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Development of Food Science and Technology

As Applied to Fish by the Government of the United States

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DEVELOPMENT OF FOOD SCIENCE AND TECHNOLOGY AS APPLIED TO FISH BY THE GOVERNMENT OF THE UNITED STATES

by

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ABSTRACT

Fishery food science and technology developed by governmental agencies of the United States is traced from its beginning during the 1870s to 1970. Developments in each of the geographical areas of the United States and types of technological problems solved are also discussed. A list of early workers in the field is included.

CONTENTS

Figure 1. Two early laboratories of Bureau of Fisheries.

A. Floor plan of San Pedro, California Laboratory. This laboratory, occupying rented quarters, operated from 1918 to 1924.

B. Washington, D.C. Laboratory of Bureau of Fisheries. This was the first government owned building built and used for fishery food science research. It operated from 1919 to 1931.

Figure 2. Two laboratories operated in rented quarters between 1925 and 1935.

A. Summer field station for investigations at Reedville, Virginia dealing with fish meal and oil and operated 1925 to 1930.

B. Gloucester Technological Laboratory which worked on both industrial products and handling of fresh and preserved fish from 1931 to 1935.

Figure 3. Experimental equipment for investigating canning of fish at San Pedro, California about 1922.

Figure 4. Portion of chemical laboratory in the 1931 to 1935 Gloucester Technological Laboratory.

Figure 5. Experimental steam-jacketed fish meal dryer. It was originally used in the summer field station at Reedville, Virginia (1925-1930) later at the Gloucester Technological Laboratory (1931-1933). When the new technological laboratory quarters in Seattle were occupied in 1933, the dryer was shipped to Seattle where it was used for many years.

INTRODUCTION

This report traces the development of scientific and technological research on fishery food by governmental agencies of the United States from early beginnings in the latter part of the nineteenth century to the point where National Oceanic and Atmospheric Administration (NOAA) was set-up late in the year of 1970. Although the manpower and funding available was relatively small during early years, very little is generally known about it; therefore, a disproportionate share of this report deals with work in this early era. In short, developments since the late 1930s are discussed in only enough detail to give continuity between the past and the present.

Because this report is to be issued at the time when the NOAA Western Regional Center is to be dedicated in October 1983, a special section is included at the end of this report, discussing to some extent the governmental research in the field of food science and technology carried out in Seattle between the establishment of NOAA and 1983. This research is that carried out by National Marine Fisheries Center largely in Seattle.

Coverage of the research developments is restricted to efforts made by governmental agencies; thus, except for occasional brief mention where necessary to elucidate the course taken by governmental research agencies, no attempt is made to cover the considerable efforts of universities, industry, and other groups.

The research developments are traced first chronologically in a general way. This treatment is followed by more specific descriptions, first by geographical areas and then by types of research. The personnel involved in the research are listed in the appendix.

I. GENERAL CHRONOLOGICAL DEVELOPMENTS

The developments occurred in a manner that makes for a logical classification into seven periods of time. These periods are characterized in Table 1.

A. Before 1871--The Government Begins Work in Food Science

Prior to 1871, no fishery research had been carried out by any government agency of the United States, and no consideration had been given to the need for work in fishery food science or fishery food technology. Nevertheless, during this period, the principles of chemistry and other basic sciences were being applied to problems related to other foods.

During the regime of Prime Minister Pitt about 1800, the British Parliament passed an act which resulted in Sir Humphrey Davey initiating experiments to apply chemistry to the solving of practical problems of agriculture. By 1862, the value of such an experimental approach to the

Table 1. Historical development of fishery food research.

Period	Date	Elapsed time	Workers employed on technological projects: Bureau scientific employees	Workers employed on technological projects: Non-Bureau scientific employees	Highlights
Initial period		Years	Average number per year	Average number per year	
	Before 1871		0	0	Food-science work began by the government.
U.S. Fish Commission Smithsonian Institution collaborative period	1871-87	16	1	3	U.S. Fish Commission established, & pioneers work in fishery food science under Spencer Baird.
U.S. Department of Agriculture period	1887-1917	30	0	4	All food-science work by the Bureau of Fisheries halts; first full-time prolonged efforts on fish begun by the Dept. of Agriculture.
Early Bureau operations period.	1917-31	14	5	2	Several technological laboratories set up by Bureau of Fisheries; active research programs started.
Early expansion period	1931-42	11	10	0	Early laboratory at Gloucester established; laboratories at Seattle, College Park, & Ketchikan follow: budget & staffs increased.
World War II and early postwar period	1942-55	13	30	0	Program expanded during World War II, followed by retrenchment and consolidation.
Period from expansion due to SK funding until formation of NOAA	1955-70	15	100	0	Technological laboratories at Gloucester, Pascagoula, Ann Arbor, & Terminal Island & the Food Science Pioneer Research Lab at Seattle established; programs expanded under Saltonstall-Kennedy Act.
Operations at Seattle	1971-83	12	--	-	

solution of these problems was recognized by President Lincoln and by Congress, which passed a law directing the Department of Agriculture to employ chemists, botanists, entomologists, and other scientists to work on the agricultural problems in this country.

The new law was implemented on January 1, 1863, with the appointment to the Department of Agriculture of Charles M. Wetherill, a distinguished American chemist. He and his successors--notably Henry Erni, who worked for the Department from 1863 to 1866 and a Mr. Antisell, who worked from 1866 to 1871--carried out chemical investigations on sugar, soils, fertilizers, tanning methods, and meats. Apparently they did no work on fish, but they did set a precedent that encouraged subsequent investigators to carry out similar work on fish.

B. From 1871 to 1887--Newly Formed Fish Commission Pioneers Fishery Research

Early in 1871, Congress established a position of Commissioner of Fish and Fisheries. This position was created specifically for Dr. Spencer Baird, then Assistant Secretary of the Smithsonian Institution, who became the first commissioner. The Smithsonian was at that time the foremost scientific organization in this country, and Baird, who had previously been associated with the National Museum, was its leading naturalist. Baird became Secretary of the Smithsonian Institution in 1878 and from then until his death in 1887 was head of both the Institution and the United States Commission of Fish and Fisheries.

The budget of the newly formed Fish Commission was very small; in 1872 it was only $15,000 and the Commissioner served with no compensation. Under these circumstances, much of the research had to be carried out by other agencies of the government, the universities, or by other scientists working in facilities provided by the government and coordinated by the Commissioner of Fish and Fisheries. In 1873, for example, oceanographic work was conducted aboard one of the United States Navy's steam tugs, the Blue Light, which was anchored off Peak's Island near Portland, Maine.

During this time, scientists who carried out research under Baird's general direction were professors from Yale University, Mount Tabor College (Iowa), Delaware College (Ohio), Wesleyan University (Connecticut) and elsewhere. The site of the projects they worked on each summer changed from year to year. In 1878, the summer site was at Gloucester, Massachusetts. The field station, which was set up at Fort Square, was the first to be established in a center of the commercial fishing industry. It was used by the Commission for several subsequent years. As a result of the summer station's location, problems of the commercial fisheries were impressed on the Commissioner, and this resulted in the initiation of the first fishery food scientific and technological projects.

During the latter part of the 19th century, scientific research in this country was in its infancy with most of the important work being carried out abroad. Except where close liaison was possible with work going on in Europe, little progress was made. Baird had many contacts with scientists abroad. As a result, the people he selected for technological work were put in touch with the latest developments in the scientific world and were able to accomplish much along technological lines in the years that he remained with the Commission.

Baird brought W. O. Atwater of Wesleyan University, Middletown, Connecticut, in touch with the need for information about the nutritive value and the chemical composition of fish. Atwater spent time in several German laboratories learning experimental techniques, which he applied to determine the digestibility of fish as compared with that of meat and other foods. He and his students accurately determined the chemical composition of many species of fish (Atwater 1892). Most of the analyses were carried out by Charles Woods, one of Atwater's students while Atwater was in Europe (Stansby 1978). For the next 50 years or more, these analyses served as the basis of our knowledge in this field.

Atwater and his students represented some of the finest talent then available in fishery food science. He went on to become known as the father of the agriculture experiment stations in this country. Of the seven students who worked with him on fish, three became heads of state experiment stations, one the curator of the National Museum, one the head of the Chemistry Department at the University of Iowa, and one a prominent member of the Medical School at Northwestern University.

Baird selected W. G. Farlow of Harvard University to investigate the cause of reddening in salt cod. Farlow found that the reddening was the result of bacterial action, a fact not known in the United States at that time. Methods devised by Farlow for improved cleanliness in the cod-fish plants and changes in the kind of salt used brought this problem under control.

With projects such as these, an excellent start was made toward the development of fishery food science and technology. In fact, more was accomplished by the U.S. Government's fishery agency during this 14-year period (1873-86) than in the 30-year period that followed. This early pioneering effort in fishery food science is due to Baird's excellent scientific background and his contacts among scientists. He was probably the most eminent scientist ever connected with fishery research in this country.

C. From 1887 to 1917--Department of Agriculture Given Major Role in Fishery Food Science Research

In 1887 Baird died. Thereafter the close personal ties between the scientists in the Smithsonian Institution and those in the Fish Commission (and its successor, the Bureau of Fisheries) no longer existed. After his death, the work of the Fish Commission gradually moved away from general scientific matters into the relatively narrow field of practical fish hatchery production.

Such work as might today be classified as food science and technology came under a small division of the Commission called Division of Statistics and Methods of the Fisheries. (This organization later became the Division of Fishery Industry; still later it was called the Division of Industrial Research.) The work of this division was carried out by field agents who each summer went from the office at Washington into various sections of the country to collect statistics of fish landings and to observe how fish were being handled. During the winter months, the statistics were compiled and articles were written on the manner in which certain fisheries were operated. Many of the fishery agents were prodigious writers who turned out several hundred pages of reports a year. In 1894, for example, the division staff of only four persons published 725 pages of material. This work resulted in a monumental record of what was going on in the fishing industry. Several of these fishery agents--notably Hugh Smith (later Commissioner), Charles Stevenson, and John N. Cobb--left many important reports that thoroughly document the commercial methods of the fisheries in their time. They made no attempt, however, to carry out experimental work or research that would improve handling methods.

For the first 33 years of its existence, the Fish Commission was an independent agency. In 1903, however, its functions were transferred to the Department of Commerce and Labor, and the agency was renamed the Bureau of Fisheries. From the death of Baird in 1887 until 1917, no research was done in the Bureau of Fisheries in food science and technology. The Bureau, however, did authorize, in several written agreements, the Department of Agriculture to carry out work on fish analogous to the work which that Department was doing on other food products.

Much of the early research by Agriculture on fish was carried out as a part of other programs--for example, the analyses of fish and fishery products that were made around the turn of the century during studies of the nutritive value of foods.

In 1913, the Bureau of Chemistry of the Department of Agriculture formalized its work on fish by making research on fish an official function of its Philadelphia Food Research Laboratory under the directorship of Mary Pennington. Up until that time, the laboratory had been engaged exclusively with research on poultry and eggs. Ernest D. Clark and L. H. Almy were assigned to work on fishery problems. They did much of their work in the Philadelphia laboratory, but in the summer they carried out field work at points near commercial fishery operations. The first summer they set up a temporary field station in New Haven, Connecticut, for work on oysters; another year, Clark surveyed Pacific Coast fisheries; later, a temporary operation was set up in Maine to study problems of the sardine (herring) industry.

In 1916, Clark set up a small laboratory in Seattle, and with several assistants, conducted work on fish of the Pacific Coast. Later, he and others did research on California fisheries, working out of the Food and Drug Administration's laboratory in San Francisco. Meantime, the main effort on fish continued to be centered in the Philadelphia laboratory.

