast operations.

Each summer biological field studies were performed by Charles Gilbert and temporary assistants (often Stanford University students) in Alaska, sometimes on the Columbia River, and occasionally in northern California. Almost all of this work was concerned with salmon. Around the turn of the century at least one salmon hatchery was in operation in Alaska in which hatchery fish were deposited virtually directly in the ocean. At that time nothing was known about the anadromous nature of salmon and it was puzzling to these early hatchery operators as to why their efforts, conducted over about a 20-year period, all came to naught. Meantime, Gilbert and his co-workers were unravelling the life history of the various species of salmon so that by 1912 much of this information had been developed.

In 1918, Willis H. Rich, who had received his Ph.D. that year from Stanford working under Charles Gilbert, was appointed as a field assistant in the Bureau of Fisheries to work with Gilbert on Alaskan salmon problems. Each year he accompanied Gilbert to Alaska. In 1922 Rich was appointed to be in charge of all the Bureau's Scientific Inquiry, a post later designated as Biological Inquiry. Rich held this position in Washington, D.C., until 1926, and he still usually spent part of each summer in Alaska on salmon work. By this time the Alaskan investigations had several other employees on the salmon or other fishery investigations, both in Alaska and on the Columbia River. These individuals worked out of the Stanford University Field Station of the Bureau of Fisheries. They included Harlan B. Holmes, who performed biological work on salmon starting in 1922 and who worked some summers on the Columbia River and some summers in Alaska; George Rounsefell, who was in charge of herring investigations in Alaska starting in 1925; J. Thomas Barnaby who, starting in 1927, worked on salmon investigations, particularly in the Karluk River fishery; Edwin Dahlgren, who worked with Rounsefell on Alaskan herring investigations starting in 1929; Joseph Craig, who worked at the Stanford field station starting in 1929; and F. A. Davidson who began work in 1929 on biology of pink salmon in Alaska.

In 1927, Charles Gilbert retired as head of the Pacific coast fishery investigations, the position he had held since 1909; he died shortly thereafter. Willis Rich was appointed, starting in 1927, as director of salmon investigations on the Pacific coast, a post which he held until 1930 when he returned to Stanford University as a professor.



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

In 1928 Congress anticipated the need for planning as a means for providing passage of salmon up and down the Columbia River after construction of dams projected at that time for completion in the 1930's. Funds were provided at $25,000 per year for 5 years beginning in 1928, to survey the situation with regards to information available as a result of previous dam construction in other parts of the country. Shirley Baker, a consulting engineer from San Francisco, was employed to coordinate this work, and he was assisted by U. B. Gilroy, a civil engineer.

Some preliminary design work on the use of electrical screens for fish was conducted by F. O. McMillan of Oregon State College. A considerable volume of information was assembled on practices already prevailing on rivers and streams throughout the United States.

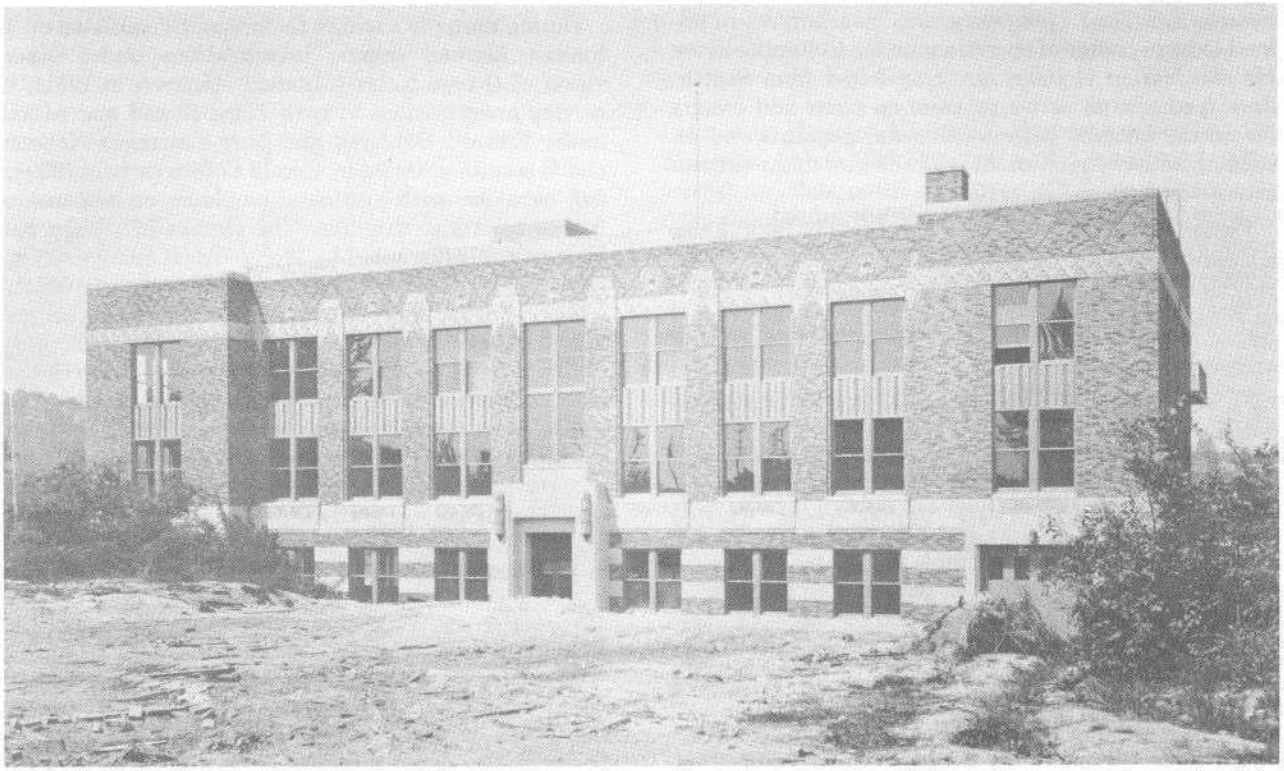
During the early 1920's, under the White Act, authorizing legislation was passed by Congress to provide for a long-term expansion of permanent facilities for the Bureau of Fisheries. One such facility was to be a laboratory building to house research activities, both biological and technological. Such a structure was designed for location on Montlake Boulevard in Seattle and the building construction was completed in 1931. In 1930, as the first step toward providing a biological unit which could move into the new structure, the field station status of the unit at Stanford University was restructured to that of a biological laboratory and Joseph Craig installed as laboratory director. Plans were also made for transfer later from the Atlantic Coast Technological Operations several scientists to establish a technological laboratory.

BIOLOGICAL RESEARCH AT SEATTLE, 1931-71

Period of 1931 to 1951

On 22 May 1931 the new Montlake Boulevard Laboratory of the Bureau of Fisheries in Seattle opened. The personnel of the Stanford Research Laboratory had been transferred and, with Joseph Craig as laboratory director, the program got under way. With one exception, the program remained the same as what had been in effect when the work was conducted from Stanford. The one new program initiated in 1931 concerned a study of the biology of Puget Sound runs of sockeye salmon and this new program was under the direct supervision of the laboratory director, Joseph Craig. A small, short-term operation, started in the winter of 1930-31, on tagging Rogue River steelhead trout was completed.

Continuing programs at the new laboratory consisted of six programs on Alaskan fish, four dealing with red salmon, one with pink salmon, and one with herring: 1) Karluk red salmon under J. Thomas Barnaby; 2) Chignik red salmon program under Harlan Holmes assisted by George Kelez; 3) Copper River red salmon program under Seton Thompson assisted by Morris Rafn; 4) Bristol Bay red salmon program conducted by T. L. Schulte; 5) a program on Alaska pink salmon under



Montlake Blvd. Seattle Laboratory building as it appeared when it opened in 1931.

supervision of F. A. Davidson, assisted by S. J. Hutchinson; and 6) a program on Alaska herring under supervision of George Rounsefell, assisted by Edward Dahlgren.

These six Alaska programs were being conducted in order to have data to assist in determining the opening times and length of fishing seasons for fishermen in Alaska. (Alaska, as a Territory, had its fishing regulations arranged each year and patrolled by the Federal Government.)

A program was under way to obtain information for the Bureau of Fisheries to use in furnishing guidance to the Army Corps of Engineers in its planning for Columbia River dam design in such a way as to minimize 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, Civil Engineer, who also received guidance from a San Francisco consulting engineer, Shirley Baker, who had originally headed this program.

The program on fish ladders and screens was a special 5-year operation initiated by Congressional action in 1928, and funding was not a part of the Bureau of Fisheries base appropriation. After the fifth year of this special allotment of funds, the program was abolished. However, in view of the need for continuation of assistance by the Bureau of Fisheries to the Corps of Engineers in connection with future construction of many dams on the Columbia and Snake Rivers, the regular appropriations of the Bureau, beginning in the summer of 1933, were given a substantial increase. In order to give proper emphsis to this new work, Joe Craig, the Director of the Seattle Biological Laboratory, was transferred to Portland to be in charge of operations on the Columbia River. He and Harlan Holmes, also transferred from Seattle, developed a more active program on plans and designs for means whereby both downstream migrants and ascending adult salmon could pass the new dams without excessive losses of fish occurring.

Frederick Davidson was then appointed in 1933 as new laboratory director for the programs at Seattle. These programs continued along similar lines as had been started when the laboratory opened in 1931. A new program on coho salmon investigation was started in 1934 under direction of George Kelez and another one also begun in 1934 was concerned with statistical studies of salmon, initially under LeRoy Christey, but beginning in 1938 under Elizabeth Vaughn. Two new programs were started in 1939, one a survey of Alaskan lakes, the other an investigation of Alaskan Dolly Varden trout. During Davidson's tenure as laboratory director, some of the work entered experimental biology as contrasted to the more descriptive type which had largely prevailed up to that time. For example, a fairly extensive investigation was made to find the types of physical and chemical changes which take place during spawning of salmon (Davidson and Shostrom 1936).

Table 1 shows laboratory directors of the Seattle Biological Laboratory from the initiation of the work in 1931 until the laboratory became a part of Northwest Fisheries Center in 1971.

Table 1.—Laboratory directors of Seattle Biological Laboratory from 1931 to 1971.

Name	Dates
Joseph Craig	1931-33
Frederick Davidson	1934-41
Harlan Holmes	1941-43
Willis Rich	1943-44
J. T. Barnaby	1944-51
Clifford Burner	1951-52
Clinton Atkinson	1952-65
Gerald Collins	1966-71

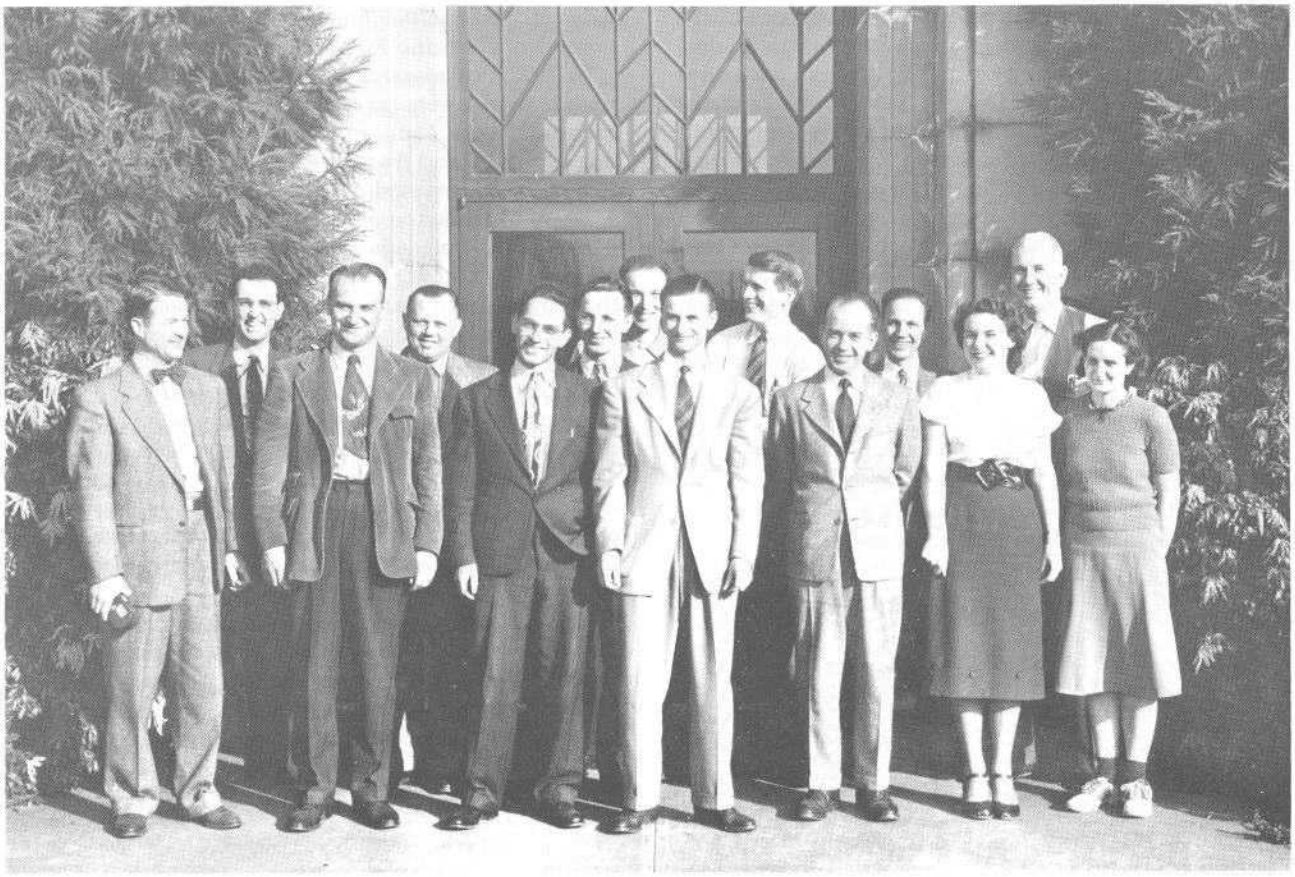
Except for some personnel changes and certain minor program alterations brought about by World War II, programs continued along the same lines until the early 1950's. Davidson's earlier career had been in the agricultural field and he had worked for a period of years in the Illinois Agricultural Experiment Station. In 1941 he left the Bureau of Fisheries to resume his career in agriculture. His position as laboratory director at Seattle was assumed by Harlan Holmes, transferred from his work on the Columbia River. In 1943, when Joseph Craig left his position in charge of the Columbia River Investigations to accept a position as Chief Biologist with the Washington State Fisheries Department, Holmes returned to Oregon for the work on fish passage on the Columbia River. For part of a year, 1943-44, Willis Rich, on loan from Stanford University, assumed the directorship of the Seattle Biological Laboratory. Then from 1944 to 1951 J. T. Barnaby held this position.

During Barnaby's tenure the programs consisted of: 1) limited Alaskan salmon investigations under supervision of George Kelez (Mitchell Hanavan in 1951); 2) herring investigations in both Puget Sound and Alaska under Edward Dahlgren and later Lawrence Kolloen; and 3) studies initiated by Gerald Collins early in 1950 on fish behavior, with particular emphasis on response of fish to electrical stimulus. The studies in Alaska had been partially disrupted by World War II and were then, for the most part, limited to work in southeast Alaska.