During this period, work on fish by the Department of Agriculture covered a wide range of subjects (United States Department of Agriculture 1921). This work has been described as follows:

"The Food Research Laboratory undertook work upon the handling, transportation, and utilization of seafoods analogous to that it was doing upon poultry and eggs. It determined the food value of fish. It studied the changes in food value of fish dependent upon size, conditions, season; method of icing, freezing, and transportation of fresh fish, and of preserving them such as salting, smoking, kippering, and canning; the changes frozen fish undergo in cold storage for long and short periods; and the utilization of fishery byproducts. It succeeded, especially during the war, in widening the consumption and in organizing the rational distribution over railroads of fish particularly from the Gulf of Mexico. As in the case of handling poultry and eggs, so the work of this laboratory represents almost the first fundamental scientific work upon the American fish handling industry."

The Philadelphia Food Research Laboratory was discontinued in 1921. Thereafter, only a small amount of fishery work was continued by the Department of Agriculture. Most of this work related to the operations of the Bureau of Chemistry, which then was responsible for enforcing food and drug laws that now would be enforced by the Food and Drug Administration.

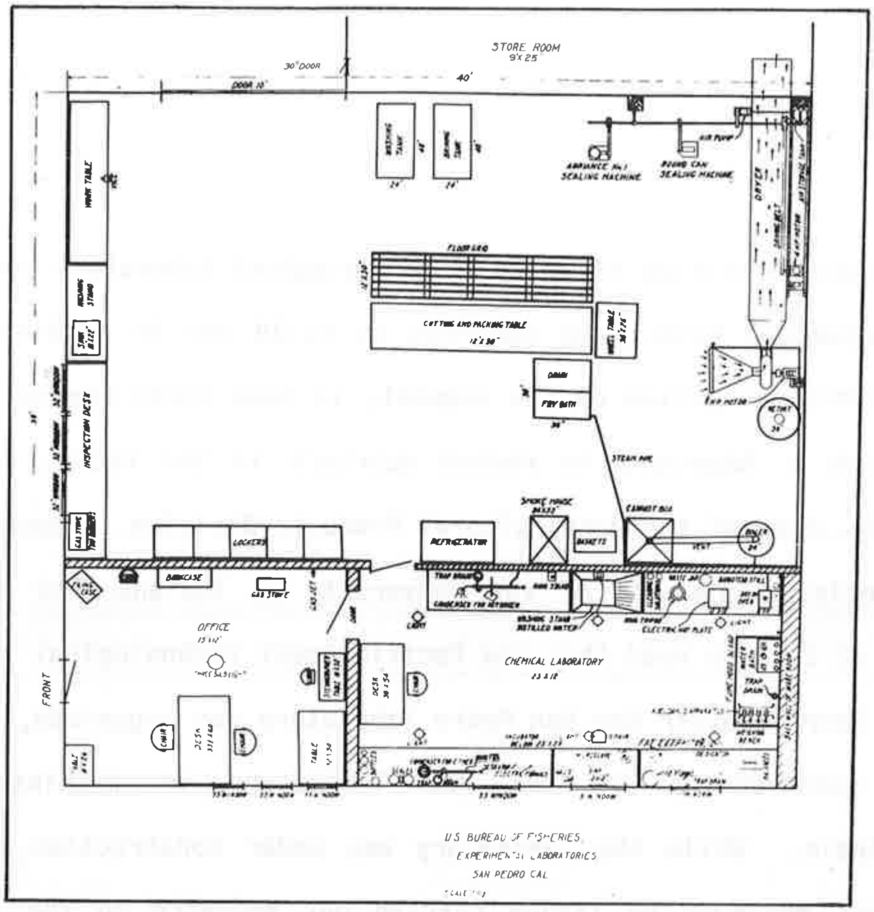
D. From 1917 to 1931--Bureau of Fisheries Assumes Responsibility for Food Science Aspects of Fishery and Research

In 1917, Lewis Radcliffe became Chief of the Division on Statistics and Methods of the Bureau of Fisheries, succeeding Alvin B. Alexander, who had held the post since 1903. Radcliffe felt strongly that technological research had too long been neglected by the Bureau. During 1917, with the United States just having entered World War I, the Bureau of Fisheries began some scattered work in fishery technology. Recommendations were developed for methods of canning dogfish and of using several other species of fish not then being utilized. Methods of shipping live carp to market were devised, and techniques for making use of fish skins for leather were investigated in cooperation with leather-tanning firms. These activities were carried out with available facilities and personnel mostly in the biological laboratories.

On July 31, 1918, Harden F. Taylor was appointed to set up research specifically in fishery technology. His title was Assistant for Developing Fisheries and for Saving and Use of Fishery Products. Since the Bureau had no physical facilities in which a technological laboratory could be established, it requested funds from Congress to build one in Washington, D.C. Pending Congressional action on the request, it took steps toward immediately setting up such a laboraory in rented quarters in San Pedro, California. Lester Lingle--head of the Horticultural Products Division, Oregon State College, and a chemistry graduate of the University of Indiana--was employed during the fall of 1918 to head this new Pacific Coast technological laboratory.

Shortly after the San Pedro laboratory was organized, Congressional funds for construction of the new laboratory in Washington, D.C., became available. While the laboratory was under construction, Donald Tressler, a chemist employed by Taylor carried out research on the salting of fish at temporary field stations on the South Atlantic Coast and performed other work at Gloucester, Massachusetts.

The new San Pedro laboratory opened in 1919. Operating funds were so limited, however, that at the beginning of a fiscal year, the staff might be told that there was no assurance that money would be available for their salaries but that they could continue working without compensation and perhaps funds would become available later. The laboratory at San Pedro had no operating funds for an entire year; during this time, it was funded and operated by the California Department of Fish and Game. After Lingle resigned in 1921, the San Pedro laborary was put under the supervision of Harry Beard, but its staff was gradually transferred to the laboratory in Washington,



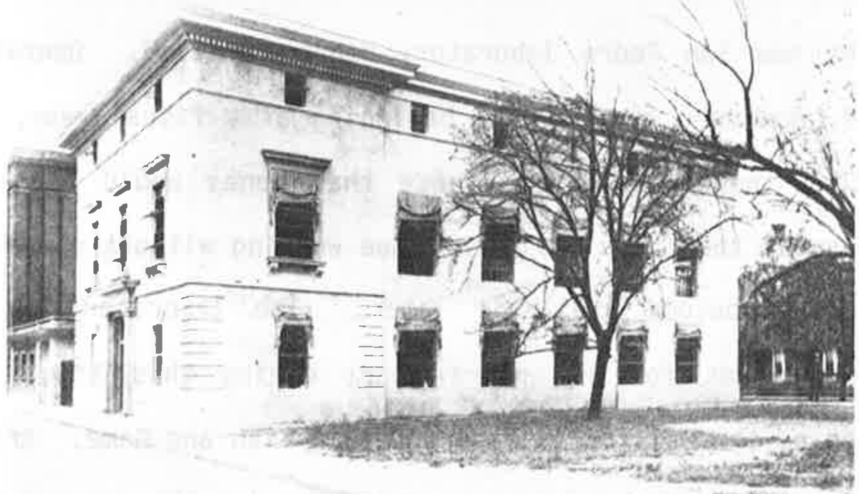


Figure 1. Two early laboratories of Bureau of Fisheries.
A. Floor plan of San Pedro, California Laboratory. This laboratory, occupying rented quarters, operated from 1918 to 1924.

B. Washington, D.C. Laboratory of Bureau of Fisheries. This was the first government owned building built and used for fishery food science research. It operated from 1919 to 1931.

D.C. In 1924, when Taylor resigned to go into private industry (Atlantic Coast Fisheries Company), Beard became Chief Technologist, and the laboratory at San Pedro was discontinued.

Beard's staff consisted of Arthur Wells (who had started work at the San Pedro laboratory in 1920, at the same time as Beard, but who had been transferred to Washington, D.C. in 1921) and Wallace Conn. Budgetary conditions for technology improved considerably about this time, making it possible to hire two new people--Robert Taylor, a chemical engineer engaged to work on fish meal and oil, and Gerald Fitzgerald, hired as a naval architect to work full time on fishing gear and methods.

In 1925, the first summer field station was opened at Reedville, Virginia. For the next 5 years, it was operated for 8 or 9 months a year as a base for research on methods of manufacturing fish meal and oil. Also in 1925, surveys were carried out in southern states on methods for handling shrimp and for utilizing shrimp waste.

In 1926, fellowship cooperative work was begun at Johns Hopkins University, and this program continued for 5 years. A new employee, Joseph Ridlon, was added to work on the byproducts project at Reedville, and he remained on this project for the next 4 years. Robert Taylor carried out some excellent research on methods of utilizing small quantities of fish waste. He resigned at the end of 1926.

Beard resigned in November 1927 to direct the research efforts of a commercial fishing company (New England Fish Company), and Conn then became Chief Technologist. Alfred C. Robertson was employed to carry on the work on net preservation and to help with the research on byproducts.

In 1928, Roger W. Harrison was employed to direct the work at the Reedville Laboratory which up to then had been carried out on menhaden by Robertson and Ridlon. The research was expanded to include drying herring, and preparing fish-liver oils. Three new temporary laboratories were set up: one, on the Boston Fish Pier, was for year-round work on handling fresh fish and on manufacturing cod-liver oil; one, at a summer station on Lake Erie, was for investigating the preservation of nets; and the third, at a summer station at Brunswick, Georgia, was for investigating the utilization of shrimp. Eric Loffler and a Mr. Cutler were employed at the Boston station. At the end of the year, Fitzgerald resigned from the Washington, D.C. laboratory. John R. Manning was employed during the year to work on the nutritive value of fish. This work had been going on for several years as a Bureau sponsored fellowship program at Johns Hopkins University. James Lemon was employed to work on the handling of fresh and frozen fish.

In 1929, S. R. Pottinger was employed to assist Harrison and others in the byproducts laboratory at Reedville. He also assisted Conn on preservations for fish nets. During the year, Ridlon and Robertson resigned. Lemon worked at Columbia, South Carolina, on the brine chilling of

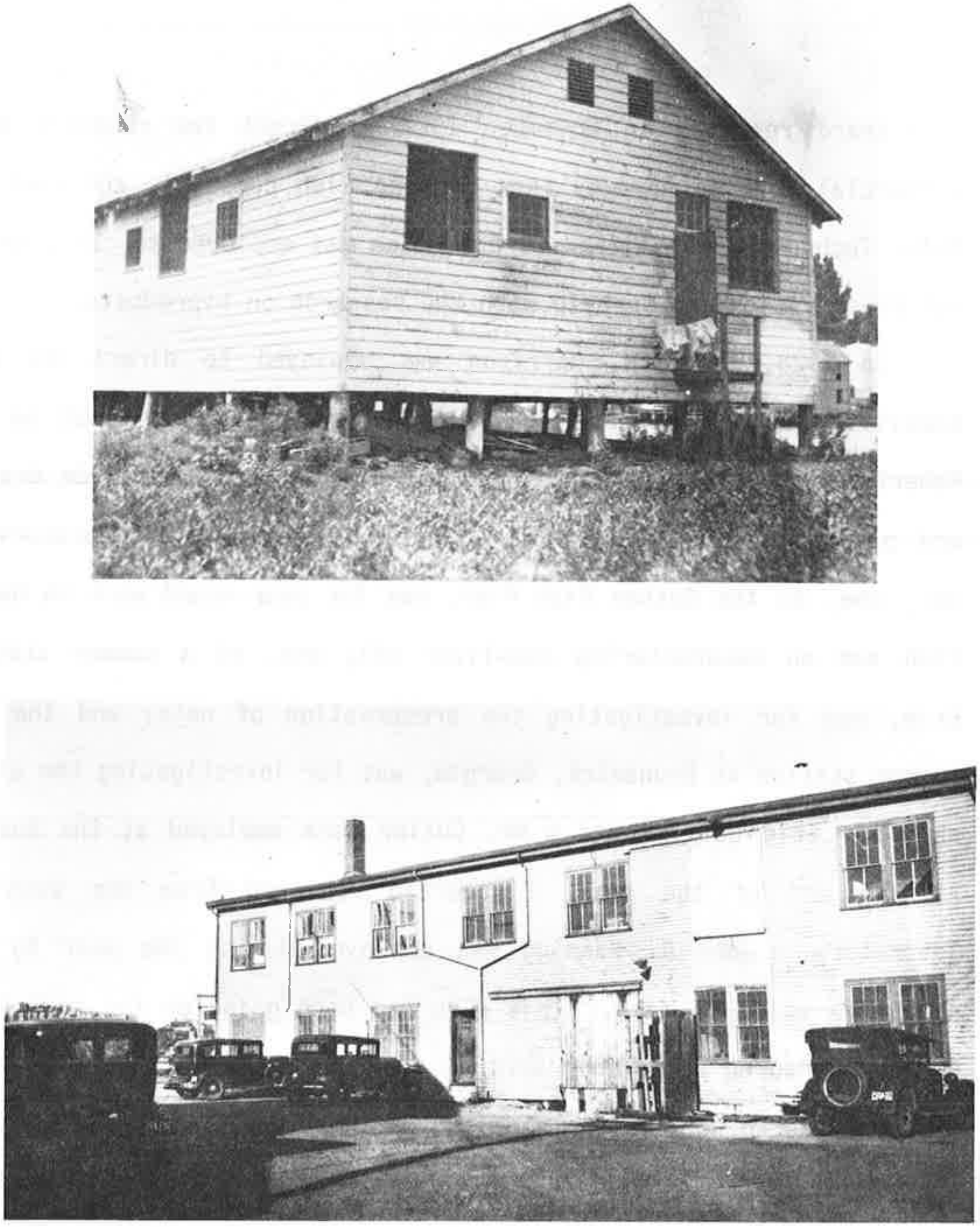


Figure 2. Two laboratories operated in rented quarters between 1925 and 1935.

A. Summer field station for investigations at Reedville, Virginia dealing with fish meal and oil and operated 1925 to 1930.

B. Gloucester Technological Laboratory which worked on both industrial products and handling of fresh and preserved fish from 1931 to 1935.

fish. In the fall, Loffler resigned, and the Boston station was closed. Manning expanded the program at Johns Hopkins University to include studies on the nutritive value of fish meal.

In 1930, Manning succeeded Conn as Chief Technologist. Conn carried out work in Florida on converting shark to fertilizer. Harrison conducted a survey of end-users of fish oils and began research on the vitamin content of fish-liver oils.

E. From 1931 to 1942--Fishery Food Research Expands

In 1930, Congress passed appropriation legislation for the White Bill which provided new funds for expanded research and building construction by the Bureau of Fisheries. This funding plus later developments, resulted in considerable expansion in both the facilities and the number of personnel assigned to research in fishery food science and technology. From 1931 to the start of World War II, the number of the Bureau's permanent technological laboratories, increased from zero to three. These were laboratories at Gloucester; College Park, Maryland (recently relocated to Charleston, South Carolina); and Seattle.

In 1931, the Bureau set up a new laboratory at Gloucester. This laboratory was the forerunner of the Seattle and College Park laboratories since all the Gloucester laboratory personnel were eventually transferred to start these new laboratories. The staff at Gloucester consisted of James Lemon, laboratory director; F. P. Griffiths, microbiologist; and Maurice E. Stansby, chemist. Griffiths and Stansby were detailed to work on fresh, frozen, and preserved fish. Also at Gloucester were Roger W. Harrison, chemical engineer, who was in charge of industrial byproducts work, A. W. Anderson, fishery technologist, and S. R. Pottinger, chemist, who assisted him. The byproducts group remained at Gloucester pending completion of laboratory facilities in Seattle. In 1933, Harrison and Anderson were transferred to Seattle to initiate operation there.

The program of that laboratory at Gloucester included the following:

1. Effect of manufacturing variables, such as drying temperature, on the composition and nutritive value of fish meal. (Chemical analyses were made by Pottinger; nutritive value of fish meal was studied cooperatively with workers at Ohio State University and Cornell University.)

2. Utilization of livers from various species of fish as a source of vitamin oils.

3. Manufacture and utilization of fish flour (later called fish protein concentrate-FPC).

4. Preparation of smoked fish (mostly finnan haddie).

5. Bacteriology of fresh fish.

6. Freshness tests for fish.

7. Oxidative changes in fish oils.

8. Improved handling of haddock and mackerel, including use of a carbon dioxide atmosphere.

The laboratory had been set up at Gloucester partly because rent-free space was provided for 4 years by the Gloucester Chamber of Commerce. At the end of this period, no funds were available for rent. So in 1935 when the University of Maryland offered free space in the basement of the Horticulture Building at College Park, the laboratory was transferred completely--both equipment and personnel--to the University of Maryland campus.

During the same time that the laboratory was functioning at Gloucester (1931-35), the nutritional properties of fish were being studied by Charles F. Lee, working first in Washington, D.C., and later at the old Rossborough Inn on the campus of the University of Maryland. At the same time, E. J. Coulson, a Bureau employee, was working under the direction of Roe E. Remington at the South Carolina Food Research Laboratory and at the Medical College of the University of South Carolina, at Charleston, mostly on mineral content and metabolism of minerals in diets containing fish. When the laboratory at College Park was set up, Lee, who continued his research on the nutritional properties of fish, was transferred from Washington, D. C. Coulson was also transferred to College Park, but he remained for only a short time before resigning to accept a position with the Department of Agriculture. Coulson's place was taken by Hugo W. Nilson who took charge of the nutrition program and was assisted by Lee. During this period, almost the entire program at College

Park was concerned with some aspect of the nutritional properties of fish; the main part of the program was the determination of the amino acid content of fish.

Besides the nutrition program, two fellowship projects were conducted from the College Park laboratory. One was a cooperative study with Aquacide Company for the development of a preservative for fish and fish livers. Connected with the project were Aquacide fellows H. E. Crowther, Joseph Puncochar, Richard Flowers, and C. E. Swift; Stansby represented the Bureau in a part-time capacity. The other project, a somewhat smaller one, was conducted both at College Park and at Seattle during the late 1930s. Sponsored by the Musher Foundation, it dealt with the use of Avenex (a product based on oat flour) as an antioxidant for fish products.

Starting in 1933, Laboratory Director Harrison, assisted by Anderson, carried out projects in Seattle dealing with both salmon-body oil and fish-liver oils. Several temporary employees worked at the Seattle laboratory during this period. Among them were Charles Butler, John Dassow, and William Clegg. In 1938, Anderson was transferred to Washington D.C. to start the Market News Service. He was replaced by Stansby, who was transferred from Boston, where he had been detailed from the College Park laboratory to assist a large frozen-fish concern in adapting a freshness test to their operations. The program at Seattle, primarily on byproducts up to this time, was then broadened to include work on frozen fish, on preservation, and on composition.

From 1939 to 1942, an extensive exploratory-fishing program on king crab was carried out from Seattle. During that time, all the Bureau's exploratory fishing work was conducted by the Branch of Technology. The king crab program was organized and supervised by Harrison of the Seattle laboratory.

With Public Works Administration funds, a new fishery products laboratory was erected and opened in 1940 at Ketchikan, Alaska, with Stansby as laboratory director. It was operated jointly by the Alaska Fisheries Experimental Commission (an agency of the Territory of Alaska) and by the Bureau of Fisheries. The initial program of the laboratory dealt with ways of increasing the production of off-season fisheries (those other than salmon and halibut) in Alaska. Research was conducted on the production of fish fillets, clams, and vitamin A oils from fish livers.

Also in 1940, a technological laboratory was set up at Mayaguez, Puerto Rico, for the purpose of developing the latent fisheries in the area. Joseph Puncochar, the director of the laboratory, was assisted by Richard Whiteleather. Both exploratory fishing and fish preservation studies were carried out. After only a few years, Puncochar and Whiteleather had demonstrated that the underutilized species in the vicinity of Puerto Rico were not nearly as extensive as had been believed earlier. As a result, this Bureau laboratory was discontinued.

Although the technological laboratory that was built in Washington, D.C. in 1919 was abandoned by the Bureau by 1932, some technological work was still carried out in the Washington office between 1930 and 1942, notably by Norman Jarvis. During this time, he compiled and published material on the canning of fish. Over the years since it was first published, this lengthy government bulletin (Jarvis 1943) has served as the standard treatise on the subject. Work was also carried out in Washington on recipes for fish, a field of study that at that time was included in the Branch of Technology.

F. From 1942 to 1955--World War II Expansion Followed by Retrenchment

From 1942 to 1955, the Branch of Technology's activities, and the staff to conduct them, were expanded considerably in support of certain aspects of the war effort; during the postwar period, retrenchment and a consolidation of effort followed. Nevertheless, a new laboratory was established in New England.

Largest of the special wartime programs was the one dealing with substitute containers for fishery products. In this program, various kinds of tin plate, all containing reduced amounts of tin, were compared, and the feasibility of their use for canned fishery products was evaluated. With supplies of tin cut off from the Far East, it was necessary to make what was available go as far as possible; the result was electroplated cans having so little tin that severe corrosion was a distinct possibility. Use of these new tin plates was tested at both the College Park and the Seattle laboratories with many species of fish. Cardboard substitutes for fillet tins and other applications were also tested.

Other wartime programs included (1) a project carried out at Seattle and College Park to develop a dehydrated fish product for Army field use; (2) a project carried on from the Seattle laboratory at a field station in La Jolla, California, to investigate substitute seaweed products for bacteriological agar, the supply of which was no longer available from Japan; and (3) a project carried out at Seattle to resolve the problems associated with stockpiling vitamin A fish-liver oils by the War Production Board. Several staff members from different laboratories were detailed for varying periods of time to the Army Quartermaster Corps' laboratory in Chicago as advisors on matters concerning the use of fish by the Armed Forces.

In 1947, as a result of curtailment of the wartime programs, Technology's budget was cut about 50%. Although the staffs and the levels of activity were greatly reduced, the number of programs being worked on was still somewhat greater than the pre-war number. The technological programs were soon augmented by establishment of a new laboratory. Late in 1947 a very small station was set up in the Appraisers Stores Building on the Boston waterfront with Puncochar as laboratory director. About this time, new funds were made available to investigate what happened to fish that were frozen in the round aboard trawlers, thawed out ashore, and then filleted and refrozen. This made possible an enlargement of the staff, and the laboratory was then moved to surplus government buildings in East Boston with Pottinger as director. The operation remained there until November 1959, when the laboratory was moved into its new building in Gloucester, Massachusetts, with Slavin as laboratory director from 1960 to 1966. After 1966, John Holston became laboratory director.

During the 1940s and early 1950s, operations at the College Park laboratory continued. Leslie Sandholzer succeeded Nilson as laboratory director in 1946. For the next 4 years--2 years under Sandholzer and 2 under his successor, Clifford Evers--considerable emphasis was placed on the microbiological aspects of the fisheries. But when Nilson became director for the second time in 1950, programs involving the nutritive value of fish became prominent again.