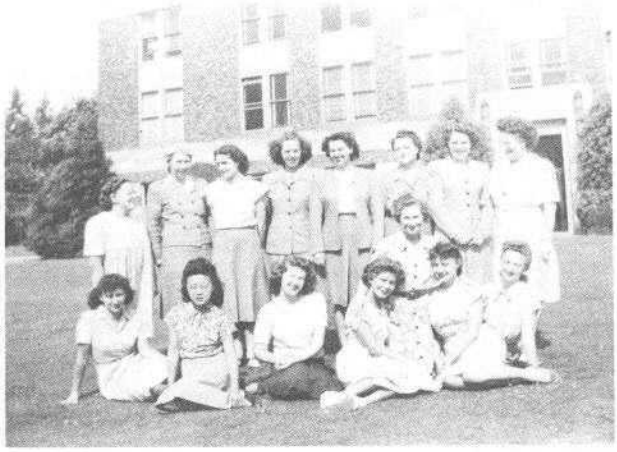
The work on the Columbia River included very detailed surveys of many small tributary streams on the Columbia and Snake Rivers. Also, thorough surveys of past experience using special screens and fish ladders, which were conducted primarily by Harlan Holmes, showed that experience in the past did not clearly indicate the best procedure for salmon diversion at dams on the Columbia River system. It was for this reason that some experimental work was initiated in 1950 by Collins in the Seattle laboratory on salmon behavior.

Period of 1952 to 1971

J. T. Barnaby left his position as Seattle Biological Laboratory Director in 1951 to become Regional Staff Biologist and later Regional Chief of the Division of Sport Fisheries in Portland, Oreg. Barnaby's Deputy



Staff of Alaska Fisheries Investigations, May 1948, Montlake Laboratory, Seattle, Wash. Left to right: William M. (Mark) Morton, Robert L. Hacker, George J. Eicher, Richard F. Shuman, Lawrence N. Kolloen, Philip R. Nelson, Willard Brewington, Paul T. Macy, William L. Peck, Edwin K. (Ken) Stanton, George B. Kelez, Bonnie Thompson (Mrs. William Peck), Samuel J. Hutchinson, and Elizabeth Vaughan.



Women employees at the Montlake Laboratory in 1948. All worked in the biological laboratory except those indicated by "T" who worked in the technological laboratory. Back row, left to right: Kathryn Osterhaug (T), Lillie Anderson, Elizabeth Vaughan, Geraldine Oswald, Lenora Smith, Esther Barker, Mildred Martin (T), and Myrtle Nutt. Front row, left to right: Neva Karrick (T), Patricia Terao (T), Phyllis J. Abbeglen, Betty L. Woods (Mrs. Smith)(T), Mabel Edwards (T), unidentified, and Ms. Harris.

Laboratory Director, Clifford J. Burner, was the Seattle Biological Laboratory Director in 1951, and he was succeeded in this position during 1952 by Clinton E. Atkinson. During the period 1952 to 1965, while Atkinson was director, some quite drastic changes took place in the program. As a result of regionalization whereby Alaska was placed in a separate region from Seattle, a new Alaskan biological laboratory was built at Auke Bay (suburb of Juneau), Alaska, and in 1956 the various programs concerning Alaska were transferred from the Seattle Laboratory to the laboratory at Auke Bay. Work at Auke Bay is described in a subsequent section.

Most of the work at Seattle was at that time concentrated within two areas, one concerning high seas fisheries, especially for salmon, and the other being concerned with passage of salmon at dams on the Columbia River. Most of the other scattered programs at Seattle were either dropped or combined as a minor part of the two major programs. A third, much smaller program concerning salmon in freshwater lakes or streams, was also developed.

The high seas program began as a result of the formation of the International North Pacific Fisheries Commission (INPFC) in 1953. The Bureau of Fisheries was

designated as one of the principal research arms of the U.S. section of this Commission and the Seattle Biological Laboratory, soon after 1953, began extensive research projects for the INPFC. The objectives of the overall INPFC research in very broad terms were undertaken for the purpose of insuring the maximum sustained productivity of the "fishery resources of the North Pacific Ocean and to encourage the conservation of such resources" (International North Pacific Fisheries Commission 1954). The objectives of the NMFS research more specifically were concerned with the distribution and movement of salmon in the North Pacific and on the identification and separation of the North American and Asian stocks of salmon inhabiting these waters (International North Pacific Fisheries Commission 1957).

In 1955 two research vessels engaged in surveys in which samples were taken in the North Pacific Ocean on each side of the Aleutian Island chain. In 1956 the work was expanded and five vessels participated. During this survey, which covered 2 million square miles from the coast of Washington and Oregon to long. 175° E, 195 gillnet sets were made at predetermined stations from May to September. For the next several years several thousand salmon samples were taken each year on the high seas. Fish taken were examined, measured, and frozen for return to Seattle for detailed analyses. In many cases blood samples of the fish were taken and frozen. Oceanographic measurements were made at many of the catching stations. Water samples were taken at different depths for subsequent chemical analysis and other measurements made, e.g., temperature. Ashore, research on collected samples involved various morphometric measurements, examination of fish scale characteristics, and serological tests of salmon blood.

In addition to collection and examination of samples, numerous tagging experiments were conducted. Such experiments gave direct evidence as to movement of the various races of salmon. It was hoped that one or more of the other examination procedures undergoing testing

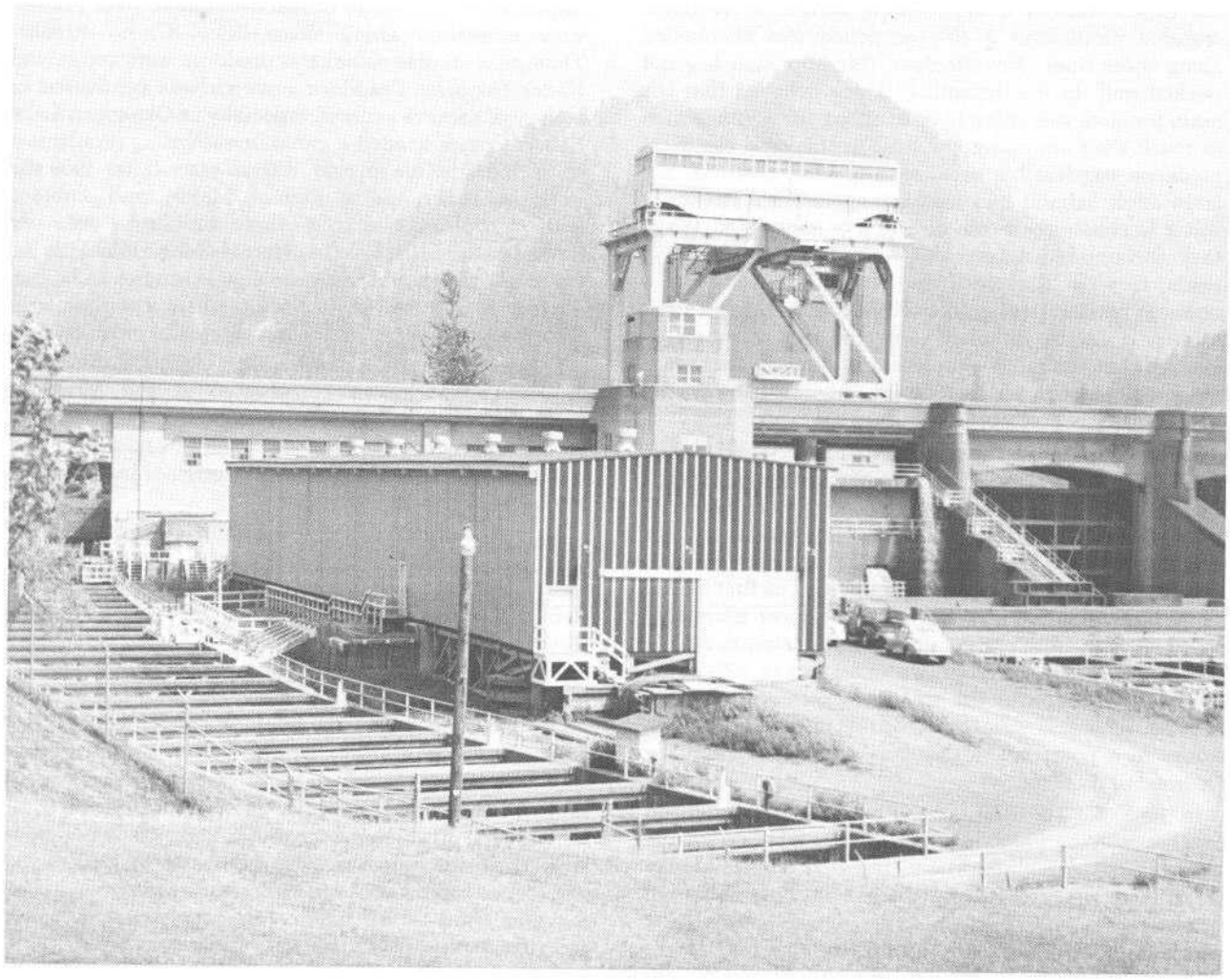
Sections of sockeye salmon scales to illustrate most obvious differences among fish from different areas. Area of scale between A and B represents growth during the first year in the ocean. Note that in Rivers Inlet, B.C., upper left, fish circuli in this growth zone are numerous and closely spaced. The circuli of the second ocean year are more widely spaced (broad pointer). Most fish from Asian areas, lower left, have the circuli widely spaced over the entire first ocean zone, or near the end of the zone (broad pointer) while most fish from Bristol Bay, lower right, have the widest circuli (broad pointer) near the freshwater zone (arrow A indicates the end of freshwater growth). Other differences also exist.

would prove to be a measure of the precise race of salmon involved.

The INPFC research was a massive program which extended over a period of many years. Results gradually evolved indicating that there was good correlation between scale characteristics and the particular geographic races of salmon. Quite good correlation also occurred between some of the morphometric measurements and race, but since these measurements were considerably more time consuming, the scale analysis was the method of choice. The serological method was found to be too sensitive a test in as much as it showed differences between different races of salmon but also between different groups of fish of the same race. It was also a more difficult test to perform both from the standpoint of sampling of blood and from the measurement techniques required.

The behavior studies related to problems of fish passage at dams expanded very rapidly during the 1952-66 period (Trefethen 1968). Examination was made of various procedures, many based upon sophisticated electronic methodology. This work led in two directions. On the one hand it resulted in development of new methods for tagging and tracking of fish, such as the use of the sonic tag. These new techniques became very useful in tracking the fish passing dams in the Columbia River and its tributaries. Another portion of the work involved use of various means for altering the direction in which salmon moved in ascending or descending the river. Much research was concentrated upon effects of pulses of electrical currents of different frequencies to repulse or attract fish, e.g., Raymond (1956). In other work, effects of light and sound were studied.

Two large-scale laboratory facilities were employed in this work. One of these was the Fisheries Engineering Research Laboratory on the Columbia River near Bonneville Dam. This facility was a tank 104 feet long, 24 feet wide, and 17 feet deep. It was supplied with moving water whose flow rate could be varied up to 200 cubic feet/second. Lighting within the roofed facility was adjustable using 80 1,000-W mercury vapor lamps. The laboratory was very useful for obtaining reproducible



Fish passage laboratory located adjacent to Bonneville Dam and used for research on fish guidance.

results when studying movements of large fish in water moving at different velocities and the attractant qualities of various hydraulic conditions in fishways.

The other facility was a smaller one constructed within a building at the Biological Laboratory in Seattle. The main experimental area consisted of a concrete tank about 60 feet long having a headbox at one end and a sump at the other, from which water could be recirculated employing four vertical axial flow pumps mounted over the sump. The width and depth of the tank could be adjusted up to 20 feet and 4 feet, respectively. Water velocity could also be adjusted. This facility provided the means for research on effects of different flow rates upon salmon close to the Seattle Laboratory, where other tests could be rapidly made in connection with the hydraulic studies.

From the earliest inception of thinking with regard to ways of guiding fish past dams on the Columbia River, even including the earliest work of Shirley Baker and his associates starting in the 1920's, the idea that electrical guidance would in all probability be the answer, was paramount. As a result, a tremendous effort involving the expenditure of a considerable portion of available research funds over a 40-year period was channelled along these lines. Nevertheless, this approach has not worked well. In the beginning, it was believed that the main problem was going to be enabling the adult salmon to reach their spawning grounds. In this case electrical guidance was feasible because in moving upstream the large adult salmon had mobility against the stream of water to choose their own direction of movement. When they encountered unfavorable factors such as electrical fields, they could avoid them. While the results of the research on electrical guidance indicated that the adult salmon could be directed along the proper course, it evolved that the much simpler improvements that gradually took place in physical design of better fishways did not require any accessory electrical apparatus.

On the other hand, the main difficulty occurred in preventing the small downstream salmon migrants from going through the turbines where they often were damaged or killed. Here the velocity of the water was often so high that the fish were unable to respond to any stimulus such as that of electrical guidance equipment. The first efforts along lines that today seem to be the most promising practical method of overcoming this downstream migration problem were initiated in a small way in 1964. This involved collection of the small downstream migrants above a dam and then transporting them in live tank trucks to a point below the dam where they could be returned to the river.

In 1965, for the first time, a project was begun on another problem which in future years was to become the basis for considerable additional research. This related to the adverse effect of supersaturated solutions of nitrogen in water (Ebel 1969). When water plunges over a dam, considerable air (which is four-fifths nitrogen) is entrapped as foam, and when it reaches the surface below the dam, the entrapped air is forced well below the surface where the nitrogen content soon exceeds the amount ordinarily soluble in the water. This supersaturated condition continues for some miles downstream and can cause fish, particularly salmon, to develop a condition known as gas bubble disease.

Another aspect of the fish passage program to which attention was being paid during this period was the effect of change in salmon environment where, in many cases, the erection of large dams caused the fish to live in large placid lakes above the dams in lieu of their former environment of a swift flowing river. One aspect of such a situation is the possibility of downstream migrants not continuing their descent through such large bodies of water but remaining in the lake. Here again the need for artificial collection and transport of the fish was being investigated.

Although the high seas work for INPFC and the fish passage over dams project in the Columbia River made up the largest portion of the work, several other small projects were also being pursued in the late 1950's and early 1960's. Most of these constituted a program headed by Kingsley Weber called Freshwater Studies. These were biological studies of salmon in lakes and rivers unconnected with passage of fish over dams. Four projects were underway along these lines. Under Richard Thompson studies on salmon preditors were conducted. Under Donovan Craddock research was conducted on biology of sockeye salmon, especially in Okanogan Lake. Robert French headed a group investigating problems of chinook and silver salmon in freshwater (after 1959 this work was supervised by Richard Major), and problems with chinook salmon in northern California were performed under supervision of Harold Gangmark. This latter investigation was begun to enable studies to be conducted in a warm environment where environmental factors would be expected to have a greater effect on fish.

In December 1964, a new building of 65,000 square feet of useable space was constructed at the Montlake Boulevard site in Seattle. This increased useable laboratory and office floor space several fold over that which had been available since the original building had been occupied in 1931.

At the end of 1965, Clinton Atkinson left his position as laboratory director to accept the position of Fishery Attache in Tokyo. His position at Seattle was filled by Gerald Collins, who remained as laboratory director through 1971.

The general research areas during the period when Collins headed the laboratory remained similar to those immediately preceding the period although there was considerable reorganization. Several new program aspects were also begun including: 1) an expansion in oceanography programs, under Felix Favorite, with a total of 13 individuals, of which 6 were professional grade oceanographers, in the program. With launching in 1967 of the 215-foot research vessel *Miller Freeman* with capacity for carrying nine scientists, much improved floating facilities for oceanographic work became available. 2) A salmon aquaculture program was started based at temporary facilities at Manchester, Wash., across Puget Sound opposite West Seattle. 3) a section on Physiology

and Biochemistry was organized under supervision of Harold Hodgins. 4) Some biological work on hake was undertaken. 5) New studies were initiated on effects of changes in the environment upon fish, especially in 1969 in connection with thermal effects caused by heat from thermonuclear electricity generating plants and on pollution from petroleum spilled in the environment, which was first begun in 1968.

The high seas salmon program largely concerned with INPFC research continued as in previous years. The fish passage program also continued with increasing effort on transportation of downstream migrants around dams and on nitrogen supersaturation problems. Another valuable tool for use in fish passage research was developed—a radio-frequency fish tag and tracking device (Monan et al. 1975). This type of tag was first developed in 1956 but was greatly improved by research over the next 15 years for use in highly turbulent waters such as just below a large dam where turbulence interferred with the effective use of sonic tags.