During this period, the Seattle laboratory with Maurice Stansby succeeding Roger Harrison in 1942 as laboratory director, worked extensively on utilization of the wastes from salmon canneries and on vitamin A from fish-liver oils. Stansby conceived and started the Bureau's monthly periodical, Commercial Fisheries Abstracts. Considerable work on the compositon and the nutritive value of hatchery feeds was carried on for the Bureau's fish hatcheries. Near the end of the period, two new projects were begun--one on the chemistry of fish oils and the other on the composition of fish--that were to become the basis of important, larger programs in the subsequent period.

At the Ketchikan laboratory, Lyle K. Anderson was director from 1942 to 1945, Harrison W. Magnusson from 1945 to 1950, and John Dassow from 1950 to 1955. One of the most extensive projects at Ketchikan concerned the toxicity of clams caused by gonyaulax and the means of reducing it. Another project conerned fuller utilization of Alaska fisheries.

G. From 1955 to 1970--Programs Expand and Laboratories Specialize

During the period from the mid 1950s to 1970, four new technological laboratories were established: two in 1958--one in Ann Arbor, Michigan, for work on problems of the inland fisheries with Nilson as first laboratory director; one at Pascagoula, Mississippi, for work on problems of the fisheries in the Gulf of Mexico and South Atlantic areas with Travis Love as laboratory director; one in 1964--at Terminal Island, California, for work on California fisheries (primarily tuna) with Roland Finch as director; and one in 1966--in Seattle, Washington, the Food Science Pioneer Research Laboratory, for work at a fairly basic level on problems connected with the oxidation of fish and fishery products. In 1966, Stansby who had been laboratory director of the technological laboratory at Seattle since 1942 became head of this latter new laboratory. He was succeeded by Maynard Steinberg as director of the technological laboratory at Seattle.

Under the Saltonstall-Kennedy Act, which became effective in 1955, the Branch of Technology expanded its program considerably. The large programs at

Seattle on fish oils and those at College Park on fish meals and fish protein concentrate owed their start to this act, as did the development of the grade standards and inspection programs.

During this period, each of the various laboratories began specializing in certain fields of research. At Gloucester, under Joseph Slavin as laboratory director, specialties were developed to include the working out of inspection standards, the biochemistry and physical chemistry of muscle-protein denaturation, and the chemistry of odor and flavors. Slavin was succeeded in 1966 by John Holston as laboratory director. At College Park, where Donald Snyder was laboratory director, the focus was on the nutritional value of fish and fishery products and the development of fish protein concentrate. At Pascagoula under Travis Love, the principal specialty was the composition of fish. At Ann Arbor with Harry Seagran as director, most of the research was involved with the development of safe processing methods for smoked fish, with particular reference to botulism. At Terminal Island, the specialty was the science and technology of tuna products and tuna processing. At Seattle, the technological laboratory specialized in the chemistry and utilization of fish oils, and the Food Science Pioneer Research Laboratory specialized in research on the oxidation of fish and fishery products. At Ketchikan, with Murray Hayes as laboratory director, the specialty was the food technology of decapod crustaceans.

Thus we see that research in fishery food science and technology by the government grew from the random work performed by unpaid staffs in various unconnected agencies during the nineteeth century to the present systematic research carried out by organized staffs in a number of coordinated laboratories throughout the country. By 1970, research under the Bureau of (Commercial) Fisheries terminated with the reorganization under the newly formed NOAA getting fully underway in 1971.

II. SPECIFIC DEVELOPMENTS

A. Developments by Geographical Area

1. Pacific Coast

a. California. In California, the first technological research on fishery products by the government for which record could be found was carried out by Ernest D. Clark, Bureau of Chemistry of the Department of Agriculture. He conducted this work between 1918 and 1919 at the San Francisco Food and Drug Laboratory. The work, a continuation of the studies he had carried out in 1916 and 1917 in Seattle, was largely connected with wartime problems. When Clark left his position with the Department of Agriculture in the fall of 1919 to direct the newly established National Canners Association Laboratory in Seattle, this work ceased.

San Pedro, California, was the location of the Bureau's first year-round laboratory devoted to technological research. This laboratory was established in 1918 with Lester Lingle as director. In preparation for his new responsibilities, he spent the latter part of 1918 on the East Coast visiting fishery plants and working in Washington office. Then he went to San Pedro early in 1919, rented a building from the Los Angeles Harbor Department and set up the laboratory which opened in May 1919. In addition to Lingle, workers in the San Pedro laboratory were Clarence Anderson, a food technologist who had recently graduated from the School of Fisheries at the University of Washington, and W. R. Sadler, a microbiologist. The first research project, was directed toward development of new packs of canned mackerel, barracuda, and pilchard. Sixteen different processing procedures were evaluated.

During the summer of 1919, Braxton, a chemist, was added to the staff. Braxton, Anderson, and Sadler resigned the following year. During the summer of 1920, Harry Beard, a University of Wisconsin graduate in chemistry who had been working in a Chicago meat-packing firm, and Arthur Wells, a chemist at a steel mill in Indiana, were employed. For Fiscal Year 1921, the Bureau ran out of funds for technological work, and the laboratory was financed by the California Department of Fish and Game under Norman Scofield. In July 1921, at the beginning of the new fiscal year, federal funds became available, and the laboratory again became the financial responsiblity of the Bureau. In

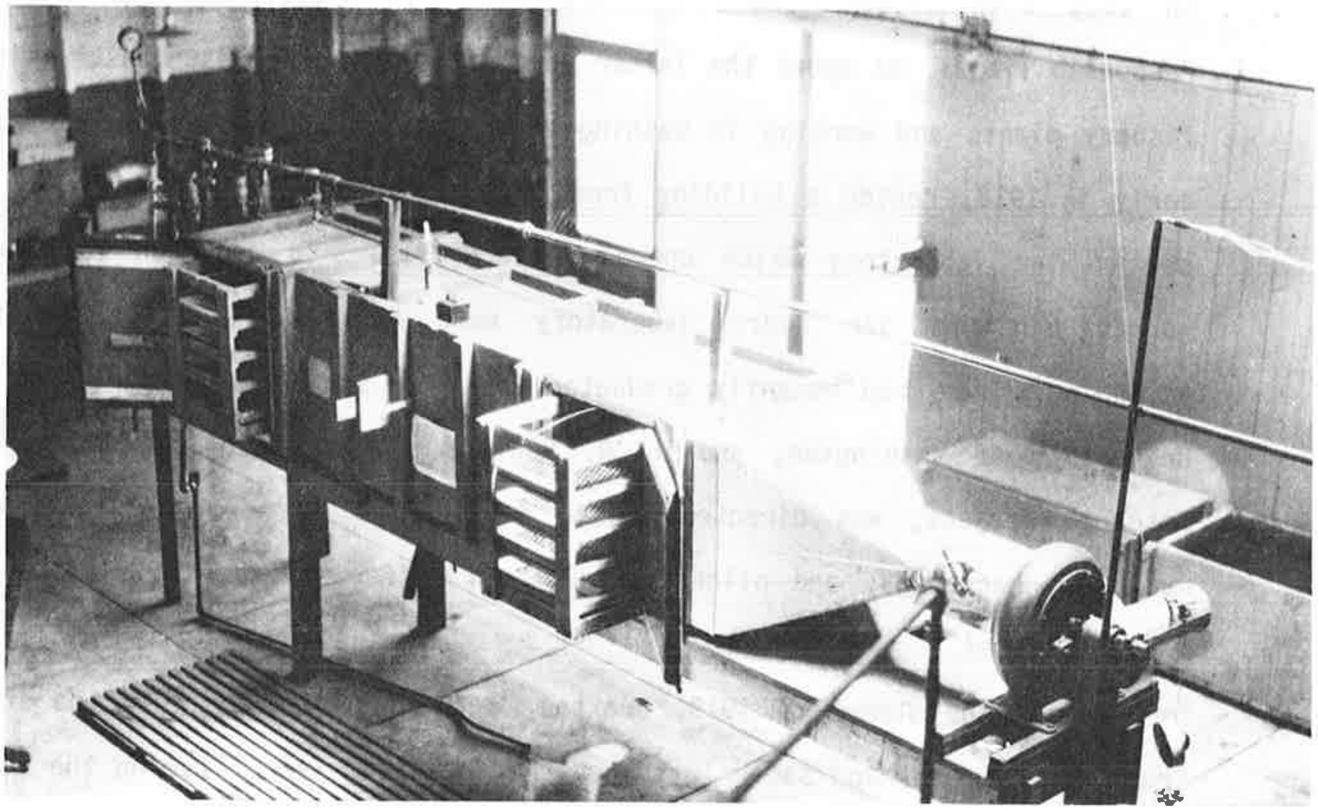


Figure 3. Experimental equipment for investigating canning of fish at San Pedro, California about 1922.

September 1921, Wells was transferred to Washington, D. C. and in October of that year Lingle resigned. Beard became head of the laboratory and remained in that capacity until the laboratory operations at San Pedro were discontinued in 1924. Throughout his directorship, he had only occasional part-time student help. The program was concerned largely with improving the quality of canned California sardines. In June 1924, Beard was transferred to Washington, D. C. where he became Chief Technologist for the Bureau, and the Bureau's first year-round technological laboratory was closed.

The next technological activity of the federal government in California was a brief project conducted during World War II concerning the use of California seaweeds as a source of bacteriological agar. This project was carried out as part of the program of the Seattle Technological Laboratory. A field station was set up on the campus of Scripps Institute of Oceanography, University of California; Victor Scheffer and Vincent Senn carried out research which continued from 1943 to 1945.

A long gap now appeared in the work done by the federal government in fishery food science and technology in California, although considerable work in the field of quality control and inspection was done by the State of California through the Hooper Foundation for Medical Research, University of California. From 1933 to 1955, as part of the Seattle Technological Laboratory's program of research for the entire Pacific Coast, laboratory personnel made occasional field trips to California to take samples for later study in Seattle.

It was not until 1955 that the Bureau of Commercial Fisheries resumed technological work in California on a continuing basis. A cooperative research program was entered into by the Bureau's Seattle Technological Laboratory and the University of California. Projects were carried out in the Food Science and Technology Department at Davis and in the Institute of Marine Resources at Berkeley. These projects, which dealt largely with the oxidation of fish oils, continued for years. Also started in 1955 was a program on tuna technology; it likewise was a part of the program of the Seattle Technological Laboratory. Initially, the work was conducted largely on a contract basis with the California Department of Fish and Game, which then subcontracted the work to the Hooper Foundation. Because neither of these agencies had technological facilities close to the tuna industry in Southern California, the contract was later transferred to the Philip R. Park Research Foundation of San Pedro, where extensive studies were carried out under Sven Lassen of Van Camp Seafoods Company. The Seattle Technological Laboratory carried out some work in connection with this project and eventually established a field station on Terminal Island, manned by Clarence Carlson. The work at the field station continued on past the termination of the Philip R. Park contract in 1961. In 1964, an independent laboratory headed by Roland Finch was established at Terminal Island.

b. Pacific Northwest and Alaska. The first governmental technological work in fisheries in the Pacific Northwest was that carried out by the Bureau of Chemistry of the Department of Agriculture in 1916 and 1917. Dr. Ernest D. Clark was employed by the Bureau of Chemistry in 1913. After having worked on fishery technological projects on the East Coast, he made in 1915 a survey of the commercial fisheries of the Pacific Coast. In 1916, he was transferred to Seattle where he set up a laboratory in the Arcade Building. He had several assistants to help with this work. These included M. J. Blish, a Dr. Prim, and Leslie McNaughton. One of the projects they worked on involved the temperature of iced and frozen fish shipped from Seattle in refrigerator cars. Thermocouples were run from the cars to the caboose, where a laboratory assistant accompanying the shipment monitored the temperatures. Another project involved a study of the decomposition of salmon in which the formation of ammonia and amines was followed. This early U.S. Department of Agriculture laboratory was closed in 1917. Among presently operated Bureau Technological Laboratories, the Seattle laboratory opened in 1933 was the first to be established. During the first 3 or 4 years of its existence, the laboratory operated exclusively in the field of fishery byproducts, with emphasis on fish oils. Gradually over the years, the interests of this laboratory have broadened until today it covers a wide scope of work.