In the new aquaculture project coho salmon were reared from 0.3 ounce to marketable size of 0.5 pound within 6 months. Similar work was continuing on raising of market size chinook salmon.

As of 1 January 1968, the staff was reorganized into units as shown in Tables 2 to 4, inclusive, where program leaders and number of total workers are given, also for the Marine Research Program (Table 2), for the Freshwater and Estuarine Research Program (Table 3), and for miscellaneous units (Table 4). The Biometrics Institute was a new group which served other programs with assistance in statistical and biometric problems and which also functioned on a program basis in the high seas INPFC area.

Tables 2, 3, and 4 show the organization of the laboratory under Collins not long before formation of NWFC.

Table 2.—Personnel in Marine Research Programs in 1969; Assistant Laboratory Director, Francis M. Fukuhara.

Program	Program leader	Total staff
Groundfish	Herbert A. Larkins	7
Identification of fish stocks	Richard L. Major	8
Marine behavior	Richard B. Thompson	5
Ocean distribution, migration and abundance of salmon	Robert R. French	6
Oceanography	Felix Favorite	13
Physiology and biochemistry	Harold O. Hodgins	7

Table 3.—Personnel in Freshwater and Estuarine Research in 1969; Assistant Director, Carl Elling.

Program	Program leader	Total staff	Remarks
Behavior laboratory	Alan B. Groves	5	
Fingerling collection	Daniel W. Bates	2	Located at Portland
Migration rates and timing	Howard L. Raymond	6	Worked at several field stations on the Columbia River
Turbine studies	Clifford Long	6	Worked at Pasco, Wash., field station
Prediction of environment	George R. Snyder	4	Worked at Seattle and Prescott, Oreg.
Production in inaccessible areas	Leonard A. Fulton	1	
Sonic fish tracking	James H. Johnson	7	
Transportation of migratory fish	Wesley J. Ebel	1	

Table 4.—Personnel in miscellaneous units in 1969.

Program	Program leader	Total staff
Biometrics Institute	Reynold A. Fredin	14
Engineering & gear development	Winston E. Farr	3
Publication unit	Roger E. Pearson	7
Staff services	Gerald E. Monan	2
Vessels operations	Ralph E. Sandvigen	2
Research Vessel *George B. Kelez*	Roy L. Robek (Master)	10
Research Vessel *Miller Freeman*	Harry J. Jacobsen (Master)	15
Administration	Beryl P. Mortensen	11

BIOLOGICAL RESEARCH AT AUKE BAY, 1956-76[2]

Activities

Fisheries in the Territory of Alaska were managed by the Federal Government until the advent of statehood in 1959. In 1955, Secretary of Interior McKay issued a statement transferring Donad McKernan to Alaska to fill the newly established post of Alaska Fishery Administrator.

[2]This section was prepared by Robert R. Simpson of the Auke Bay Laboratory.

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 anagement 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 and a fresh staff of biologists had to be recruited. Research concerned with the INPFC remained in Seattle. William Royce was appointed as the Assistant Administrator in charge of Research and he established a new Alaska commercial fisheries group that was initially based in the Alaska-Juneau Mine Building in 1957. 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. He also established salmon survival investigations in southeastern Alaska, Bristol Bay, and Kodiak. A Marine Fish Investigation was established primarily for herring and king crab studies and a Biometrics Unit was established to service the other research activities. Other individuals involved in the new research organization were Harry Rietze, Charles DiCostanzo, Theodore Merrell, Richard Myron, Richard Straty, Chester Mattson, Fred Thorsteinson, Norman Willimovsky, and Howard Tait. George Y. Harry replaced Royce when he resigned in 1958 to become director of the Fisheries Research Institute 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 George Harry. In 1967, Harry transferred out of Alaska and William A. Smoker became the Auke Bay Laboratory Director. 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 square feet 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 has the longest continuous operation of all Alaska fisheries facilities. 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 to present. 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 freshwater. In the 1970's 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 Service's 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 Fed-

First field station in Alaska. Still in operation, this facility was established at Little Port Walter in 1940.

eral management of Alaska's fisheries and during the period 1956-60 it supported the seasonal activities of nearly 100 full-time permanent and temporary personnel. During recent years the King Salmon base has been in caretaker status.

The Brooks Lake field station at Bristol Bay was established in 1940, enlarged in 1958 and 1960, and was forced to be abandoned in 1973 because of severe bear depredation 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.

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 reemphasis during th latter part of the 1960's for determining the effects of the Great Alaska Earthquake on production of pink salmon in Prince William Sound.

Although Karluk Lake on Kodiak Island has been a site for intermittant Federal sockeye salmon research since 1921, the program was expanded in 1956, and the main living and field laboratory 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 adult escapements and smolt migrations have been continued by the Alaska Department of Fish and Game.

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-rond field facility for shellfish research. Studies at this station have been concerned with: 1) life history of Alaska shrimp and crab pecies; 2) population dynamics leading to derivation of regulated annual harvest levels of Kachemak Bay shrimp; and 3) 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 NWAFC's Kodiak faciity.

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 land based. Exceptions to this mode 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 facilitie were installed at Auke Creek and a massive freshwater pipeline serving new hatchery and rearing facilities at Little Port Walter were all installed with substantial assistance and funding from the State of Alaska.

By the 1970's the activities at the Auke Bay Laboratory focused on research and development of salmon ocean ranching, studies of the impacts of petroleum 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 which was part of the National Marine Fisheries Service (NMFS), except for that at Auke Bay, became a part of the Northwest Fisheries Center when it was formed in 1971. The Auke Bay Laboratory in 1976 became a part of what was then renamed the Northwest and Alaska Fisheries Center.

Intensive planning is now underway for orienting a dominant part of the laboratory's activities into the Center's MARMAP-Fisheries-Oceanography program which now has national emphasis within NMFS. The collective activities of the laboratory will focus on studies of the environmental processes that operate in the nearshore community during the egg-through-early-juvenile life of a species and that govern year-class strength of fish populations. Such research will accelerate our understanding of resource-environment interactions and aid the center in identifying indices that permit establishing long-range forecasts of marine fisheries managed by State and national regulatory agencies.

Accomplishments

A number of notable accomplishments produced by individual scientists and research team members of the staff have brought regional recognition and credit to the Auke Bay Laboratory (ABL). This recognition is indicated by a multitude of close alliances that have been evolving between the laboratory and agencies of the Alaska and Federal governments 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 a sharing of facilities, personnel, logistics, and other program costs. Members of the Laboratory serve on the Governor's Fishery Council that was 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 Alaska fish. The U.S. Fish and Wildlife Service has sponsored and recurringly renewed a contract with ABL 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

Auke Bay Laboratory, located near Juneau, has been in use since 1960.

crab resources has been accomplished in harmony with counterpart members of the Alaska Department of Fish and Game.

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 the 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 1950's.
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 methodology 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 that is now used and refined by the Alaska Department of Fish and Game 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 samon streams in southeastern Alaska and for research in Bristol Bay to determine impacts of predation and lake fertilization on sockeye salmon smolts, to develop a description of lake environment supporting sockeye salmon, and to derive indices of smolt migrations.

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 tanner crab stocks that were being harvested in multinational fisheries. Developed a yield-per-recruit model used for establishing annual harvest levels of Bering Sea king crab.
3. Developed a complete description of larval stages of major pandalid shrimp species.

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 the dynamics of herring populations, schooling ecology, determined rates of growth and mortality, estimated sizes of spring spawning populations and, in recent years, allied with the State to assess wintering stocks harvested in new food herring fisheries. Perfected methods of tagging herring.

General

Assisted in the creation of a comprehensive State of Alaska Fisheries Management Policy—that declares 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 with 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 and was nearly devoid of bottom organisms. Criteria for recommending permitting of sites for log dumping to minimize effects on fishery resources are based on these surveys.
4. Tested the effects of aerial spraying of DDT on fish and aquatic insects in forest streams and achieved a local moratorium before use of DDT became forbidden by national laws. Determined critical toxicity levels of various concentrations of a herbicide (2-4-D) on salmonids in Alaska watersheds. Pinpointed residual DDT accumulations in freshwater fishes throughout Alaska.
5. Provided key information on Kachemak Bay shrimp and crab nursery areas 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 to 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. 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 Great 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-Alaska Pipeline and recommended procedures to minimize damage at stream crossings.
13. Defined oceanic conditions in several areas that were considered for abrupt 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, technology, and development of Alaska salmon

species and a concomitant alliance with the Alaska Department of Fish and Game and with the Governor's Council for restoration of salmon resources.

1. Published the very popular Salmon Ranchers Manual that translates findings in salmon hatchery and rearing research into a practical state-of-the-art 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.

MARINE MAMMAL RESEARCH—1890 to 1971[3]

The work on marine mammal research is described separately from that of the other biological research conducted at Seattle because this project, for much of the time it operated, reported directly to the Washington Office and was never a part of the Seattle Biological Laboratory.

Sealing for fur seals was conducted by the Russians between 1798 and 1862. So far as is now known, no scientific work was performed during that period before Alaska was sold to the United States. By 1868 sealing was conducted by four private U.S. companies. In 1868 Congress passed a law forbidding private sealing in the Pribilof Islands area and all such activities were conducted by the U.S. Government, first within the Treasury Department starting in 1868. As mentioned earlier, the U.S. Fish Commission vessel *Albatross* was used between 1890 and 1895 to obtain biological information to support the U.S. position at the international hearing at Paris to settle disputes among U.S., Canada, and Japan. In 1910 the Bureau of Fisheries was appointed to administer the sealing operations for fur seals in the Pribilofs. A position of Naturalist was established for making scientific observations. During the period 1910 to 1913 four different individuals served in this capacity. Only the second of these, Walter L. Holin, took an active interest in biological studies. He set up a small, temporary laboratory converted from an abandoned native hut upon his arrival in August 1910. Unfortunately, he drowned the next summer and succeeding holders of the position failed to show much interest in scientific endeavors. This position was abolished in 1913.

In 1914 a semiscientific study was conducted on Pribilof sealing by a commission, composed of Osgood, Prible, and Parker, appointed by the National Academy of Sciences. Although these individuals were not scientists, they did set about their work in a business-like manner. They made a census of the seal rookeries and they developed a seal management set of criteria for certain routine techniques such as counting bulls and pups, measuring rookery areas, photographing the rookeries, and estimating age composition. These criteria, established by 1915, were used by the Bureau of Fisheries for the succeeding 25 years. Although they were not developed in a scientific manner, at least they resulted in statistics being collected in a uniform manner so that data could be compared from one time period to another.

By 1939 the growth of the seal population had ceased with some indication that a decline might be occurring. In 1940, after formation of the U.S. Fish and Wildlife Service, Ira Gabrielson, head of the new agency, visited the Pribilof Islands. As a result of his interest in fur seal research, in 1941 an appropriation of $290,000 was obtained from Congress for purchase of a vessel and employment of research biologists. A vessel, the *Black Douglas,* was purchased and a staff of six biologists employed; Victor Scheffer, biologist in charge, plus biologists A. Henry Banner, Kelshaw Bonham, Wilbert Chapman, Donald D. Shipley, and Ford Wilke. A research trip of the *Black Douglas* was made during the fall of 1941, and 10,000 seal pups were tagged. In 1942, because of the imminence of war, all work on this project terminated. The natives were evacuated from the Pribilof Islands and sealing operations ceased. In 1943 sealing operations were resumed and one biologist was sent to St. Paul Island. In 1944 to 1946, Scheffer made trips to the fur sealing operations and was accompanied in 1945 by one American biologist and in 1946 by two Canadian biologists. The main biological program and the special funding provided in 1941, however, were not available at this time.

In 1947, with the war over, the *Black Douglas* was returned to the Bureau of Fisheries and two biologists, William Sholes and Karl Kenyon, were employed. They and Scheffer made two trips to the Pribilofs, and 19,000 seal pups were tagged. In 1948 the seal rookeries in the Pribilofs were photographed. Although the full-time permanent scientific staff at this stage numbered only three individuals, funding permitted hiring additional summer scientific staff. In 1949 biologists C. Abegglen, C. Fiscus, A. Y. Roppel, V. Scheffer, and F. Wilke worked on the islands.

The size of the program remained small during most of the 1950's, even smaller than what had been planned before the war in 1941 when the program was first initiated.

In 1953 Victor Scheffer, who had been in charge of the laboratory activities since the program began in 1941, was transferred to another program and leadership of the Pribilof operations was assumed by Ford Wilke. Toward the end of the 1950's, some staff expansion occurred. In 1957 Karl Niggol was employed as a biologist and put in

[3]Some of the facts cited on early marine mammal research were obtained from the following manuscript: Scheffer, V. B., and E. I. Todd. 1967. History of scientific study of the Alaskan fur seal 1786-1964. Unpubl. manuscr., 324 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

charge of pelagic research. Clifford Fiscus joined the staff in 1958 and when Karl Niggol left in 1962, Fiscus replaced him as head of pelagic research. In 1962 Mark Keyes was employed as veterinarian, giving the program expertise in the disease field.

The programs in 1958, which will be described here, are typical of what was being done then and in succeeding years. Two major operations were conducted. One of these investigated migrations of seals from southern California to the Pribilofs. The first major work in this field started in 1958 under the terms of the Interim Convention of the North Pacific Fur Seal Program which was a 6-year investigation. Three vessels were chartered for the operation extending from 1 February to 1 July. The vessels operated from the northern portion of the Channel Islands (California) to Bristol Bay. A total of 7,024 seals were encountered, of which 1,503 were collected. Age of the seals was determined (using external and internal growth ridge procedures). The pregnancy rate for seals 4 to 22 years of age was found to be 74%. There was no correlation between water temperature and density of seals in any of the areas observed. Feed, as observed from stomach contents, varied with location. Off California 73% of the food was found to be saury, hake, and anchovy. These items accounted for 83% of the food off Oregon. Off Alaska 93% of the feed was herring, capelin, sand lance, and Alaska pollock. Salmon was a very minor food, occurring in only 1 seal off Washington and 12 off Alaska.

The other main part of the activities was conducted in the Pribilofs. The program activities in 1958 concerned: 1) population studies (age distribution of male seals, tagging and tag recovery, homing tendancies, census of bull seals, and weighing of seal pups); 2) reproduction studies (including lactation); 3) mortality studies; and 4) related studies which included blood studies and a study of fur seal pelage.

In the years after 1958 the size of the staff showed a gradual increase until a more or less stable size of about 12 full-time permanent scientists was reached by the mid-1960's.

One aspect which was prominent in the 1962-71 period was the investigation into causes of seal mortality. Prior to 1962, a decade-long series of research contracts with a parasitologist at Colorado State University provided much of the mechanism of the action of hookworm in seals, a leading cause of seal deaths. In 1971, while working as veterinarian on the Pribilofs, Mark Keyes and his assistants examined close to 2,000 dead seal pups to determine the causes of death. Most of the deaths (73% in 1971) have been due either to malnutrition or hookworm disease. A modern laboratory for clinical pathology was started in the basement of the physician's quarters on St. Paul Island where microbiology, histopathology, parasitology, chemistry, and other types of examination were made. Numerous secondary causes of death of pups, in addition to hookworm disease, have been found. Research has also led to development of a whole fish-kelp feed for seal pups compounded in line with their nutritional requirements.

The work also was augmented by initiation during this period of biological studies of whales undertaken to aid in enforcing newly inaugurated whaling regulations. The work included collection of information on size, age, sex, reproduction, parasites, abnormal conditions, food, distribution, migration, and population dynamics. This work, although based from Seattle, was performed in California where the shore-based whaling stations were located.

In 1970, Ford Wilke retired as director of marine mammals research and his position was filled by George Harry.