Although as early as 1915 Cark surveyed the technological problems in Alaska, no experimental work on the problems was done until after the Bureau of Fishery's Seattle Technological Laboratory was established. Initially the laboratory at Seattle was considered as being concerned with problems for the entire Pacific Coast. One of the first projects undertaken after its opening in 1933 was an investigation of the utilization of waste from Alaskan Salmon canneries. At a field station set up at Larson Bay on Kodiak Island, Roger W. Harrison and A. W. Anderson ran experiments from May to September 1934 on manufacture of salmon oil from cannery trimmings.

Another very important project, carried out in Alaska but working from the Seattle laboratory, was the King Crab Expedition conducted during 1940 and 1941. Two vessels, the Tondeleyo and the Dorothy, left Seattle in August 1940 and carried out exploratory operations between False Pass and Kodiak Island. Waldo L. Schmidt of the National Museum, Washington, D.C. was head of the field party with Roger W. Harrison as overall program leader in Seattle. Others involved in the 1940 expedition included Carl B. Carlson, fishery engineer; LeRoy Christey, economist; Joseph Puncochar, technologists; and Marvin Wallace and Camile J. Pertuit, biologists. The vessels returned to Seattle on December 9, 1940; a second trip was made by the Dorothy and two other vessels, the Champion and the Locks, during the spring of 1941.

A laboratory was opened at Ketchikan in October 1940 as the Fishery Products Laboratory. It was financed and operated jointly by the Bureau of Fisheries and the Alaska Fisheries Experimental Commission, an agency of the Territory of Alaska. Maurice Stansby was its first director. Working in the laboratory during the first several years of operation were Lyle Anderson, John Dassow, and Frank Piskur, chemists. Carl Carlson and LeRoy Christey, employees of the Fisheries Experimental Commission, were nominally members of the Ketchikan laboratory, but they spent most of their time on the king crab project and were stationed in Seattle for several years during preparation of the detailed report of this extensive work. Dr. Murray Hayes was director from 1962 to 1970 and Jefferson Collins from 1970 to 1971 at which time the laboratory was moved from Ketchikan to Kodiak with Collins continuing as laboratory director.

2. New England

The first technological project undertaken by the United States Commission of Fish and Fisheries, predecessor agency of the Bureau of Fisheries, got underway in Gloucester, the summer site of operations in 1878. W. G. Farlow, a Harvard Professor, happened to visit the laboratory that summer, and Spencer Baird, Commissioner of Fish and Fisheries, interested him in the problem of the reddening of salt cod, the cause of which was unknown at that time, at least in the United States. Farlow observed this condition in the Gloucester salt-fish plants, made microscopic examinations of materials on the spot, and then took samples back to Cambridge, where he identified the organism causing the red discoloration as *Clatrocystis roseopersicina*, a species belonging to the group *Schizophytae* and known today as *Lamprocystis*. Farlow found the organism to be prevalent in the type of salt then used, called Cadiz salt, and almost absent from another type of salt called Trepani. He recommended thorough cleaning of the plants, application of fresh white paint on all the wooden surfaces, and use of the Trepani salt only. When these recommendations were followed, the problem was overcome (Farlow 1880).

Also in 1878, during the time when the Commission headquarters were in Gloucester, W. O. Atwater of Wesleyan University, Middletown, Connecticut, visited the laboratory. Baird interested him and his students (especially Charles Woods) in carrying out for the Commission at Middletown the now famous investigations on the proximate composition of fish (Atwater 1892). At about this time, the Commission made efforts to popularize two underutilized species of fish, pole flounder and tilefish.

No record could be found of any further fishery technological work done in New England until about 1908, when the Department of Agriculture set up a field station in Maine to study the canning of sardines. Some scattered work was carried out during the next 10 years in New England by the Department of Agriculture. Included in this work was an investigation by Ernest D. Clark and L. H. Almy at Yale University, during the summer of 1915, of the spoilage of oysters.

The first "modern" technological work by the Bureau got underway in May 1928 following establishment of a small office-laboratory on the Boston Fish Pier. Eric Loffler, a fishery engineer, was in charge. Loffler tried to develop methods that would eliminate the need to fork fish during unloading. Also working at this station was a laboratory assistant named Cutler, who studied methods for improving the manufacture of cod-liver oil. This office maintained a supply of Bureau bulletins for distribution. It closed at the end of 1929.

The laboratory that operated from 1931 to 1935 at Gloucester with James Lemon as director investigated problems of such diverse nature as those concerned with the processing of byproducts, the microbiology of fish, and the changes in fish oil that result from oxidation. In 1933, part of this laboratory was moved to Seattle; the rest was moved in 1935 to the campus of the University of Maryland. These moves were the actual beginning of the Bureau's present technological laboratories at Seattle and Charleston, South Carolina (which much later was set up by transfer of equipment and personnel from College Park when that laboratory was closed).

The College Park laboratory remained largely one with programs built around nutritional properties of fish. It had a succession of laboratory directors (James Lemon 1935-1943; Hugo Nilson 1943 to 1946 and again 1950 to 1958; Leslie Sandholzer 1946-1948; Cliff Evers 1948-1950; Frank Piskur 1958-1961; and Donald Snyder 1961 until after reorganization for establishment of NOAA. Perhaps because Dr. Hugo Nilson's background was heaviliy oriented toward nutrition and he served as laboratory director for a total of 11 years over two spans of time the program remained strongly oriented to nutrition. Furthermore, it was the only laboratory with animal testing facilities. After Donald Snyder became laboratory director in 1961, the College Park laboratory

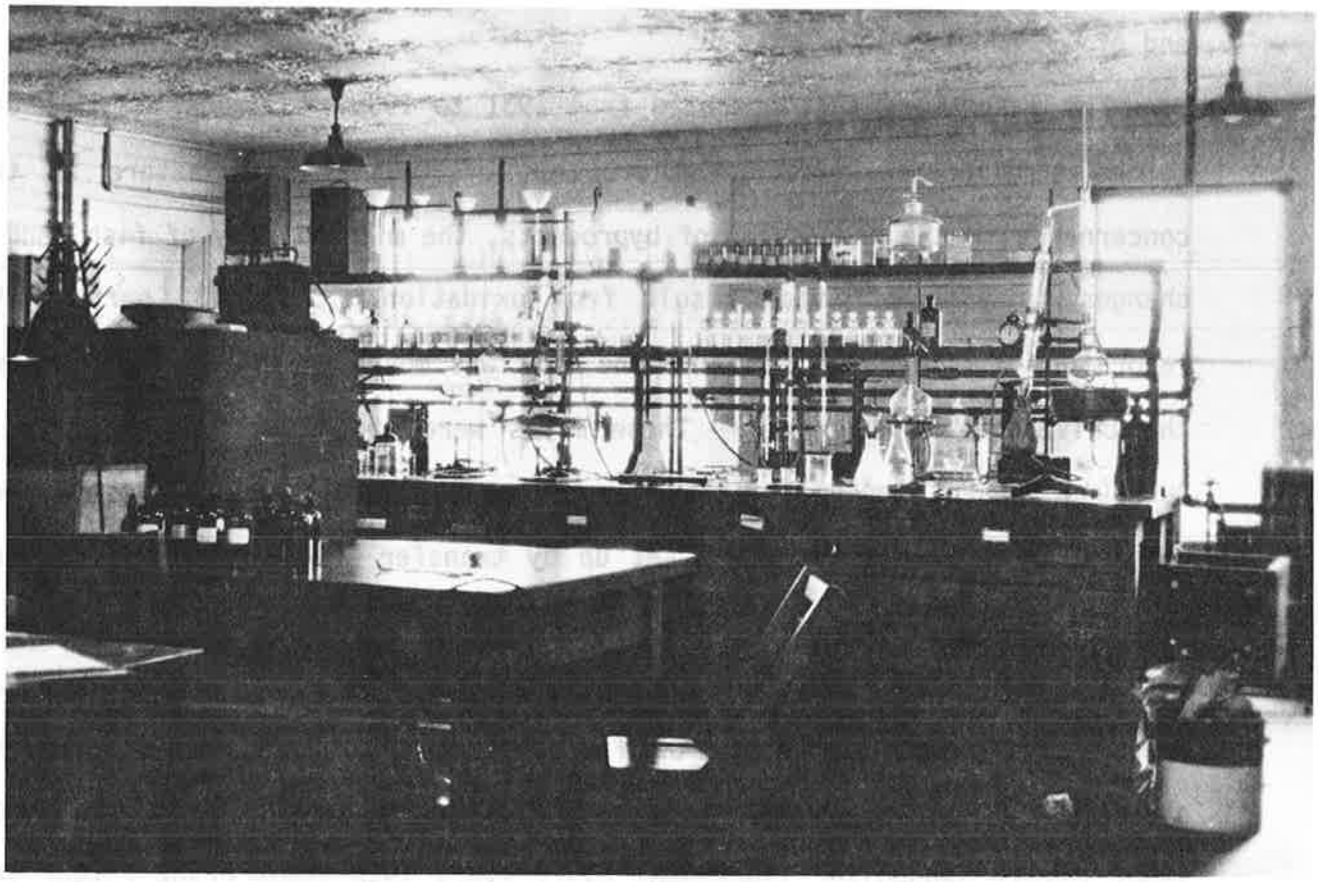


Figure 4. Portion of chemical laboratory in the 1931 to 1935 Gloucester Technological Laboratory.

added engineering aspects in connection with development of procedures for making fish protein concentrate (FPC).

The present Gloucester technological laboratory had its beginning with Puncochar as director as a temporary, small operation set up in 1947 in the Appraisers Stores Building in Boston. It soon moved to larger quarters in some surplus Navy buildings in East Boston. The present building in Gloucester was occupied in 1959.

3. Middle Atlantic, South Atlantic, and Gulf Areas

The first technological efforts in the Middle Atlantic and South Atlantic areas were begun between 1914 and 1921 as a part of the Department of Agriculture's program on fish. Up to this time, the program had been carried out from the Food Research Laboratory in Philadelphia. Much of this effort was related to preservation and shipment of fish from the Southern States to the Middle Atlantic and North Atlantic States. The motive for the work was the fear that during World War I German submarine activity in the North Atlantic would disrupt the principal American fishery operations there and require expansion of fishing operations to the south. This same line of work was the first type of program in which the Bureau of Fisheries engaged when technological work first was begun in 1918. For the work, Donald K. Tressler, with headquarters in laboratories at Johns Hopkins University, set up field operations at Palatka, Florida, and Edenton, North Carolina, where he conducted experiments on the salting of fish in warm climates.

At the field station operated by the Bureau from 1925 to 1930 at Reedville, Virginia, mostly as a temporary summer base, menhaden meal and oil were extensively studied. Investigations on preservation of fish nets was also carried out from the Reedville laboratory. In 1928 and 1929, the Bureau investigated the utilization of shrimp waste in cooperation with the University of North Carolina, at temporary facilities set up at the Glynn Canning Company at New Brunswick, Georgia. Professor Vilbrandt and Roy Abernethy, both of the Department of Applied Chemistry of the University of North Carolina, were active in this work. In 1929, James Lemon of the Bureau, conducted experiments on the chilling of fish at Columbia, South Carolina.