EXPLORATORY FISHING AND GEAR DEVELOPMENT ACTIVITIES

Early Work Prior to 1949

Although work in the field of exploratory fishing and gear development did not start within the Bureau of Fisheries as a separate endeavor until 1949, considerable work involving related objectives was conducted earlier as a part of other activities. Among the earliet such work off the North Pacific coast were expeditions as those of the U.S. Fish Commission steamer *Albatross* which, for example, in 1899 explored waters off Oregon, Washington, and southeast Alaska and in 1900 in Bristol Bay. Such work, although employing in some cases trawling gear, was conducted not with any particular view toward finding productive commercial fishing grounds but more from the standpoint of classification of species occurring in different waters.

The first major commercially oriented venture in North Pacific coast waters performed by the Federal Government was the Bureau of Fisheries' Alaska king crab expedition conducted during the summers of 1940 and 1941 (Anonymous 1942). No successful American king crab industry had been operated until that time although a large Japanese industry had been operating in nearby waters for more than a decade. The U.S. Congress authorized, in 1940 and again in 1941, expenditure of funds for work to establish areas of abundance of king crab in Alaskan waters, methods by which such crab could best be caught, and preservation methods. This two-season study established the necessary basic knowledge so that after cessation of hostilities of World War II, a very large U.S. king crab industry was initiated in 1947.

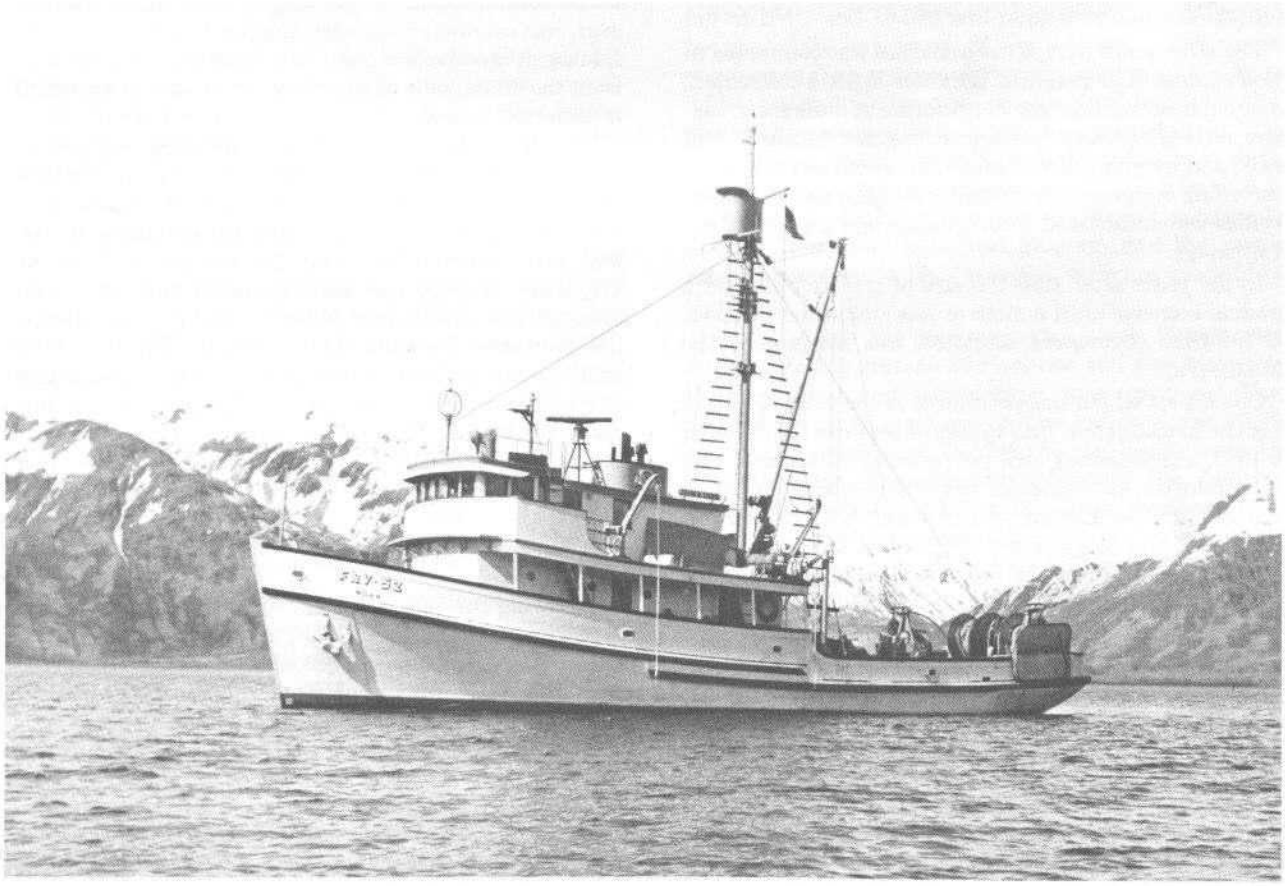
Following the end of the active work of the king crab expedition and before the beginning of formal operations under a new unit in 1949, some work was conducted from the Seattle Technological Laboratory by fishery engineers. Several of the staff of the crab expedition, but chiefly Carl Carlson, who was on the payroll of the Alaska Fishery Experimental Station, remained at Seattle to prepare further reports from the king crab data. Carlson's activities at Seattle then shifted over to aid given to the Reconstruction Finance Corporation (RFC), an agency of the U.S. Government, in connection with design and construction of a Government-owned factory

ship for processing large quantities of fish in Alaskan waters. This vessel, the *Pacific Explorer,* was constructed but not completed until after the end of World War II. Although the vessel was Government financed with the aim of boosting production of additional protein food in connection with the war, since the vessel was already available, the Government operated it on a contract basis for one trip into Alaskan waters for otter trawl production of bottom fish and one trip in southern waters for production of tuna. Carlson worked closely on the vessel aspects of this operation.

By 1947 the operations for both the king crab expedition and the *Pacific Explorer* ventures were completed, but it was by then quite certain that an Exploratory Fishing and Gear Development unit was to be set up shortly. During 1948, therefore, exploratory fishing and gear development activities were started within the Seattle Technological Laboratory, under Maurice Stansby, with the aim of having a working group organized and ready to operate on the Pacific coast just as soon as the new activity could be developed. Funds amounting to $92,680 were available for Exploratory Fishing operating expenses as of 1 July 1948.

The MV *Washington,* which had been a part of the RFC's Pacific Exploration Activities, was transferred to the Seattle Laboratory in July 1948 to be used in the new Exploratory Fishing Project. The *Washington* made a trip to the Bering Sea, leaving Seattle on 23 August. Aboard this trip were Joseph G. Ellson, who had been designated as Project Leader for the new Exploratory Fishing Project at Seattle; Boris Knake, a fishery engineer temporarily detailed to Seattle from the Bureau's program in Boston; John Dassow (for a part of the trip); plus the vessel crew under Edwin J. Hansen. Late in 1948 it was decided that the *Washington* was not suitable for the kind of activities needed in the Seattle-based operation, and this vessel was sold for $150,000, which was applied toward construction of a new vessel to be named the *John N. Cobb.* During the first part of 1949, most of the time was spent upon plans for the *John N. Cobb*; therefore, during the summer of 1949, the *Deep Sea* was chartered for summer field work.

Also, during 1949 work was being performed in Seattle toward development of an Exploratory Fishing Unit for operating in a new laboratory in Honolulu, which was to conduct a program then known as the Pacific Oceanic Fishery Investigation (POFI). Carl Carlson and another fishery engineer, Thomas Roseberry, were stationed at Seattle during 1948 making preparations for fishery engineering work in the POFI program as soon as the Honolulu laboratory building was completed. Although Carlson and Roseberry were transferred in 1948 to the



John N. Cobb, **built in 1949 for exploratory fishing, has been in use since then.**

new Honolulu laboratory and an exploratory fishing unit started, the program operated for only about 2 years and was then discontinued.

Later in the year the Exploratory Fishing Project was transferred from the Technological Laboratory to work as a separate entity, remaining under the local supervision of Joseph Ellson, who reported to Richard Whiteleather in the Washington Office.

Work from 1949 Through 1971

Atlantic Coast Precedents for Exploration and Gear Work

When the Exploratory Fishing and Gear Development Branch was established in 1949, the Bureau of Fisheries had other precedents for such an endeavor beyond what has been mentioned here. During the period from the late 1920's until about 1940, considerable work was performed upon methods of preserving fish nets by chemical means, especially by W. T. Conn. This work was performed both for nets as used along the North Atlantic coast and for nets used in the Great Lakes. During the late 1930's, the Bureau of Fisheries had a Technological Laboratory at Mayaguez, Puerto Rico, set up for the purpose of attempting to greatly enlarge the utilization of fish from nearby waters. One major activity of this program was an exploratory fishing program in the vicinity of Puerto Rico and the Virgin Islands. When these efforts revealed that there were insufficient stocks of fish in these areas to support a commercial fishing industry, these operations were transferred to a program under the coordination of the Anglo-American Caribbean Commission with the program centered at Trinidad.

Unit for Exploratory Fishing Established

Coincident with a rapid improvement in survey methods and equipment that occurred after World War II was a growing realization that simple pre-war concepts of exploratory fishing were not adequate to provide the detailed knowledge required for efficient use of the oceans' living resources. Until World War II, "exploratory fishing" was more often thought of as simply cataloging the fauna, scouting for commercial quantities of fish, and relaying the information to fishermen. This simplistic approach did not meet post-World War II needs for detailed information on fisheries resources and stocks brought about by increased harvests in all the world's oceans. It also did not account for effects of environmental changes—both natural and man-induced—which often had an equal or greater effect on the condition of fisheries resources than the removals by man.

Establishment of a Section—later renamed Branch—of Exploratory Fishing[4] in 1949 was in response to the needs for broader scientific and geographic study of fisheries resources and their environment, and a better understanding of the economic and conservational aspects of using various harvest systems. "Exploratory fishing" now involves assessing both latent and utilized resources from the standpoint of their relation to other elements within the ecosystem, their distribution and abundance in time and space, and their relation to environmental properties. It provides for 1) cataloging and describing all faunal elements available to different sampling and fishing gear, 2) describing the zoogeographic distribution patterns of animals encountered and the relationship of the patterns to environmental features, 3) determining the abundance of the animals in time and space and their vulnerability to different gears, and 4) estimating the size of important resources and the physical yields that these resources might provide mankind.

As practiced today, exploratory fishing involves a blending of many skills, including those possessed by fishery biologists, animal behavioral specialists, oceanographers, experts on fishing and sampling gears, and engineers. Major emphasis has been on the practical application of results to bring about efficient utilization of the resources by industry. Of equal and less obvious value has been the contribution to the general body of scientific knowledge about our fisheries resources and their environment.

Program at Seattle Base, 1949-59

In late 1949 the Exploratory Fishing Program began in Seattle as a part of the new national program. Because of the earlier informal endeavor conducted as part of Technology, this program was already an active one with two cruises in Alaska completed during the summers of 1948 and 1949. A new vessel, the *John N. Cobb,* designed specifically for exploratory fishing and gear development, was under construction and nearly complete at the time that the full implementation of the program at Seattle was initiated during the autum of 1949. It was, therefore, possible to get into full operation during 1950. The Seattle program was under the local supervision of Joseph G. Ellson. Table 5 lists chiefs of the North Pacific Exploratory Fishing operations from 1949 to 1971.

During the first 10 years of operation at Seattle as an Exploratory Fishing and Gear Research entity, the work

Table 5.—Individuals serving as Chief, North Pacific Fisheries Exploration and Gear Research, 1949-71.

Individual	Dates
Joseph G. Ellson	1949 to July 1950
Donald E. Powell[1]	July 1950 to March 1951
Joseph G. Ellson	March 1951 to April 1955
Donald E. Powell	April 1955 to April 1958
Dayton L. Alverson	April 1958 to December 1968
A. T. Pruter	January 1969 to September 1971

[1]Joseph Ellson was Chief of Branch of Exploratory Fishing and Gear Development, Washington, D.C., from July 1950 to March 1951.

[4]This subsection on establishment of the Branch of Exploratory Fishing was written by A. T. Pruter in connection with the Centennial ceremonies of the Bureau of Fisheries and is used here without change.

new Honolulu laboratory and an exploratory fishing unit started, the program operated for only about 2 years and was then discontinued.

Later in the year the Exploratory Fishing Project was transferred from the Technological Laboratory to work as a separate entity, remaining under the local supervision of Joseph Ellson, who reported to Richard Whiteleather in the Washington Office.

Work from 1949 Through 1971

Atlantic Coast Precedents for Exploration and Gear Work

When the Exploratory Fishing and Gear Development Branch was established in 1949, the Bureau of Fisheries had other precedents for such an endeavor beyond what has been mentioned here. During the period from the late 1920's until about 1940, considerable work was performed upon methods of preserving fish nets by chemical means, especially by W. T. Conn. This work was performed both for nets as used along the North Atlantic coast and for nets used in the Great Lakes. During the late 1930's, the Bureau of Fisheries had a Technological Laboratory at Mayaguez, Puerto Rico, set up for the purpose of attempting to greatly enlarge the utilization of fish from nearby waters. One major activity of this program was an exploratory fishing program in the vicinity of Puerto Rico and the Virgin Islands. When these efforts revealed that there were insufficient stocks of fish in these areas to support a commercial fishing industry, these operations were transferred to a program under the coordination of the Anglo-American Caribbean Commission with the program centered at Trinidad.

Unit for Exploratory Fishing Established

Coincident with a rapid improvement in survey methods and equipment that occurred after World War II was a growing realization that simple pre-war concepts of exploratory fishing were not adequate to provide the detailed knowledge required for efficient use of the oceans' living resources. Until World War II, "exploratory fishing" was more often thought of as simply cataloging the fauna, scouting for commercial quantities of fish, and relaying the information to fishermen. This simplistic approach did not meet post-World War II needs for detailed information on fisheries resources and stocks brought about by increased harvests in all the world's oceans. It also did not account for effects of environmental changes—both natural and man-induced—which often had an equal or greater effect on the condition of fisheries resources than the removals by man.

Establishment of a Section—later renamed Branch—of Exploratory Fishing[4] in 1949 was in response to the needs for broader scientific and geographic study of fisheries resources and their environment, and a better understanding of the economic and conservational aspects of using various harvest systems. "Exploratory fishing" now involves assessing both latent and utilized resources from the standpoint of their relation to other elements within the ecosystem, their distribution and abundance in time and space, and their relation to environmental properties. It provides for 1) cataloging and describing all faunal elements available to different sampling and fishing gear, 2) describing the zoogeographic distribution patterns of animals encountered and the relationship of the patterns to environmental features, 3) determining the abundance of the animals in time and space and their vulnerability to different gears, and 4) estimating the size of important resources and the physical yields that these resources might provide mankind.

As practiced today, exploratory fishing involves a blending of many skills, including those possessed by fishery biologists, animal behavioral specialists, oceanographers, experts on fishing and sampling gears, and engineers. Major emphasis has been on the practical application of results to bring about efficient utilization of the resources by industry. Of equal and less obvious value has been the contribution to the general body of scientific knowledge about our fisheries resources and their environment.

Program at Seattle Base, 1949-59

In late 1949 the Exploratory Fishing Program began in Seattle as a part of the new national program. Because of the earlier informal endeavor conducted as part of Technology, this program was already an active one with two cruises in Alaska completed during the summers of 1948 and 1949. A new vessel, the *John N. Cobb,* designed specifically for exploratory fishing and gear development, was under construction and nearly complete at the time that the full implementation of the program at Seattle was initiated during the autum of 1949. It was, therefore, possible to get into full operation during 1950. The Seattle program was under the local supervision of Joseph G. Ellson. Table 5 lists chiefs of the North Pacific Exploratory Fishing operations from 1949 to 1971.

During the first 10 years of operation at Seattle as an Exploratory Fishing and Gear Research entity, the work

Table 5.—Individuals serving as Chief, North Pacific Fisheries Exploration and Gear Research, 1949-71.

Individual	Dates
Joseph G. Ellson	1949 to July 1950
Donald E. Powell[1]	July 1950 to March 1951
Joseph G. Ellson	March 1951 to April 1955
Donald E. Powell	April 1955 to April 1958
Dayton L. Alverson	April 1958 to December 1968
A. T. Pruter	January 1969 to September 1971

[1]Joseph Ellson was Chief of Branch of Exploratory Fishing and Gear Development, Washington, D.C., from July 1950 to March 1951.

[4]This subsection on establishment of the Branch of Exploratory Fishing was written by A. T. Pruter in connection with the Centennial ceremonies of the Bureau of Fisheries and is used here without change.

Table 6.—Exploratory fishing and gear testing cruises, 1940-58, from Seattle based operations.

Type of investigation	Cruises made	Remarks
Crab	1) 1940 and 1941 (summers) King Crab Program Alaska; 2) 1948 factory ship operation March to July 1948; 3) Cruise 32 *John N. Cobb* May to October 1957.	Operation furnished basis for development of U.S. king crab fishery in Alaska.
Shrimp	1) Cruise 7 *John Cobb* Alaska March to May 1951; 2) Cruise 15 *John Cobb* Alaska March & April 1953; 3) Cruise 20 *John Cobb* Alaska July-Sept. 1954; 4) Cruise 24 *John Cobb* Washington Oct. & Nov. 1955; 5) Cruise 26 *John Cobb* Washington Mar. & Apr. 1956; 6) Cruise 36 Wash. & Oreg. *John Cobb* Mar. & Apr. 1956; 7) Cruise 37 *John Cobb* Wash. & Oreg. Apr. & May 1958; 8) Cruise 38 Oreg. *John Cobb* June 1958; 9) Cruise 39 *John Cobb* Alaska July-Sept. 1958; 10) Cruise 40 Wash. *John Cobb* Oct. 1958.	Furnished basis for expansion of the Alaskan shrimp industry.
Scallops	1) Cruise 11 Wash. *John Cobb* May-June 1952.	
Misc. shellfish	1) Cruise 6 Alaska *John Cobb* Oct.-Dec. 1950.	
Albacore tuna	1) Cruise 5 Oreg. *John Cobb* June-Sept. 1950; 2) Cruise 8 Oreg. *John Cobb* June-Aug. 1951; 3) Cruise 12 Calif., Oreg., Wash. *John Cobb* June-Aug. 1952; 4) Cruise 28 Calif., Oreg., Wash., British Columbia *John Cobb* July-Aug. 1956.	Cobb Seamount discovered on Cruise 28.
Bottomfish misc.	1) Cruise 9 Wash. *John Cobb* Aug.-Oct. 1951; 2) Cruise 13 Wash. & Oreg. *John Cobb* Aug.-Oct. 1952; 3) Cruise 18 Alaska *John Cobb* Feb.-Apr. 1954; 4) Cruise 20 Alaska *John Cobb* July-Sept. 1954; 5) Cruise 25 Wash. *John Cobb* Feb.-Mar. 1955; 6) Cruise 29 Alaska *John Cobb* Oct. & Nov. 1956; 7) Cruise 32 Alaska *John Cobb* May-Oct. 1957; 8) Cruise 35 Wash. *John Cobb* Feb. 1958.	
Bottomfish-sole	1) Factory ship operation Alaska Mar.-July 1948; 2) Cruise 22 Wash. *John Cobb* Mar. 1955	
Bottomfish-rockfish	1) Cruise 34 Wash. *John Cobb* Oct. & Nov. 1957.	
Dogfish	1) Cruise 34 Wash. *John Cobb* Oct. & Nov. 1957.	
Hake	1) Cruise 34 Wash. *John Cobb* Oct. & Nov. 1957.	
Herring	1) Cruise 14 Alaska *John Cobb* Nov. & Dec. 1952; 2) Cruise 17 Alaska *John Cobb* Nov. & Dec. 1952; 3) Cruise 33 Alaska (Southeast and Central) *John Cobb* July & Aug. 1957.	
Salmon	1) Cruise 16 Alaska *John Cobb* May-Aug. 1953; 2) Cruise 23 Alaska *John Cobb* June-Sept. 1955.	
Gear studies	1) Cruise 19 Wash. *John Cobb* June 1954; 2) Cruise 21 Wash. *John Cobb* Oct. 1954; 3) Cruise 27 Wash., Oreg. *John Cobb* May-June 1956; 4) Cruise 30 Wash., Alaska *John Cobb* Feb.-Apr. 1957; 5) Cruise 31 Wash. *John Cobb* May-June 1957; 6) Cruise 34 Wash. *John Cobb* Oct.-Nov. 1957.	All gear work dealt with development of mid-water trawl except Cruise 21 on fish pumps. The work provided the basis for development of a Puget Sound hake fishery.

was largely with exploratory fishing. Table 6 summarizes the operations during this period. Considerable effort was expended on two types of work—exploration for shrimp and for bottomfish. Ten cruises were made in which shrimp was the major species under consideration and eight cruises for bottomfish. Although only two cruises studied salmon, these were very long cruises extending over several months each and represented major endeavors. Four cruises were devoted to exploration activities concerning tuna, three for crab, and another three for herring. Other species for which the major portion of one cruise was expended included miscellaneous shellfish, scallops, rockfish, and hake. In addition, one cruise was concerned with factory ship problems and five with operation of midwater trawl gear.

Program at Seattle Base, 1959-71

Starting in 1959 and extending until the late 1960's, a major part of the operations, in addition to general exploratory fishing, concerned a study of the effects of changing environment upon fish, especially as related to atomic energy operations. A number of research grants were obtained from the Atomic Energy Commission to make such studies. The first of these was concerned with the project "Chariot" proposal which, under the "Plowshare Program," would have involved use of atomic explosions for peace-time activities in connection with development of harbors in Alaska in the vicinity of the Chukchi Sea. Certain bioenvironmental studies were conducted from 1959 to 1960 (Alverson and Wilimovsky 1961) in connection with this proposal before it was abandoned in 1962. The Exploratory Fishing Base at Seattle became involved in this work in connection with baseline studies of the numbers of marine organisms near the proposed site.

Of greater magnitude was the work conducted near the mouth of the Columbia River. This program, which was also funded by the Atomic Energy Commission, concerned potential changes in fish populations caused by discharge into the ocean of water containing small amounts of radionuclides. These substances were present in the water as a result of the Atomic Energy Commission's operation at Hanford, Wash., of a nuclear plant

Professional staff, in 1958, of the Exploratory Fishing ad Gear Development Base in Seattle aboard the *John N. Cobb*. Left to right: Melvin Greenwood, Harold Johnson, Dayton Lee Alverson, and Richard McNeely.

which used water from the Columbia River. This program continued as a monitoring one throughout the 1960's until most of the reactors were shut down.

The exploratory fishing aspects continued throughout the 1960's. During the 1950's, the abundance of fish was estimated largely through fishing operations based on use of commercial fishing gear. With development of various electronic instruments which could rapidly estimate the quantity of fish in the water, it became possible to supplement the more conventional exploratory fishing techniques with these newer, more sophisticated procedures. A portion of the time during the 1960's was spent by the Exploratory Fishing Program in perfecting instrumentation adapted to estimating fish populations (Moose et al. 1971), and during the 1970's these techniques assumed an even more important role. Also during the 1960's, especially toward the end of that decade, the emphasis shifted from efforts primarily aimed at finding new or more productive fishing grounds to a monitoring program designed to measure changes in fish populations by systematic surveys for use in management of the fisheries.

As the Exploratory Fishing and Gear Development Program based at Seattle expanded, the work became too detailed to follow in depth over the years in this report. In order to give some idea of the scope of the program, some description is given here of operations during fiscal year 1969 which may be considered as fairly typical of the programs at the latter part of the time that exploratory fishing and gear development operations were conducted as a separate entity within the Bureau of Commercial Fisheries.

During fiscal year 1969 research at the Seattle base was performed under two main programs, each consisting of two or more projects. The programs were Resource Assessment, under supervision of Hiromu Heyamoto, and Ocean Engineering, under supervision of Richard L. McNeely. In addition, a smaller program on Antarctic Resources Survey was under way. Details of the projects within these programs, and the names of the project leaders, are given in Table 7.

The field work during fiscal year 1969 was performed by means of 16 cruises conducted aboard 4 vessels. Nine cruises were made aboard the Government-owned vessel *John N. Cobb* and one on the *George B. Kelez*. The remaining cruises employed chartered vessels. Three cruises were conducted on the vessel *Baron* and one each on the vessels *New Roma, Pacific Raider,* and *Commando*.

Individuals who were employed in a professional capacity during 1969 included: Miles Alton, Dayton Lee Alverson, Alan J. Beardsley, Forrest E. Carvey, Hiromu Heyamoto, William L. High, Fred W. Hipkins, C. R.

Table 7.—Exploratory Fishing and Gear Development Operations, Seattle Base in Fiscal Year 1969.

Resource Assessment—H. Heyamoto
- Bottomfish Program—H. Heyamoto
  - Bottomfish explorations to medium depth (to 500 fathoms)—C. R. Hitz
  - Bottomfish explorations in deepwater (over 500 fathoms)—W. T. Pereyra
- Marine Invertebrate Program—H. Heyamoto
  - Scallop Investigations—C. R. Hitz
  - Clam Explorations—Miles Alton
  - Shrimp and Crab Explorations—M. O. Nelson
- Pelagic Program—H. Heyamoto
  - Surface and Midwater Explorations—M. O. Nelson
  - Bureau-A.E.C. Pelagic Explorations—A. T. Pruter

Ocean Engineering—R. L. McNeely
- Ocean Engineering Program—R. L. McNeely
  - Ocean Engineering Project—R. L. McNeely
- Fishing Gear Research and Development Program—R. L. McNeely
  - Upgrading Conventional Fishing Techniques—J. Jurkovich
  - Development of New Fishing Techniques—L. Johnson

Antarctic Resources Survey—Miles Alton
- Antarctic Resources Program—Miles Alton

Hitz, Steven B. Hughes, Harold C. Johnson, Leonard Johnson, Jerry E. Jurkovich, Larry D. Lusz, Richard L. McNeely, Martin O. Nelson, Norman B. Parks, Walter Pereyra, and A. T. Pruter.

The Seattle base was headed by Dayton Lee Alverson from July 1968 to April 1969 and by A. T. Pruter from April through June 1969. The annual budget provided by the Bureau of Commercial Fisheries for the Seattle base program as of June 1970 was $562,000.

Alaska Based Work

All of the exploratory fishing and gear development concerning Alaska up to and including 1960 was performed through the Seattle base. Starting in 1961, a base was set up at Juneau to conduct the work specifically applicable to Alaska. The new base was under the direction of Warren Rathjen, who reported to the Alaska Regional Director, from 1962 to 1964, and from 1964 to 1970 it was under the supervision of Benjamin Jones. In the spring of 1970 the Juneau base was transferred to Kodiak, Alaska, and was then under the supervision of Lael Ronholt who, in turn, reported to Murray Hayes, Chief of the Kodiak facility. That facility also included the Technological Laboratory which, until 1970, had been located at Ketchikan.

The Alaska base acquired and operated in 1965 the *John R. Manning*. Before that date only charter vessels had been available. The *Manning* was disposed of in 1968 and replaced with the *Oregon*.

Early field work demonstrated that there were commercial quantities of scallops in the vicinity of Yakutat. Much of the later work was concerned with surveys to locate areas of abundance of shrimp, mostly in southeast Alaska. Other activities included trawl surveys for bottomfish and various salmon purse seine operations. The Alaska-based staff by 1968 had reached the full complement of eight plus the crew of the *Manning*.

TECHNOLOGICAL RESEARCH

Pacific Coast Prior to 1933

Although the first technological research by the Bureau of Fisheries in the Pacific Northwest began in 1933 after the Montlake Laboratory building had been in use for 2 years, other such work had been performed on the Pacific coast earlier. This consisted of work by the Bureau of Fisheries in California from 1918 to 1924 and earlier work conducted in the Pacific Northwest by the U.S. Department of Agriculture.

During the 1870's and 1880's, technological work was performed in New England by the Commission of Fish and Fisheries (predecessor agency of the Bureau of Fisheries). After the death, in 1887, of Spencer Baird, first Commissioner of Fish and Fisheries, who had broad interests in different kinds of research, all technological work ceased. Some time around 1903 the Bureau of Fisheries signed an agreement with the Department of Agriculture authorizing that agency to conduct technological research on fisheries just as they were doing on all other foods. At first such work was limited to small field operations on the Atlantic coast, mostly operating from Washington, D.C. In 1913, the Bureau of Chemistry of the Department of Agriculture made the work on fish an additional function of their egg and poultry laboratory at Philadelphia, which was under the direction of Mary Pennington. The work on fish was assigned to Ernest D. Clark and L. H. Almy who worked on fish in their Philadelphia laboratory but usually conducted temporary field studies during the summer, 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 upon problems encountered in the transportation of fish.

In 1921 the Philadelphia laboratory was closed and, as a result, the work on fish by the Department of Agriculture was discontinued.

Meantime, in 1917, Lewis Radcliffe became Chief of the Division of Statistics and Methods of the Bureau of Fisheries succeeding Alvin B. Alexander, who had been in charge since 1903. Unlike Alexander, Radcliffe felt strongly that technological research should be conducted by the Bureau of Fisheries. As a result, in 1918 the first Bureau of Fisheries laboratory was established in temporary quarters in San Pedro, Calif., under the direction of Leslie Lingle. After Lingle resigned in 1921, Harry Beard became laboratory director, and he was assisted by Arthur Wells and one or two temporary assistants. 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, Mass. Later a small permanent laboratory was opened in Washington, D.C., which operated during all of the 1920's but was closed about 1930. In the late 1920's, the principal technological station of the Bureau of Fisheries was in Reedville, Va., and the work there was concerned with menhaden fish meal and oil. In 1931, the personnel of this station, and most of those then working in Washington, D.C., were transferred to Gloucester, Mass. 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, Md.

Seattle, 1933 through 1976

Period 1933 Through 1941

When plans were being formulated in the late 1920's for a new building in Seattle to house Pacific coast Bureau of Fisheries activities, space was included for technological investigations. It had been hoped that funds would be available after completion of the building to employ a staff for the technological operation in Seattle. When the budget did not include special funds for such work, two employees, Roger Harrison and A. W. Anderson, were transferred in May 1933 from the Glou-

cester laboratory and began technological research at the new Montlake Laboratory.

Harrison, who was in charge of the new Seattle Technological Laboratory, was a chemical engineer and Anderson a fishery technologist. They had been working in Gloucester on fishery by-products, especially fish meal and fish liver oils, and the first activities in their new work at Seattle also were concerned with fishery by-products. One of their first projects concerned utilization of salmon trimmings and resulted in 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 in instances where the oil content of the raw fish was less than average. This practice soon became wide-spread 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) Development of 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. Recommendations were made for improvement in manufacturing methods of the meal to increase nutritive value. 4) Designing of a small scale fish reduction unit for use at a Bureau of Fisheries salmon hatchery at Quilcene, Wash., for rendering spent carcasses of salmon.

Beginning 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 led ultimately to a broadening of the scope of research at the laboratory.

In 1937 the laboratory acquired the services of several temporary Works Progress Administration (WPA) sponsored chemists. These positions continued during the subsequent 5-year period. Employed under this program for different time periods were William Clegg, Charles Butler, Louis Simonson, Jacob Ash, and Robert Carlson. 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.

Technological Laboratory's pilot plant building, Seattle, as it appeared in 1938. This building, built at a cost of $2,000 (including some equipment), has since been more than doubled in size and given an exterior facing of brick.