From 1930 to 1935, E. J. Coulson, a Bureau employee, carried out research on the mineral content and its nutritional availability in fish. The work was done at the laboratories of the South Carolina Food Research Commission, at Charleston, South Carolina. The permanent College Park laboratory was established on the campus of the University of Maryland in 1935 when both personnel and equipment were transferred from the laboratory at Gloucester which was being closed. Lemon was director of the new College Park laboratory; other personnel included Charles Lee, Pottinger, and Stansby. Hugo Nilson was employed shortly after the laboratory opened. He replaced Coulson who transferred to a post with the Department of Agriculture.

The College Park laboratory has been discussed in the preceding section and will not be mentioned again at this point.

Not until 1958, when the Bureau set up a technological laboratory at Pascagoula, Mississippi, with Travis Love as director, was any continuing research begun in the Gulf of Mexico region. This laboratory carried out technological research for fisheries in the states bordering on the South Atlantic and the Gulf of Mexico.

4. Inland Areas

The earliest technological work of any kind on freshwater fishes of which record is available was the inclusion by W. O. Atwater during the early 1880s of a few limited samples of freshwater species in his proximate composition studies. Species included with number of samples in parenthesis were: black bass (2), lake trout (2), lake herring (4), muskellunge (1), pickerel (4), pike-perch (1), sheepshead (4), walleye (2), white fish (1), white perch (4), and yellow perch (10). These fishes were obtained from Lakes Ontario and Erie and from a number of small lakes located in New York, Florida, and elsewhere (Atwater 1892).

The next work on the technology of freshwater fishes on record was carried out at the Bureau of Fishery's biological station at Fairport, Iowa. This station, established in 1910, was transferred to a new building in 1914, at which time it became the principal facility for research on freshwater fishes for the Bureau. Following destruction by fire in December 1917, it was rebuilt. During 1915-18, some technological work was done at the station on the utilization of freshwater species. Since much of the biological work dealt with mussels, the shells of which were used in the large button industries located along the Mississippi River, one of the principal technological activities involved finding new uses for mussel meats. Connected with the laboratory was a smokehouse where experiments on the smoking of carp and related species were also conducted.

From 1927 to 1929, the Bureau operated a summer field station on Lake Erie (at Erie, Pennsylvania) where the preservation of fish nets was investigated. Wallace Conn was in charge of this work. The University of Wisconsin cooperated by detailing a microbiologist, W. H. Wright and a student named Hildebrand to aid in this work during 1928 and 1929.

From 1940 to 1950, various technological investigations were carried out by a number of organizations. During World War II, a firm in Mankato, Minnesota, assisted by the Seattle Technological Laboratory, developed a canned carp product, which for a time was in fairly strong demand. From 1950 to 1958, the Seattle Technological Laboratory carried out a small but continuing program on proximate composition and cold-storage life of freshwater species. The program was supplemented by grants from the Refrigeration Research Foundation. The earlier part of this work, as well as a summary of work done at the Midwest universities, was described by Stansby in 1955. Several subsequent publications, and Seattle manuscript reports, deal further with this work, which represented, up to establishment of the Ann Arbor Technological Laboratory, the most continuous technological effort expended by the Bureau on freshwater species.

The Ann Arbor Technological Laboratory was set up on a small scale in 1958 with Hugo Nilson as director. Later, it rapidly expanded in response to urgently needed research on the botulism hazards connected with smoked freshwater fish. Harry Seagren was laboratory director beginning in 1960.

B. Development by Types of Operations

A brief survey of the developments in technological research and exploratory fishing operations will now be presented. In the United States, the latter type of work is not at present considered to be a part of fishery food science and technology. Currently, in the National Marine Fisheries Service, work on exploratory fishing and gear research is carried out as a part of biological research programs separate from research on technology of fish utilization. In the early days of the Bureau and its predecessor agencies, however, no such separation existed, and developments on gear research and fish preservation went on side by side in the Branch of Technology. Hence both are considered here.

1. Food Science and Technological Research.

Briefly summarized in this section is the work that had been done on composition and nutritional value; on fresh, frozen, canned, and cured fish; on meal and oil production; and on oxidation of fish oil.

a. Composition and nutritive value of fishery products. The work done on proximate composition of fish during the early 1880s by Charles Woods and

W. O. Atwater and sponsored by the Bureau has already been mentioned. During this period, Atwater also carried out important research, far advanced for the time, on the digestibility of fish. This work--which was conducted at the laboratory of Professor Van Voit in Munich, Germany, and at the laboratory of Professor Kuehne in Heidelberg--showed that fish can be digested at least as well as any other flesh food.

During the 1920s, the Bureau of Fisheries did a considerable amount of work on the nutritive value of fishery products, especially of fish meal, which at that time was being introduced in the United States for use as an animal feed rather than for exclusive use as a fertilizer. Much of this work was done in the laboratories at Johns Hopkins University under the direction of E. V. McCollum, a foremost nutritionist of the day. Research was also carried out on the nutritive value of fish protein and on the mineral components and vitamin content of fish.

During the early 1930s, the Bureau carried out work on the vitamin A and D content in fish-liver oils. This work was done both alone in the Bureau's own laboratories (by Chester Tolle and Charles F. Lee) and collaboratively in those of the Food and Drug Administration. Cooperative work on the nutritive value of fish meals was also carried out at this time with Cornell University, Ohio State University, and Washington State College (now Washington State University).

For several years (1931-1935), E. J. Coulson, a Bureau employee stationed in the laboratories of the South Carolina Food Research Commission, worked under Roe E. Remington investigating the mineral content of fish. This work included a determination not only of the content in fish of such elements as iodine and copper but also of how well these elements are metabolized and deposited in the human body. Coulson found, for example, that copper and arsenic, which sometimes occur in fish in quantities above that normally considered safe for human consumption, are not assimilated as completely in the organic form as they would be in the inorganic form.

At the Seattle laboratory from 1937 to the early 1960s, a very large amount of research was carried out on the proximate composition (oil, protein, ash, and moisture contents) and in some cases the sodium and potassium content. During the earlier part of this period the work was largely carried out by William Clegg. During the latter part of work was done and supervised by Dr. Claude Thurston. A thorough coverage was made of fish of the Pacific Northwest. Considerable work was also carried out on fresh-water species from the Great Lakes and elsewhere.

Beginning in the 1950s as a part of the broad fish oil program at the Seattle Technological Laboratory in cooperative work with a Seattle heart specialist, Dr. Averly Nelson involving a 20-year clinical tests, it was shown that less than 1/4 as many deaths from heart attacks occurred if the patients ate fish as a main coarse at least three times per week. During the same period of time contract research by the Seattle laboratory with Hormel Institute of the University of Minnesota (J. J. Peifer) showed that fish oil polyunsaturates were more effective in lowering serum cholesterol levels of rats than were vegetable oil polyunsaturates.

In much more recent research (summarized by Barlow and Stansby (1982) the specific reason for this great effectiveness of fish oil is explained. Oils from fish but not from any other food contain components which can greatly reduce the clumping together of blood cells within arteries which can in turn result in a heart attacks.

b. Handling fresh and frozen fish. The first extensive investigation of the handling of fresh and frozen fish was carried out in the Department of Agriculture laboratories in Philadelphia and Seattle between 1915 and 1920. Changes in frozen fish due to alteration of nitrogen fractions were extensively studied in Philadelphia. In Seattle, Ernest D. Clark and his assistants thoroughly tested fresh and frozen halibut that were shipped by rail from Seattle to the East Coast; their laboratory tests were carried out in the caboose of the freight train hauling the fish.

At the Washington, D. C., laboratory in the early 1920s, Harden Taylor, Donald Tressler, and others investigated the brine freezing of fish. A 133-page bulletin resulted from this work (Taylor 1927).

James M. Lemon investigated the glazing of frozen fish in the late 1920s and published several Bureau reports on this work (Lemon 1932a and 1932b). At the Boston Fish Pier, Eric Loffler deomonstrated ways of eliminating the use of forks in unloading fish.

In more recent years, all laboratories of the Bureau have extensively investigated the handling of fresh and frozen fish. One of the major efforts by the Bureau was conceived and started in Seattle (Stansby and Dassow 1948) and was continued in great depth in Boston in the 1950s (Holston and Pottinger 1954)--the refreezing of fish fillets ashore from fish that had been first frozen in the round aboard the fishing vessel. Several fishery leaflets (United States Fish and Wildlife Service, 1956a, b, c, d, e) dealing with different aspects of refrigeration of fish report on best commercial practices in this field.

c. Canning of fish. The first efforts of the Bureau to aid the canned-fish industry failed. During World War I, a need for more protein food had prompted the Bureau to sponsor the purchase of canned dogfish by the government. Not realizing that, because of the presence of urea, dogfish require special precanning treatment, the Bureau issued canning guides based on standard canning procedures. Many of the packs put up by these standard methods spoiled, resulting in lawsuits against the government.

Later efforts on canning were more successful. Between 1918 and 1924, the San Pedro laboratory did considerable research on methods to improve the quality of canned sardines. This work was reported in a 156-page publication (Beard 1927). From this time to 1940, Norman Jarvis, Bureau technologist,

worked extensively on canning techniques for fish, publishing his findings in a 366-page bulletin (Jarvis 1943). During World War II, the Bureau investigated the canning of fish in containers coated with a minimum thickness of tin. In the postwar period, the Seattle Technological Laboratory studied the quality of canned salmon prepared from frozen fish, and under a fellowship program sponsored by a can company, investigated sulfide discoloration in canned fish.

d. Curing of fish. Many early compilations of commercial fish-curing methods were made during the late nineteenth and early twentieth century by Bureau employees such as G. Browne Goode, Hugh Smith, and especially Charles Stevenson. The first actual experiment in this field was the work on reddening of salt cod by W. G. Farlow for the Fish Commission in 1878. About 1916, the biological laboratory at Fairport, Iowa, worked on the smoking of carp. Later, Donald Tressler and Harden Taylor studied the salting of fish in warm climates, and published several long reports on their findings (Tressler 1920). In 1932 and 1933, James Lemon at the old Gloucester laboratory designed and built an experimental smokehouse and, with Francis Griffiths, investigated the smoking of finnan haddie (Griffiths and Lemon 1934). Later, Norman Jarvis worked in Washington, D. C. and in College Park on his 271-page curing bulletin (Jarvis 1950).

e. Fish meal and oil. The first research done on fish oil by the Bureau was in 1921 and 1922 by Tressler and others, partly at a summer field station