In 1937 Anderson was transferred to Washington, D.C., and in February 1938 his vacancy was filled by transfer of Maurice Stansby (a chemist) 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 his vacancy was filled by F. Bruce Sanford, a chemist who had been employed at an oil concern which processed fish and other oils. Stansby started several programs 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 plan was constructed which permitted large-scale experiments, particularly in the by-products field. 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 determination of oil in fish meal. The various WPA-sponsored employees working under Harrison and Stansby performed work on proximate composition determinations on Pacific Northwest fish (much of this work 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 on development of information needed for starting an American utilization of Alaska king crab was performed under Harrison in 1940 and 1941 (see also section on Exploratory Fishing).

Considerable work was conducted on improving 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 determination of volatile bases as a freshness test for fish.

Summary of 1933-41 Accomplishments

During this 9-year period 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 permitted an expansion of only from two to three full-time permanent staff, Harrison overcame the problem of inadequate staffing by arranging for WPA temporary employees and use of 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 were as follows.

By-products work

1. Salmon oils and halibut liver oils were characterized as to chemical composition and vitamin content.
2. Fish liver oil extraction methods were improved.
3. Properties of dogfish meal were determined and manufacturing methods improved.
4. Methods of utilizing salmon trimmings to make oil for adding to canned salmon were devised.

Food fish studies

1. Knowledge of location and handling methods of king crab was developed so that a new industry was established.
2. Long-term studies on characterization of chemical composition of fishes of the Pacific Northwest were initiated.
3. New chemical methods were developed for analysis of fish and fishery products.
4. Studies on cold storage life of frozen fish were initiated.

Period 1942 Through 1954

In 1942 Roger Harrison was transferred to Washington, D.C., to serve as Chief Technologist for the Bureau of Fisheries and Maurice Stansby returned from Ketchikan to replace Harrison as laboratory director of the Seattle Technological Laboratory. The programming changed drastically in order to cover important war-time activities, and the budget and staff size increased considerably in order 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, and by the end of 1943, when the war-time projects reached full implementation, there were 20 individuals on the staff; 16 of them were full-time professionals.

New projects included investigation of feasibility of substitute containers. Such aspects were investigated as to whether or not 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. imports were 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 the vitamin A industry representatives and standardized analytical methods adopted in connection with stockpiling vitamin A from fish livers. In this connection F. Bruce Sanford of the Seattle Laboratory 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 SS *Pacific Explorer*. This vessel was a Government-financed factory ship modified from a World War I 8,800 ton class 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. By that time the urgent need for additional protein food was insufficient to operate the vessel, especially when also considering the adverse economic aspects which made a profitable venture impossible.

Several employees 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 Corp 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 added to the pilot plant, doubling its size. In the new addition, cold storage and quick freezing facilities were installed, greatly facilitating research on freezing and storage of fish. Expanded facilities for dressing and handling of fresh fish were also provided.

Between 1947 and 1954, after phasing out of war-time programs, the programs changed again. In 1947 war-time budgets were eliminated, which resulted in a reduction-in-force at the Seattle Technological Laboratory by 50%. Fortunately a $48,000 grant was obtained which allowed a portion of the displaced personnel to be rehired to work on a project involving utilization of Alaska cannery waste. Methods were developed whereby substantial portions of the waste, formerly discarded in Alaska, were frozen and shipped to fish hatcheries in the Pacific Northwest for use as a fish feed. The Laboratory also worked collaboratively with the Bureau of Fisheries' Hatchery Division to improve the nutritive value of fish feed.

A new program evaluated the composition, and especially the vitamin content, of fish meal. This work, conducted by Neva Karrick and others, provided infor-

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

mation so that when poultry feeders were applying newly introduced computerized formulation of feeds, the full value of fish meals could be realized.

In 1948, from 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 from important scientific journals which concerned scientific commercial fishery topics. The abstracts were of articles from 65 journals. They were published in CFA in 3 × 5 inch spaces in such a way that they could be cut into 3 × 5 inch size cards and filed. This journal continued to be prepared at Seattle and mailed to users throughout the world for more than 25 years.

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

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

In 1954 the staff of the Seattle Technological Laboratory consisted of 5 full-time and 3 part-time professional grade scientists, 3 subprofessional employees, and 3 clerical and secretarial employees, making a total of 14. There were also several part-time graduate students assisting in the work, some of whom were employed by funds provided by the Refrigeration Research Foundation. The total laboratory annual budget amounted to $70,700.

Summary of 1942-54 Accomplishments

During this period, under Maurice Stansby as Laboratory Director, the laboratory spent about 5 years with major emphasis on special war-time projects and 8 years on peace-time projects. This was a period of great expansion in 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 provision of freezer and cold storage equipment. The principal fields of work and accomplishments were as follows.

Wartime activities

1. Provided information, including services and in some cases personnel details, to numerous war-time agencies such as War Production Board, Office of Price Administration, and Army Quartermaster Corp.
2. Developed successful method of producing dehydrated fish.
3. Developed equipment for sampling fish livers.

Peace-time activities

1. Devised method for getting current literature to fishing industry by publishing the monthly *Commercial Fisheries Abstracts.*
2. Devised successful means for utilizing Alaskan salmon cannery waste, which was adopted by industry.
3. Established B vitamin content of fish meals.
4. In absence of facilities in Great Lakes area, conducted research on cold storage properties and chemical composition of freshwater species of fish.
5. Conducted the first research on fractionization of fish oils and preparation of chemical derivatives from them.

Accomplishments during the first 25 years' operation of the Seattle Technological Laboratory have been described by Stansby (1958).

Period 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, each year a portion of the SK funds were replaced by additional regular funding so that by 1965 the SK funds were reduced to $70,000, but regular funding by then had increased to $316,000, making a total budget of $400,000.

A considerable portion of the supplementary SK funds were used for contract research at universities. This brought new ideas into the overall research programs as well as providing the additional research findings.

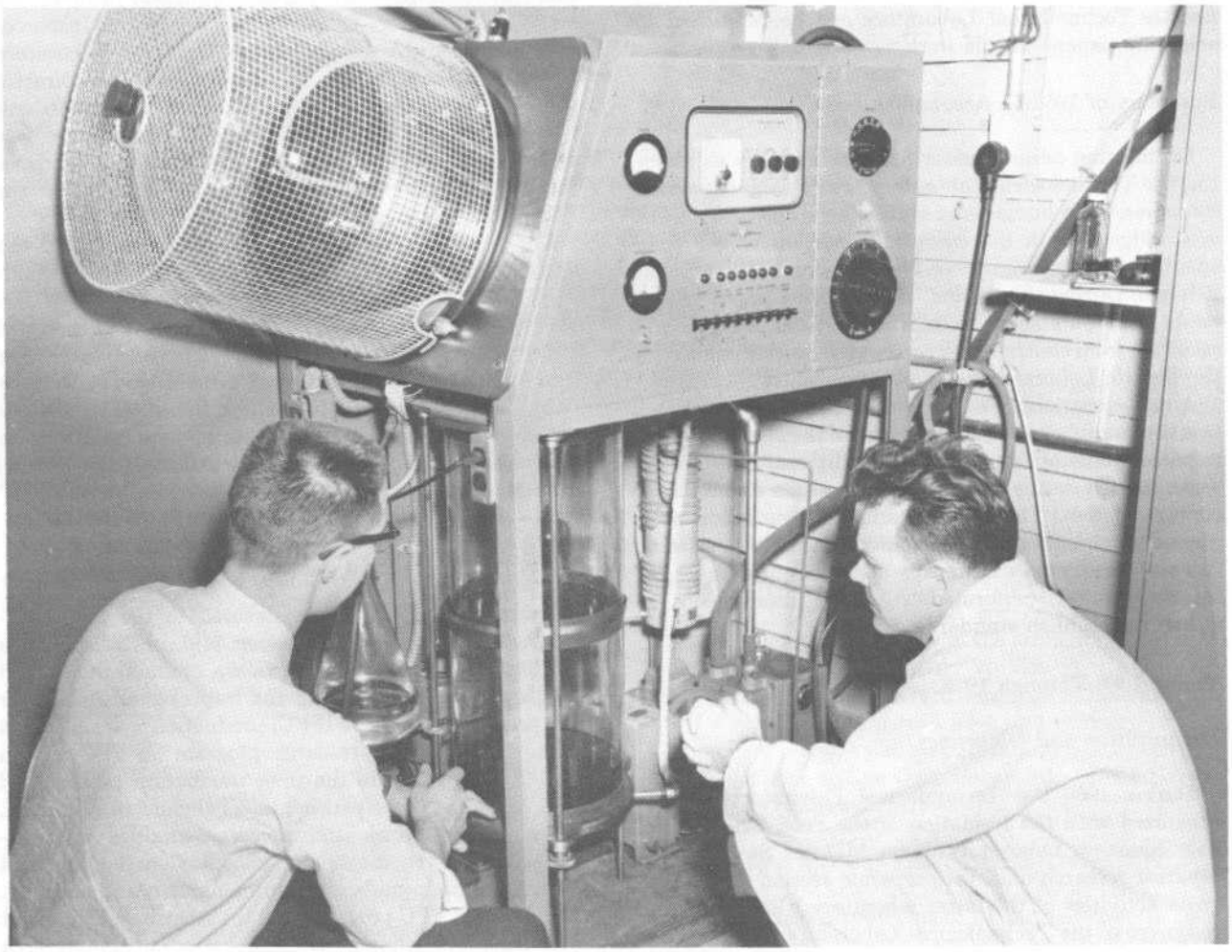
The principal research areas covered by the new funding were in fish meal, and, especially at Seattle, in fish oil research, and for work to develop standards of quality for use of the newly inaugurated inspection of fishery products program.

A major research thrust during the decade beginning in 1955 was toward obtaining background information on the chemistry of fish oils and to develop new uses for them (Stansby and Butler 1958; Karrick 1965). Fish oil work proceeded along industrial and nutritional lines. In the industrial area many new uses were investigated. These included use of fish oil derivatives for ore flotation, as 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. It will be available for future use in this country after the higher grade taconite ores, which can use the cheaper magnetic process, have been depleted.

A number of chemical firms made use of findings of the program 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 were made primarily along the line of examining the potential of polyunsaturated fish oils and fish oil fatty acids for use as cholesterol depressants. Based upon rat feeding tests performed under contract to the University of Minnesota's Hormel Institute, it was found that fish oils and fish oil fatty acids are several times as effective, weight for weight, as are vegetable oils, such as corn oil, in lowering serum cholesterol. Furthermore, in a 15 to 20 year study by a Seattle heart physician, 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 after prolonged periods of time as did heart patients on the ordinary (control) diet.

Other tests in the Seattle program on medical applications of fish oils suggested that they may be valueless in curing wounds and burns (Stansby et al. 1967). 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.



Molecular still used for preparing palatable fish oil. Operating the still are Edward Gruger, Jr. (left) and Patrick Hunter (right). Several tons of palatable fish oil were prepared in this way and distributed to various hospitals and medical institutions for testing, by human feeding, the nutritive value of fish oils.

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 long review paper by Stansby (1969).

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 (Dassow et al. 1971). These standards provided the means for inauguration of a government voluntary inspection service in the Pacific Northwest. Research on quality of fresh and frozen fish and development of standards was coordinated by John Dassow during much of this period 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. Studies on chemistry and microbiology of fresh, chilled fish were expanded when a major research project was initiated in 1961 on the feasibility of extending the storage life of chilled fish by low-dosage gamma 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 Melvin Eklund (e.g., Dassow and Miyauchi 1965), were published on the irradiation pasteurization studies. Other contributions included 12 papers on fresh fish quality determination and frozen fish inspection methodology, 6 papers on freezing and preservation, and a series of 6 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 and he published 15 scientific papers on this work.

Summary of 1955-65 Accomplishments

During this period, under Maurice Stansby as director, the Technological Laboratory activity was expanded by increases in budget and staff. The scope of the work was widened with a considerable portion of the time spent on a crash program on chemistry and utilization of fish oils. During this period, 201 scientific papers and 2 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 preservation of Pacific Northwest species of fish was conducted during this period. Considerable research was also performed to obtain information required to establish standards for fish.

Period 1966 Through 1976[5]

Organization and Objectives

During 1966 the Technological Laboratory was reorganized with the formation of the Food Science Pioneer Research Laboratory under Maurice Stansby as a separate research unit. (See separate section for the program activities of the latter laboratory.) Personnel and resources of the Technological Laboratory were assigned to either the Pioneer Research or the Technological Laboratory with a revised research program. Maynard A. Steinberg, formerly with the Gloucester Technological Laboratory, was appointed Director of the Seattle Technological Laboratory and assumed the position in August 1966.

The objectives of the technological research were defined at a program review in March 1968 as follows: 1) the development of knowledge that will improve the handling, processing, preservation, distribution, and utilization of fishery products; and 2) the demonstration to industry of this knowledge in the form of methods and techniques that result in the efficient production from our total resource of a wide variety of consistently high quality food and industrial products.

At that time (fiscal year 1968) the laboratory was organized into four research programs, inspection, and administration: 1) Chemistry of Fishery Products—E. Gauglitz, program leader; seven staff; 2) Preservation and Engineering—R. Nelson, program leader; six staff; 3) Radiation Preservation of Fishery Products—D. Miyauchi, program leader; six staff; 4) Radiation Preservation Microbiology—M. Eklund, program leader; one staff; 5) Inspection—M. Rafn, supervisor; one inspector at Bellingham; 6) Administration included Laboratory Director M. A. Steinberg, Assistant Laboratory Director John Dassow, Administrative Officer Patricia Terao, and four secretaries. Total staff was 33. 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 1970's the laboratory was designated the Pacific Utilization Research Center (PURC) with Steinberg as director. The budget increased to over $900,000 by fiscal year 1976; however, the staff remained then and at the end of 1976 at 35, including a scientific staff of 3 at the Kodiak Utilization Research Laboratory. In October 1976 PURC became the Utilization Research Division of the Northwest and Alaska Fisheries Center, with continuing emphasis on increasing the utilization of our fishery resources.

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, characteristics, and refining 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, Wash. Both species and process variables were examined; however, major emphasis was on the potential recovery of high-grade oil from menhaden and anchovy. The national FPC program and the Aberdeen FPC plant were terminated during 1972-73, including the research on improved methods of extracting and refining the oil from menhaden and anchovy in the isopropanol FPC process.

Research on the level of organic contaminants in fish oil was initiated in 1966 with major emphasis on analyses for DDT in menhaden and other industrial oils and meals. The effort was broadened within a few years to include fish species of both the Atlantic and the northeast Pacific (Stout et al. 1972). Other chlorinated pesticides such as dieldrin were determined. The developing concern over polychlorinated biphenyls (PCB's) 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 the raw fish, meal, and oil for several years. The decline in DDT usage was reflected in the decline in DDT levels in menhaden oil; however, data on PCB levels through the 1976 season 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 with the 1970 reports of high mercury levels in

[5]This section was written by John Dassow of the Utilization Research Division, Northwest and Alaska Fisheries Center.

Chemist Alice Hall determining mercury in fish with the atomic absorption spectrophotometer at the Utilization Research Laboratory, Seattle.

tuna and 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. 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 quality of fish and shellfish. Studies included live-holding and shipment of live Dungeness crabs, factors affecting water-holding capacity of fish tissue and methods of measurement, quality of chilled and frozen Dungeness and king crab meat, quality of iced halibut and methods of determining and measuring quality differences for marketing, and improved methods of chilling and holding fresh whole and dressed fish by use of modified atmosphere and modified refrigerated seawater (RSW) with use of carbon dioxide. The RSW research included several species of fish—salmon, rockfish, cod—in the early studies and pink shrimp. In 1968 work on increasing the utilization of rockfish and Pacific hake (Dassow and Beardsley 1973) was initiated with new studies on the techniques and application of mechanical flesh separation from skin and bone. Research on the properties and utilization of minced flesh (Miyauchi and Steinberg 1970) in fishery products and processed meat products continued through 1976. A total of 89 papers and 3 patents were published.

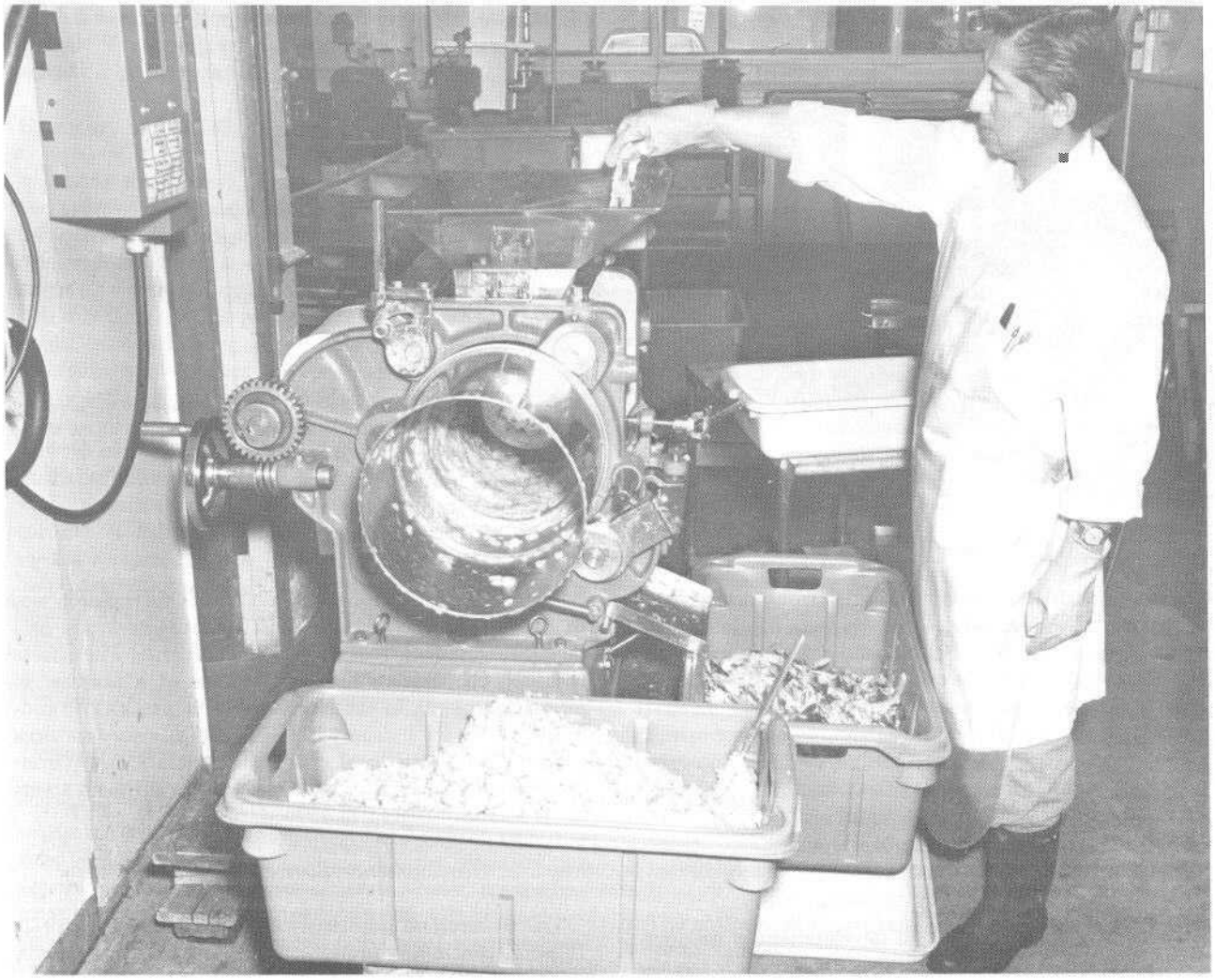
With the passage of the environmental protection and clean water legislation in 1969-72, a major study of the characterization, measurement, and treatment of fish and shellfish processing effluents was conducted during the early 1970's. A primary objective of this research was to provide objective data 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 EPA and advisory services with industry and local and state officials in environmental control. Active field research in effluent treatment was terminated in 1976.

Resource Development—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 (John Spinelli) on the aqueous phosphate process for fish proteins. Work on improving the functional characteristics of purified muscle proteins resulted in a series of studies by Herman Groninger on the preparation and properties of chemically modified (acylated) fish proteins (Spinelli et al. 1977). This research on functional proteins has resulted in 2 additional patents and 15 scientific papers.

Radiation Preservation of Fishery Products

This major research program was supported by the Atomic Energy Commission (AEC) Division of Isotopes Development from 1961 through 1969 and included a comprehensive study not only of the feasibility of radiation preservation of fresh fish and shellfish, but also the chemistry and microbiology of the early and late changes in the freshness and spoilage of fresh fish, the measurement 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 (Miyauchi 1972). In addition to accomplishing the contract objec-



Headed and gutted hake are fed between a rotating, stainless steel, perforated drum and a continuous rubber belt under tension. The belt's pressure squeezes the soft muscle through the holes to the inside of the drum while the skin and bones mat on the drum's outside surface and are scraped off into the waste chute. George Kudo, chemist, is shown operating the flesh separation equipment.

tives, the studies provided numerous spin-off 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. A total of 29 reports and scientific papers was 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 Melvin Eklund, on the survival, outgrowth, toxigenesis, and possible control of *Clostridium botulinum* in any perishable fishery product. 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 research on toxigenicity of *C. botulinum* includes the various botulinum types of public health concern and effects of the environmental factors in the products and process such as time-temperature, moisture content, salt level, and chemical additives. The continuing objective of the research is an understanding of the factors controlling *C. botulinum* outgrowth and toxin formation in order to provide a firm basis for prevention of botulism by physical-chemical control of the organism whenever it is present in food. Through 1976, 34 reports and scientific papers have been published on this 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 food proteins for use in developing aquaculture. This study under John Spinelli has emphasized two aspects to date: 1) the problems and potential of utilizing underutilized species, e.g., dogfish, and 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 were initial projects that continued through 1976.

Food Science Pioneer Research Laboratory at Seattle

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 were transferred from the Technological Laboratory to work under Stansby in a new laboratory for research of a long-term, fundamental basis. These other scientists included Neva Karrick, Edward Gruger, W. T. Roubal, 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 concerned the role of unusual lipids in sharks and porpoises, the latter in connection with sonar reception and transmission. The sonar work under Malins was conducted primarily by Usha Varanasi, who was employed from funding provided by the Office of Naval Research. A third project undertaken several years after the new laboratory started operation was concerned with nitrosamines and smoked fish.

The laboratory was located on the same floor of the research building as the Technological Laboratory, and with about five laboratories and several offices set up for exclusive use of the Food Science Laboratory. Instruments and certain other facilities were shared by the two laboratories.

Much of fiscal year 1966, the first year of the new laboratory's operation, was utilized in completing research tasks underway before the start of the Pioneer Research Laboratory. The laboratory started with its new programs in full operation by the summer of 1966. The laboratory terminated the operation in its field of work in late summer of 1971 at the time that the Northwest Fisheries Center was established. The Pioneer Research Laboratory at that time was transferred, with its personnel, to become the first unit of the Division of Environmental Conservation of the Northwest Fisheries Center with Maurice Stansby as division director. The Food Science Pioneer Research Laboratory thus conducted its operations in the food science field for just about 5 years.

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 (Roubal and Gruger) stationed at the University of California at Davis' Food Science Department. In the latter investigations, Roubal determined the effects of oxidizing lipids in fish upon proteins and established that polymerization of protein occurred. Gruger investigated the role of natural, biological antioxidants, principally alpha tocopherol, and reduced co-enzymes upon the oxidation of fish oil polyunsaturated fatty acids in model systems (Gruger and Tappel 1970). At Seattle, 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 (Roubal 1971). 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 upon 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 silver 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 ten times longer than for any other packaging method.

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

Research on Other Projects

The work by 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 such species there is a varying ratio of such compounds to triglycerides. When this ratio changes, the bouyancy 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 bouyancy levels when the fish move to different water depths (Malins and Barone 1970).

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 as required to 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 of 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 work on 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 American salmon roe preserved with nitrates for the subsequent season. Work performed by 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 from being discontinued.

Accomplishments

During the 5 years of active work of the Food Science Pioneer Research 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 upon 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 from closing 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 of 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. Owing to 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.

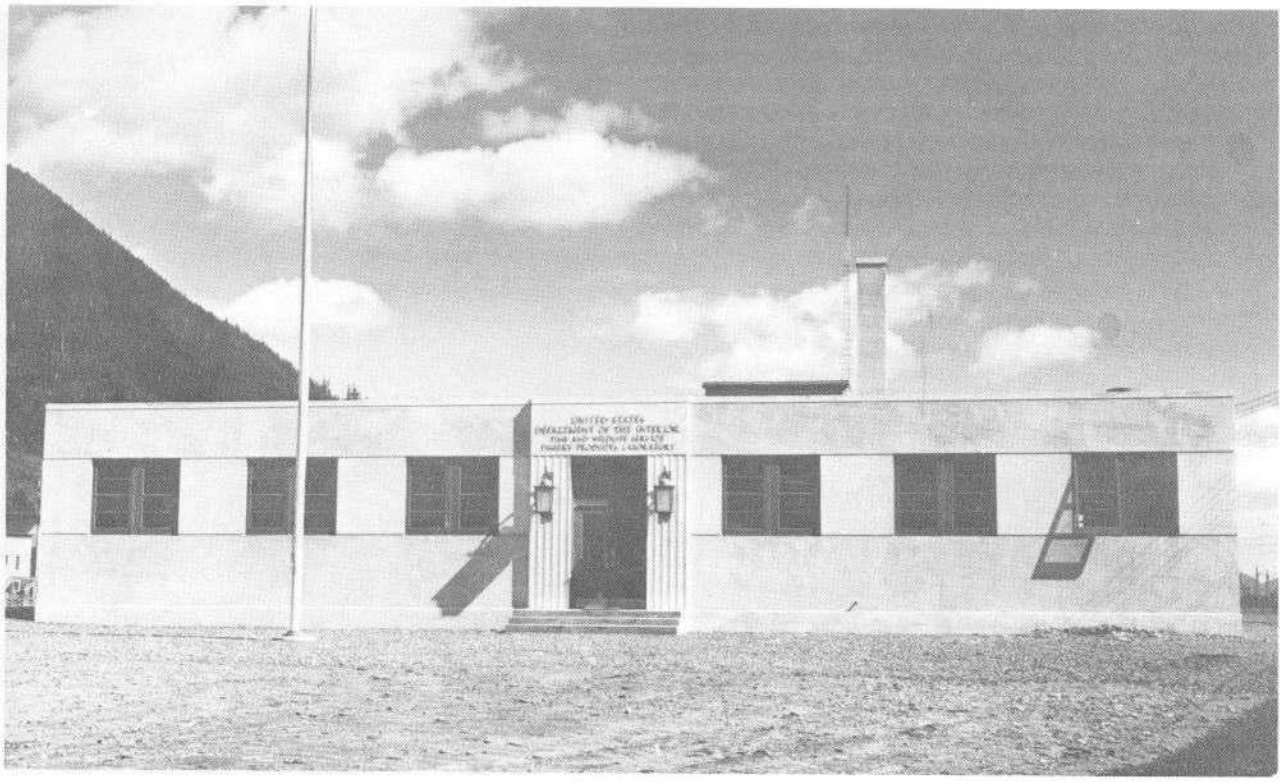
Alaska, 1940-76

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 was of about the same size personnelwise and budgetwise as the Seattle Technological Laboratory and it had a staff of five full-time permanent professional employees. It did not change in size much over the years and is today, in fact, relocated now at Kodiak, Alaska, somewhat smaller than it was in 1940.

Research in Alaska 1940-65

The laboratory, funded initially by both the Federal Government and the then Territory of Alaska, was established primarily for the purpose of aiding the Alaskan fishing industry to utilize more species than were then being caught and processed. In 1940 salmon, halibut, and herring composed 99.8% of the Alaskan fish catch. These were all species for which the supply was either dwindling or which could barely supply a practically constant catch.

Initial research sought to develop crabs and clams as major species for catching and processing in Alaska. The early efforts to develop king crab, which were directed from Seattle, have already been discussed. Today the Alaskan crab fishery composes about 25% of the total fish harvest in Alaska. Efforts at the Ketchikan Laboratory in 1940 included as one of the major projects investigation of 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 in-



Fishery Products Laboratory, Ketchikan, Alaska, in 1941.

tervals made the clams toxic and inedible. Several years' work was conducted trying to overcome this handicap to marketing these clams, such as by instituting a quality control inspection procedure to eliminate from marketing those clams which were toxic, but without success.

Later work was conducted over a period of years on investigations of 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 over 20% of the Alaskan fishery harvest.

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

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

Table 8 gives the names of individuals who have served as director at the technological laboratory in Alaska.

During the period from 1940 to 1965, 75 publications were issued resulting from the research and other activities of the Ketchikan Laboratory.

Table 8.—Ketchikan Laboratory Directors, 1940-76.

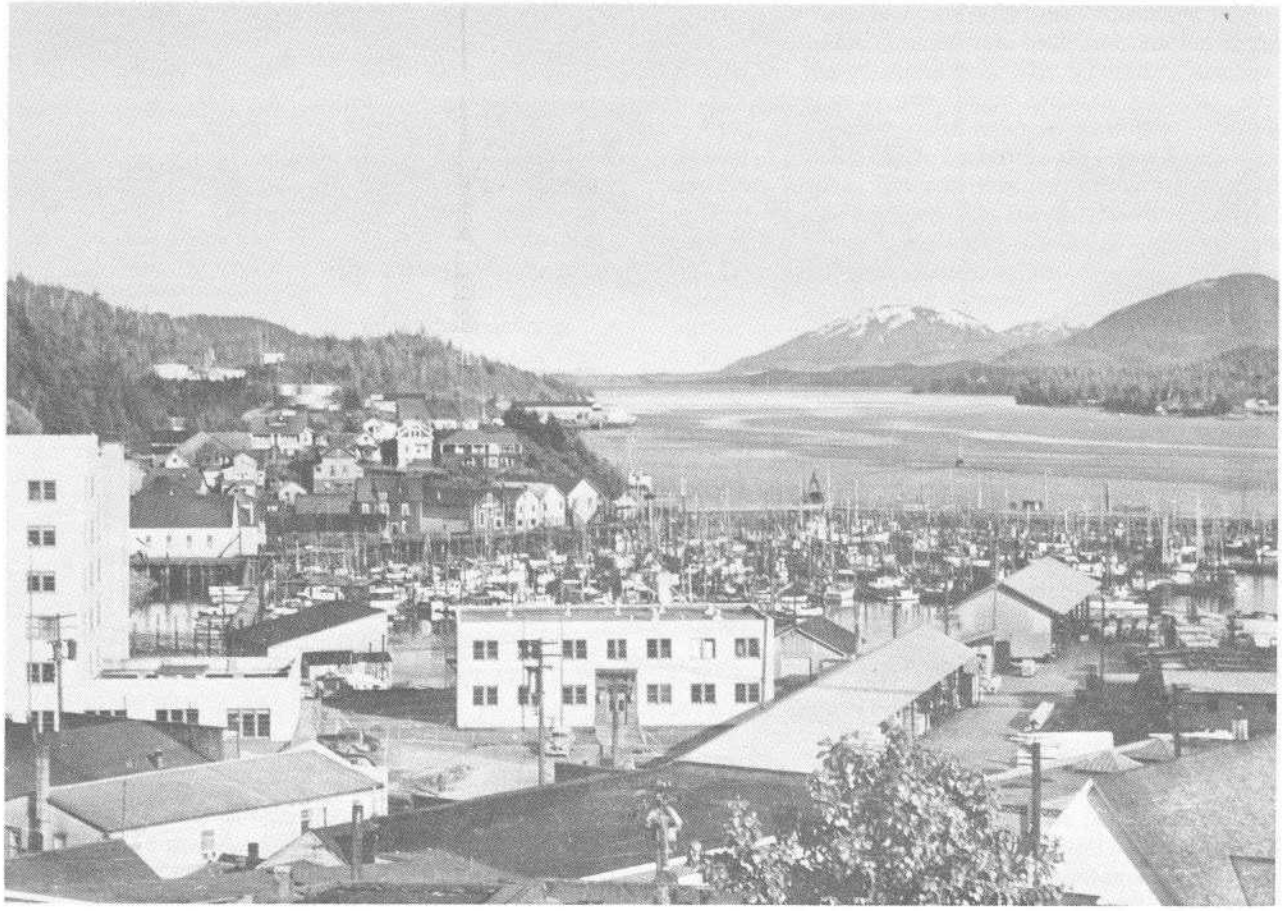
Name	Years
Maurice E. Stansby	1940-42
Lyle Anderson	1942-45
Harris N. Magnusson	1945-50
John A. Dassow	1950-55
Clarence J. Carlson	1955-57
Eyestein Einset	1957-60
Jefferson Collins (Acting)	1960-62
Murray Hayes	1962-70
Jefferson Collins	1970-71
Jefferson Collins	1971-present[1]

[1]After August 1971 the laboratory was relocated to Kodiak, Alaska.