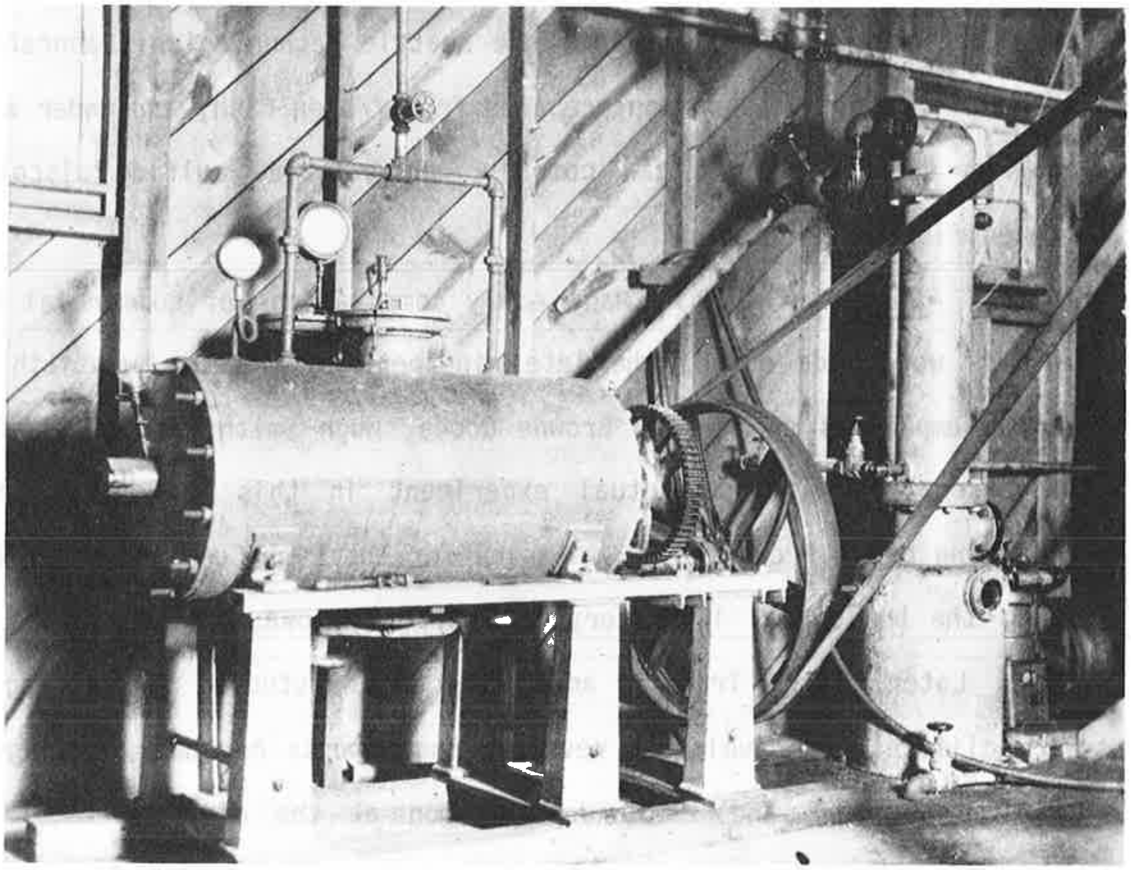


Figure 5. Experimental steam-jacketed fish meal dryer. It was originally used in the summer field station at Reedville, Virginia (1925–1930), later at the Gloucester Technological Laboratory (1931–1933). When the new technological laboratory quarters in Seattle were occupied in 1933, the dryer was shipped to Seattle where it was used for many years.

in Gloucester and partly in the new laboratory in Washington, D. C. The various fat constants of fish oil, such as iodine number and the saponifiable number, were determined, and this information was brought to the attention of the paint industry. About 1925, research on the production of meal and oil was centered at Reedville, Virginia, under Robert Taylor; this work, which was mostly with menhaden but included minor research on other species, such as herring continued until 1930. After 1927, Roger W. Harrison was the project leader. In 1931, the Bureau's research was continued for 2 years by Roger Harrison, A. W. Anderson, and S. R. Pottinger, mostly on the reduction of fillet waste. In 1933, this activity was transferred to Seattle, where research on fish oils was continued for many years. The work on fish meals was continued in Seattle until 1959, when this aspect of the program was transferred to the College Park technological laboratory. Starting in 1955, the Bureau began a broad program at the Seattle Technological laboratory on the chemical reactions of fish oils and on the utilization of the derivatives obtained from these oils. In very recent years when technological work has been alluded to as utilization research at programs within National Oceanic and Atmospheric Administration (NOAA) most of the work on fish oils has been carried out at the Charleston, South Carolina Laboratory[1/] under Harry Seagran.

1. Formerly the now discontinued laboratory at College Park, Maryland.

f. Oxidative deterioration of fish oils.--Although work by W. T. Conn in 1927 and Roger W. Harrison in 1929 on the increase in free fatty acids in comercial menhaden oil might be considered a forerunner of the Bureau's research on the oxidation of fish oils, no specific work in this direction got underway until 1933. In January 1933, at the old Gloucester laboratory, a series of experiments were begun by M. E. Stansby on the rate of oxidation of extracted mackerel oil. The effect of such variables as storage, temperature, light intensity, and the addition of antioxidants was studied. Peroxide number was used as the criterion for determining the amount of oxidation. This research is the first work on oxidation of fish oils, not only in the Bureau, but so far as we know, anywhere. In Canada, H. N. Brocklesby started work about a year later on the oxidation of fish oils. Whereas the Bureau's work was aimed at edible oils, Brocklesby's was related to industrial drying oils and was concerned with the addition of metallic salts as driers.

In 1936, in an effort to improve methods of analysis, the Seattle Technological Laboratory started work on the extraction of oil from fish meal. This work, which lasted about 15 years, was concerned indirectly with the oxidation of oil. In 1937, the College Park laboratory worked on the use of Avenex (an oat-flour product) as an antioxidant for fish fillets. In 1939, a similar Avenex project was started in Seattle. In 1938, work was begun by R. W. Harrison in Seattle on the measurement of temperature fluctuations that occur during the curing of fish meal as a result of oxidation of the residual oil in the meal.

Since 1940, most of the work in this field has been carried out in Seattle, although Bittenbender and Nilson did some research on antioxidants at College Park in the late 1940s. In Seattle, the oxidative deterioration of such species as salmon, halibut, and rockfish was surveyed between 1940 and 1955. Beginning in 1955 under the Saltonstall-Kennedy Act, and with much of the work being done on contract at the Universities of California and Minnesota, a small start was made toward determining the mechanism of oxidation. This subject became the principal field of investigation for the Food Science Pioneer Research Laboratory in Seattle between 1966 and 1971.

2. Exploratory Fishing and Gear Research.

Before Exploratory Fishing and Gear Research became a separate branch, Bureau work on fishing gear and explorations for new fishing grounds was done by the Branch of Technology. During the early 1920s, some work on preserving fish nets was carried out in the Washington, D. C. laboratory, Wallace T. Conn and Arthur Wells having started it in 1921. G. A. Fitzgerald, who had been employed as a naval architect, A. C. Robertson, and W. T. Conn continued the work until 1931. Most of it was concerned with prolonging the life of fish nets by treating them with various chemical preservatives. It was found that nets rot as a result of bacterial action and that rotting varied greatly according to the geographical waters in which the nets were used. Nets treated in various ways were hung in both fresh water (principally Lake Erie) and salt water (principally the waters off the Virginia coast). A special summer laboratory for the work was set up at Erie, Pennsylvania. At one stage, the Bacteriology Department of the University of Wisconsin took an interest in the experiments and detailed several people to assist in them.

In 1940, the Bureau set up a fairly ambitious exploratory fishing program under Roger W. Harrison, director of the technological laboratory in Seattle. For two seasons, several vessels were dispatched to Alaskan waters, where workers on the program looked into the best fishing areas and the best catching and canning methods for king crab. This early work, conducted before much of a king crab industry existed in Alaska, stimulated the American industry to develop its king crab operations to their present large size. This exploitation occurred after the end of World War II.

In 1944, the Seattle Technological Laboratory undertook a cooperative program with the Reconstruction Finance Corporation in designing and building a factory-freezer ship, The Pacific Explorer. Although the vessel was begun as part of the World War II conservation program, it was not completed until after the war was over. The Pacific Explorer (Carlson 1947) was a complete factory ship, containing filleting facilities and equipment for producing fish meal and oil. The vessel was operated under government financing for about 2 years.

SUMMARY

Food science and technology was started by the Department of Agriculture on foods other than fish during the administration of President Lincoln. Work on fish awaited setting up of the Fish Commission (predecessor of the later Bureau of Commercial Fisheries and still later National Marine Fisheries Service) in 1871. During the time that Spencer Fullerton Baird was both Commissioner of Fisheries and head of the Smithsonian Institution, an excellent beginning was made in food science and technology. This dealt principally with the composition and nutritive value of fish and with the cause and cure of the reddening of salt cod.

These early beginnings were interrupted in 1887 by the death of Baird; then the activities of the Fish Commission and of the Smithsonian Institution were separated. During the subsequent 30-year period, the Bureau of Fisheries abandoned all work in the food science and technology of fish, leaving such little work as was done to the Department of Agriculture. From 1913 to 1920, this agency carried out through its Food Research Laboratory at Philadelphia some studies on problems of the fishing industry. In 1916 and 1917, the Department of Agriculture also operated a fishery laboratory in Seattle.

Interest in fishery technology within the Bureau of Fisheries was awakened by events of World War I. With the appointment of Lewis Radcliffe as Chief of the Division of Fishery Industries in 1917, and with appointment of Harden F. Taylor and Donald K. Tressler in 1918, a start was made on work in

this field. One laboratory was opened in San Pedro, California, early in 1919 and one in Washington, D. C. later that year. Work continued through the 1920s under the handicap of a severely inadequate budget--the San Pedro laboratory had to be operated for a year by the California Department of Fish and Game and finally to be abandoned in 1924.

The White Act first funded in 1930 provided sufficient appropriations to allow new operations to be started; the first was at a laboratory in Gloucester, Massachusetts, in 1931. This laboratory was the nucleus of the later operations in Seattle and College Park (later transferred to Charleston, South Carolina) for a portion of its staff was transferred to Seattle to set up operations there in 1933 and the remainder of the staff was sent to start the College Park Laboratory in 1935.

New laboratories were started in 1940 in Puerto Rico and Alaska to try to help expand the unexploited fisheries there. The laboratory at Maytaguez, Puerto Rico, remained for only a few years until the latent resources were found to be less extensive than had been believed. The Fishery Products Laboratory at Ketchikan, initally operated jointly by the Territory of Alaska and the Bureau of Commercial Fisheries, was developed over the years emphasizing the utilization of different species. It was transferred to Kodiak in 1971.

Laboratories were started in Boston in 1947 (and later transferred to Gloucester); in Pascagoula, Mississippi, and Ann Arbor, Michigan, in 1958; and in Terminal Island, California, in 1964. A special, basic research laboratory for work on fish-oil oxidation was started in Seattle in 1966.

ACKNOWLEDGEMENT

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LITERATURE CITED

Atwater, W. O.

1892. The chemical composition and nutritive value of food fishes and aquatic invertebrates. Report of the United States Commissioner of Fisheries for 1888 to 1889, pages 679 to 868. (Document 185.)

Barlow, S. M. and Stansby, M. E.

1982. Nutritional evaluation of long-chain fatty acids of fish oils, pages 245-282; 307-314. Academic Press (London) 1982.

Beard, Harry.

1927. Preparation of fish for canning as sardines. Bulletin of the United States Bureau of Fisheries, 156 pages. (Document 1020.)

Carlson, Carl B.

1947. SS Pacific Explorer - a preliminary report. Commercial Fisheries Review 9(1): 1-17.

Farlow, W. G.

1880. On the nature of the peculiar reddening of salted codfish during the summer season. Report of the United States Fish Commissioner for 1878, volume 6, appendix 44: 969-974.

Griffiths, Francis P., and James M. Lemon.

1934. Studies on the smoking of haddock. United States Bureau of Fisheries, Investigational Report 20, 12 pages.

Holston, J., and S. R. Pottinger.

1954. Freezing fish at sea. Part 8. Some factors affecting the salt (sodium chloride) content of haddock during brine-freezing and water-thawing. Commercial Fisheries Review 16(8): 1-11.

Jarvis, Norman D.