Research in Alaska, 1966-76[6]

The major program change during the period was the closing of the Ketchikan Laboratory and the relocation of personnel and facilities at the Nationl Marine Fisheries Service Laboratory in Kodiak during August 1971. The change reflected the decreasing importance of fisheries in

[6]This section was written by John Dassow of the Utilization Research Division, Northwest and Alaska Fisheries Center.



Fishery Products Laboratory, Ketchikan, Alaska (center), after a second story had been added.

the southeastern Alaska area and the continuing expansion of the shrimp and crab fisheries in central and western Alaska. During the latter part of the period the Alaska industry began plans for development of the large bottomfish potential—pollock, rockfish, flounder, cod—of the area.

During the last 5 years at Ketchikan the laboratory, under Murray Hayes and later Jefferson Collins, 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 chitin and chitosan 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 this work in 1976, a major research project was initiated on development of bottomfish processing and the specific problem of handling and preservation of pollock and other trawl species. 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.

FORMATION OF NORTHWEST FISHERIES CENTER

In this section it will be shown from where and at what time the various activities were brought into the Northwest Fisheries Center. The Center was formed during the Governmental reorganization which resulted in the Bureau of Commercial Fisheries, under a new name—National Marine Fisheries Service, being brought into the new agency, National Oceanic and Atmospheric Administration (NOAA). The Northwest Fisheries Center was officially formed in September 1971 with Dayton Lee Alverson as director, and Brian Rothschild (A. T. Pruter after July 1972) as associate director. The process of full implementation, however, took an extended period of time, with the last unit now within the Center not brought in for more than 5 years.

The Center was called the North Pacific Research Center from September to November 1971, after which

Northwest and Alaska Fisheries Center buildings, Seattle. The building on the left houses offices and is the original structure built in 1931. The building on the right is the main research building while the connecting structure between contains an auditorium and library.

the name Northwest Fisheries Center was adopted. As shown in Table 9, the Center contained five divisions and a Center Director's Office. The largest division was that of Marine Fish, Shellfish, and Oceanography. It contained all of what had been the Exploratory Fishing and Gear Development Base at Seattle, plus a portion of the Seattle Biological Laboratory. It had a full-time staff of 61 individuals and was headed by Francis M. Fukuhara.

The second largest unit was the Coastal Zone and Estuarine (CZ&E) Division with a full-time staff of 46. It was composed of individuals who had been in the Freshwater and Estuarine Research programs of the Seattle Biological Laboratory. Gerald Collins was the Director of the CZ&E Division.

The Fisheries Data and Management Systems (FD&MS) Division, with a staff of 25 and headed by Reynold A. Fredin, consisted of the Biometrics Institute of the Seattle Biological Laboratory. This Division had certain program research in connection with the high seas research for INPFC. It also acted as a service organization for other divisions with units for editorial work and including a graphics unit. At the inception of the Center,

Table 9.—Organization of Northwest Fisheries Center occurring between September 1971 and August 1972.

Name of unit	Individual in charge	Source of employees brought into unit	No. full-time employees 8/72
Center Director's Office	D. L. Alverson	Most from Seattle Biological Laboratory; some from Exploratory Fishing & Gear Development Base	18
Marine Fish, Shellfish, and Oceanography Division	Francis M. Fukuhara	From Seattle Biological Laboratory & Exploratory Fishing & Gear Development Base	61
Coastal Zone and Estuarine Division	Gerald Collins	From Seattle Biological Laboratory & Exploratory Fishing & Gear Development Base	46
Fisheries Data and Management Division	Reynold A. Fredin	From Biometrics Institute of Seattle Biological Laboratory	25
Environmental Conservation Division	Maurice E. Stansby	From Pioneer Research Laboratory and from Seattle Biological Laboratory	30
Marine Mammals Management and Monitoring Division	George Harry	From Fur Seals Research and Marine Mammals Laboratory	12

the library was under the Center Director's Office, but in 1973 was added to the responsibilities of the FD&MS Division.

The Marine Mammals Management and Monitoring Division, under division director George Harry with a full-time staff of 12, was moved unchanged from the Marine Mammals Research Laboratory operations. It remained in its former location at Sand Point Naval Air Station, about 4 miles from the remainder of the Center on Montlake Boulevard.

The Environmental Conservation (EC) Division was organized to conduct work on effects of contaminants and other environmental effects upon marine resources. This field, during the decade preceding formation of NWFC, had been expanding to a great extent but it was not well covered by work in the National Marine Fisheries Service. With the formation of NWFC, this new division was established gradually to focus attention on such work by utilizing staff with multidisciplinary backgrounds best suited to solving the various problems. Initially, in September 1971, the Pioneer Research Laboratory, which had been a basic research laboratory within the Branch of Technology at Seattle, was transferred as the first unit of the EC Division and with Maurice Stansby as division director. In November two employees within the Seattle Biological Laboratory, who had worked on monitoring petroleum in marine organisms, and one biologist from the Marine Mammals Research Laboratory, who had worked on contaminants in fur seals, were transferred to the EC Division. On 1 July 1972, two other units, both from the CZ&E Division, were added to the EC Division. One of these groups was the Physiological Research Unit under Harold Hodgins, the other the biological employees, under the direction of George Snyder, who worked in three field stations on the contaminant types of work. These field stations were the Prescott and Hammond, Oreg., stations on the lower Columbia River and the Mukilteo Station just north of Seattle on Puget Sound. By August 1972 the staff of the EC Division numbered 30.

On 1 July 1974, as a result of a task force recommendation, the Auke Bay Laboratory in Alaska became a part of the Northwest Fisheries Center. The laboratory was transferred as a unit and did not become a part of any Center division. As a result of this action, in October 1976 the name of the Center was changed to the Northwest and Alaska Fisheries Center.

In November 1975, the Center's largest division, the Marine Fish and Shellfish Division, was split into two smaller divisions. One of these, which remained under Fukuhara, was called the Resource Ecology and Fishery Management (REFM) Division, the other, under Walter Pereyra, was called the Resource Assessment and Conservation Engineering (RACE) Division.

RACE Division was established primarily to conduct field operations of Marine Resources Monitoring Assessment and Prediction (MARMAP) programs; and to conduct conservation engineering investigations to answer "where, what kind, and how much" questions regarding fishery resources and to promote full utilization of fishery resources.

REFM was established with two major functions: 1) research on resource ecology and 2) research on status of stocks and development of management recommendations. REFM uses information obtained by RACE surveys and from other sources.

In October 1976, the Pacific Utilization Research Center, which had formerly been the technological laboratories in Seattle and Alaska, was brought into NWAFC as the Utilization Research Division. It included both those operations at Seattle and the small unit at Kodiak (remnant remaining from the former Ketchikan Technological Laboratory). This new division, with Maynard Steinberg as division director, had a staff of 35 including 3 at Kodiak.

SOURCES OF INFORMATION

In addition to those sources of information used in the report for which references are listed, much of the older historical information was obtained from many old reports of the Bureau of Commercial Fisheries and its predecessor agencies. In particular, the reports of Elmer Higgins on activities in the Division of Biological Inquiry, of which he was chief and which were written from 1927 to 1938, were of great value. Those written for the earlier period of 1923-27 by Willis Rich, while he served in a similar capacity, were also very helpful. For those older periods extending even further back, information obtained from the archives of Stanford University Library proved invaluable. Included in this material were original notebooks written much like diaries by Charles Gilbert and covering various years between the early 1880's and the mid-1920's.

Discussion with various retired employees of the Federal fishery agencies, some of whom began work in the 1920's, also was of great value, with the information supplied by J. T. Barnaby being especially helpful.

LITERATURE CITED

ALVERSON, D. L., and N. J. WILIMOVSKY.
1961. Fishery investigations of the southeastern Chukchi Sea. *In* N. J. Wilimovsky and J. N. Wolfe, Environment of the Cape Thompson region, Alaska, p. 843-860. U.S. AEC, Div. Tech. Inf., Wash., D.C.

ANONYMOUS.
1942. Report of the Alaska king crab investigation. U.S. Fish Wildl. Serv., Fish. Market News 4(5a), 108 p.

DASSOW, J. A., and A. J. BEARDSLEY.
1973. The United States experience with Pacific hake (*Merluccius productus*). *In* R. Kreuzer (editor), Fishery products, p. 199-203. Fish. News (Books) Ltd., Lond.

DASSOW, J. A., and D. T. MIYAUCHI.
1965. Radiation preservation of fish and shellfish of the Northeast Pacific and Gulf of Mexico. *In* Proceeding International Conference, Boston, Massachusetts, Sept. 27-30, 1964, p. 53-68. Publ. No. 1273, National Academy of Sciences-National Research Council, Wash., D.C.

DASSOW, J. A., R. W. NELSON, and W. I. TRETSVEN.
1971. Developing quality standards of fresh dressed Pacific halibut. *In* R. Kreuzer (editor), Fish inspection and quality control, p. 34-40. Fish. News (Books) Ltd., Lond.

DAVIDSON, F. A., and O. E. SHOSTROM.
1936. Physical and chemical changes in the pink salmon during the salmon migration. U.S. Dep. Inter., Invest. Rep. 33, 37 p.

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.

GRUGER, E. H., JR., and A. L. TAPPEL.
1970. Reactions of biological antioxidants: II. Fe(III)-catalyzed reactions of methyl linoleate hydroperoxides with derivatives of coenzymes Q and vitamin E. Lipids 5:332-336.

INTERNATIONAL NORTH PACIFIC FISHERIES COMMISSION.
1954. Report of the first meeting, February 1 to 12, 1954, Wash., D.C., 40 p.
1957. Part D. Report on the investigations by the United States for the International North Pacific Fisheries Commission—1956. Int. North Pac. Fish. Comm. Annu. Rep. 1956:66-88.

KARRICK, N. L.
1965. A review of marine oil research conducted and sponsored by the Bureau of Commercial Fisheries of the United States. Fette, Seifen, Anstrichmittel 67:489-494.

MALINS, D. C., and A. BARONE.
1970. Glyceryl ether metabolism: Regulation of buoyancy in dogfish, Squalus acanthias. Science (Wash., D.C.) 167:79-80.

MALINS, D. C., W. T. ROUBAL, and P. A. ROBISCH.
1970. The possible nitrosation of amines in smoked chub. J. Agric. Food Chem. 18:740-741.

MIYAUCHI, D.
1972. Radiation pasteurization of Pacific coast fishery products. Isot. Radiat. Technol. 9:299-303.

MIYAUCHI, D., and M. A. STEINBERG.
1970. Machine separation of edible flesh from fish. Fish. Ind. Res. 6:165-171.

MONAN, G. E., J. H. JOHNSON, and G. F. 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.

MOOSE, P. H., R. E. THORNE, and M. O. NELSON.
1971. Hydroacoustic techniques for fishery resource assessment. Mar. Tech. Soc. J. 5(6):35-37.

NELSON, A. M.
1972. Diet therapy in coronary disease. Effect on mortality of high-protein, high-seafood, fat-controlled diet. Geriatrics 27(12):103-116.

RAYMOND, H. L.
1956. Effect of pulse frequency and duration in guiding salmon fingerlings by electricity. U.S. Fish Wildl. Serv., Res. Rep. 43, 19 p.

ROUBAL, W. T.
1971. Nature of free radicals in freeze-dried fishery products and other lipid-protein systems. Fish. Bull., U.S. 69:371-377.

SPINELLI, J., B. KOURY, H. GRONINGER, JR., and R. MILLER.
1977. Expanded uses for fish protein from underutilized species. Food Technol. 31(5):184-187.

STANSBY, M. E.
1958. Twenty-five years of research and service by the Seattle Technological Laboratory. Commer. Fish. Rev. 20(5):7-17.
1967. Fish oils, their chemistry, technology, stability, nutritional properties, and uses. The Avi Publ. Co., Westport, Conn., 440 p.
1969. Nutritional properties of fish oils. World Rev. Nutr. Diet. 11:46-105.

STANSBY, M. E., and C. BUTLER.
1958. Bureau of Commercial Fisheries oil research program. J. Am. Oil Chem. Soc. 35(7):8-12.

STANSBY, M. E., P. E. ZOLLMAN, and R. K. WINKLEMANN.
1967. Efficacy of fish oils in healing wounds and burns. Fish. Ind. Res. 3(4):25-27.

STOUT, V. F., F. L. BEEZHOLD, and C. R. HOULE.
1972. DDT residue levels in some U.S. fishery products and some treatments in reducing them. *In* M. Ruvio (editor), Marine pollution and sea life, p. 550-553. Fish. News (Books) Ltd., Lond.

TREFETHEN, P. S.
1968. Fish-passage research. Review of progress, 1961-66. U.S. Fish Wildl. Serv. Circ. 254, 23 p.

UNITED STATES
DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL MARINE FISHERIES SERVICE
SCIENTIFIC PUBLICATIONS STAFF
ROOM 450
1107 N.E. 45TH ST.
SEATTLE, WA 98105

OFFICIAL BUSINESS

NOAA SCIENTIFIC AND TECHNICAL PUBLICATIONS

NOAA, the *National Oceanic and Atmospheric Administration*, was established as part of the Department of Commerce on October 3, 1970. The mission responsibilities of NOAA are to monitor and predict the state of the solid Earth, the oceans and their living resources, the atmosphere, and the space environment of the Earth, and to assess the socioeconomic impact of natural and technological changes in the environment.

The six Major Line Components of NOAA regularly produce various types of scientific and technical information in the following kinds of publications:

PROFESSIONAL PAPERS—Important definitive research results, major techniques, and special investigations.

TECHNICAL REPORTS—Journal quality with extensive details, mathematical developments, or data listings.

TECHNICAL MEMORANDUMS—Reports of preliminary, partial, or negative research or technology results, interim instructions, and the like.

CONTRACT AND GRANT REPORTS—Reports prepared by contractors or grantees under NOAA sponsorship.

TECHNICAL SERVICE PUBLICATIONS—These are publications containing data, observations, instructions, etc. A partial listing: Data serials; Prediction and outlook periodicals; Technical manuals, training papers, planning reports, and information serials; and Miscellaneous technical publications.

ATLAS—Analysed data generally presented in the form of maps showing distribution of rainfall, chemical and physical conditions of oceans and atmosphere, distribution of fishes and marine mammals, ionospheric conditions, etc.

Information on availability of NOAA publications can be obtained from:

ENVIRONMENTAL SCIENCE INFORMATION CENTER
ENVIRONMENTAL DATA AND INFORMATION SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

6009 Executive Boulevard
Rockville, MD 20852