1943. Principles and methods in the canning of fishery products. United States Fish and Wildlife Service, Research Report 7, 366 pages.

1950. Curing of fishery products. United States Fish and Wildlife Service, Research Report 18, 271 pages.

Karrick, Neva L.

1965. A review of marine oil research conducted and sponsored by the Bureau of Commercial Fisheries of the United States. Fette Seifen. Anstrichmittel 67 489-94.

Lemon, James M.

1932a. Reducing the shrinkage of frozen fish in cold storage. United States Bureau of Fisheries, Investigational Report 9, 12 pages.

1932b. Developments in the refrigeration of fish in the United States. United States Bureau of Fisheries, Investigational Report 16, 32 pages.

Stansby, Maurice E.

1978. Charles Woods, pioneer scientist on chemical composition of fish. Marine Fisheries Review (40(7):1-4.

Stansby, Maurice E.

1955. Technological research on the freshwater fisheries of the U.S. Commercial Fisheries Review 17(10): 31-34.

Stansby, M. E. and Charles Butler.

1958. Bureau of Commercial Fisheries oil research program. J. Am Oil Chemists Soc. 35 8-12.

Stansby, M. E., and John Dassow

1948 Can fish be frozen aboard vessel, thawed, filleted, and refrozen ashore? Pacific Fisherman 46(4): 65.

Taylor, Harden F.

1927. Refrigeration of Fish. United States Bureau of Fisheries, 133 pages. (Document 1016.)

Tressler, Donald K.

1920. Some considerations concerning the salting of fish. Report of the United States Commissioner of Fisheries, appendix 5, 54 pages. (Document 884.)

United States Department of Agriculture.

1921. Report of the Chemist. United States Department of Agriculture, Bureau of Chemistry, page 25.

United States Fish and Wildlife Service.

1956a. Refrigeration of fish - Part 1. Cold storage design and refrigeration equipment. United States Fish and Wildlife Service, Fishery Leaflet 427, 146 pages. (Section 1 - Cold storage design, by Charles Butler, Joseph W. Slavin, Max Patashnik, and F. Bruce Sanford, pages 1-74; Section 2 - Refrigeration equipment, by Joseph W. Slavin, pages 75-100; Section 3 - Refrigeration requirements and freezing methods, by Joseph W. Slavin, pages 101-146.)

1956b. Refrigeration of fish - Part 2. Handling fresh fish. United States Fish and Wildlife Service, Fishery Leaflet 428, 84 pages. (Section 1 - Spoilage of fish prior to freezing, by Charles Butler, pages 1-12; Section 2 - Handling of fish aboard the vessel, by John A. Dassow, pages 13-37; Section 3 - Handling fresh fish at the shore plant, by C. J. Carlson, Joseph Carver, and Martin Heerdt, pages 39-84.)

1956c. Refrigeration of Fish - Part 3. Factors to be considered in the freezing and cold storage of fishery products. United States Fish and Wildlife Service, Fishery Leaflet 429, 65 pages. (Section 1 - Changes taking place during freezing of fish, by Maurice E. Stansby, pages 1-14; Section 2 - Changes taking place during cold storage of fish, by S. R. Pottinger, pages 15-37; Section 3 - Protective coverings for frozen fish, by David T. Miyauchi, pages 39-65.)

1956d. Refrigeration of Fish - Part 4. Preparation, freezing, and cold storage of fish, shellfish, and precooked fishery products. United States Fish and Wildlife Service, Fishery Leaflet 430, 124 pages. (Section 1 - Fish, by John A. Dassow, pages 1-36; Section 2 - Shellfish, by S. R. Pottinger, pages 37-73; Section 3 - Raw, breaded, or precooked seafoods, pages 75-124.)

1956e. Refrigeration of Fish - Part 5. Distribution and marketing of frozen fishery products. United States Fish and Wildlife Service, Fishery Leaflet 431, 78 pages. (Section 1 - Transportation of frozen fish by, Joseph W. Salvin, pages 1-35; Section 2 - Marketing of frozen fish, by Martin Heerdt, pages 36-49; Section 3 - Locker plants and home freezers, by Martin Heerdt and Joseph W. Salvin, pages 51-78.)

APPENDIX

A. Personnel in Fishery Food Science and Technological Work

Table 2 lists many of the government employees who were prominent in the fishery food science and technological field from 1870 to 1930. Records are not readily available for these early periods, making this tabulation, although not complete, of historical interest. Unfortunately, only the surnames of some individuals are available. Until 1930, the number of persons engaged in such work was not large. Since 1930, the number of individuals pursuing this type of research has increased greatly. Since later records are more readily available, no attempt has been made to compile complete listings beyond 1930.

Table 2A.--Partial list of individuals employed by U.S. Government for work in food science and technology of fisheries 1870 to 1930.

Name	Position	Location	Approximate time	
Allen, S. P.	Laboratory mechanic USBF[a]	Technological Laboratory, Washington, D.C.	1928	Cod-liver-oil recovery.
Alsberg, C. L. (Dr.)	Chief, Bureau of Chemitsry, USDA[b]	Washington, D.C.	1913-19	Initiated research on fish in USDA.
Almy, L. H. (Dr.)	Chemist, Bureau of Chemistry, USDA	Philadelphia, Pennsylvania & Washington, D. C.	1913-26	Worked with E. D. Clark on initial USDA fisheries projects; later worked in Bureau of Chemistry on fish spoilage; was Bureau fish pathologist, 1916-18.
Anderson, C. L.	Fishery technologist, USBF	San Pedro California	1919	San Pedro Laboratory under Lester Lingle.
Atwater, W. O (Dr.)	Professor, Wesleyan University	Middletown, Connecticut	1879-85	Classical investigations on compositions and nutritive value of fish.
Baird, Spencer Fullerton	Commissioner, Fish and Fisheries	Washington, D.C.	1871-87	Also Secretary of Smithsonian Institution
Beamer, Miles C.E.	Chemist, Wesleyan University	Middletown, Connecticut	1879-81	Analyst for W. O. Atwater.
Beard, Harry	Chemist, later Chief Technologist, USBF	San Pedro, California & Washington D. C.	1920-27	In charge, San Pedro Laboratory 1921-24-, Chief Technologist, Bureau of Fisheries 1924-27.
Blish, M. J. (Dr.)	Chemist, Bureau of Chemistry, USDA	Seattle, Washington	1915-16	Under E. D. Clark.
Braxton	Temporary assistant USBF	San Pedro, California	1919-20	Under Lester Lingle at San Pedro.

Table 2A.--Continued

Name	Position	Location	Approximate time	
Clark, Ernest D. (Dr.)	Chemist, Bureau of Chemistry, USDA	Philadelphia, Pennsylvania & Seattle, Washington & San Francisco, California	1913-19	1914-16 worked on fish at Philadelphia laboratory. 1916-18 at Seattle. 1918-19 West Coast Chief of Fish Operations Food Administration World War I.
Conn, Wallace T.	Chemist, later Chief Technologist, USBF	Washington, D.C.	1921-36	Major field: preservation of fish nets; Chief Technologist, 1927-30.
Coulson, E. J.	Chemist, USBF	Charleston, South Carolina	1931-35	Metabolism of minerals in fish.
Cutler	Temporary Assistant, USBF	Boston, Massachusetts	1928	Assisted Eric Loffler on improving method of cod-liver-oil extraction.
Daniel, Esther P.	Temporary Assistant USBF	Laboratory at Johns Hopkins University Baltimore, Maryland	1929-30	Nutritive value of fish meal under E. V. McCollum.
Doughty, Randall H.	Chemist, USBF	Reedville, Virginia & Washington, D. C.	1925-26	Fish meal under Robert S. Taylor.
Farlow, W. G. (Dr.)	Botanist and M.D., Harvard University	Cambridge and Gloucester, Massachusetts	1878-79	Investigated the cause of reddened salt cod.
Field, Irving A.	Temporary Assistant, and Professor at Clark College, Worcester, Massachusetts	Woods Hole, Massachusetts	1905-20	Utilization fish and seaweed.

Table 2A. Continued.

Name	Position	Location	Approximate time	
McNaughton, Leslie	Chemist, Bureau of Chemistry, USDA	Seattle, Washington	1916-18	Assisted Ernest Clark on investigation on handling fish.
Manning, John Ruel (Dr.)	Chemist, USBF	Washington, D.C.	1928-40	Nutritive value of fish. From 1930, Chief of Technology, Washington, D.C.
Merrill, G. P.	Chemist, Weleyan University	Middletown, Connecticut	1879-82	Assisted W. O. Atwater in analyses of fish.
Montgomery, Edna	Technologist, USBF	Washington, D.C.	1927	
Morris, H. P. (Dr.)	Research Associate, USBF (Kelco Co. Fellow)	Washington, D.C.	1931-32	Nutritive value of kelp.
Nelson, E. M. (Dr.)	Bureau of Chemistry USDA	Washington, D.C.	1930	Cooperated with Bureau of Vitamin A + D in fish liver oil studies.
Newell, John M.	Temporary Assistant USBF	Laboratory at Johns Hopkins University, Baltimore, Maryland	1930-31	Spectrographic analysis of minerals in fish meals under E. V. McCollum.
Pennington, Mary (Dr.)	Laboratory Director, Food Research Laboratory, Bureau of Chemistry, USDA	Philadelphia, Pennsylvania	1908-19	Directed laboratory in which extensive research on fish was carried out.
Prim (Dr.)	Chemist, Bureau of Chemistry, USDA	Seattle, Washington	1916-18	Technology of fish under Ernest Clark.
Pottinger, S. R.	Chemist, USBF	Reedville Virginia and Washington, D.C.	1929-64	Analyses of fish meal and oil. Later at Gloucester and College Park Laboratories. Laboratory Direct at Gloucester and head of Technical Advisory Unit.

Table 2A. Continued.

Name	Position	Location	Approximate time	
Fitzgerald, G. A.	Naval Architect, USBF	Washington, D.C.	1924-28	Preservation of fishing gear and handling of fresh and frozen fish.
Harrison, Roger W.	Chemical Engineer USBF	Washington, D.C. Reedville, Virginia Gloucester, Massachusetts	1928-43	Investigated fish meal and oil problems. Later Laboratory Director, Seattle, and Branch Chief, Washington.
Hildebrand	Temporary Assistant, USBF	Erie, Pennsylvania	1928	Preservation of nets under Wright.
Jordan, W. H.	Chemist, Wesleyan University	Middletown, Connecticut	1879-81	Analyses of fish under Atwater.
Kik, M. C.	Temporary Assistant USBF	Laboratory at Johns Hopkins University, Baltimore, Maryland	1926-27	Nutritive value of haddock and herring under E. V. McCollum.
Lemon, James M.	Chemical Engineer, USBF	Columbia, South Carolina and Washington, D.C.	1928-51	Chilling and freezing of fish. Later Laboratory Director at Gloucester and College Park, and Branch Chief, Washington D.C.
Lingle, Lester	Chemist, USBF	San Pedro, California	1918-21	Laboratory Director, San Pedro, California.
Loffler, Eric	Fisheries Engineer	Boston Fish Pier	1928-29	Improved handling and unloading of fish.
Long, J. H.	Temporary Assistant Wesleyan University	Middletown, Connecticut	1882	Assisted W. O. Atwater in analyses of fish.
McCollum, E.V. (Dr.)	Professor, Johns Hopkins University	Baltimore, Maryland	1926-31	Cooperator with Bureau on programs on nutritive value of fish.

Table 2A. Continued.

Name	Position	Location	Approximate time	
Remington, Roe E. (Dr.)	Laboratory Director, South Carolina Food Research Commission Laboratory.	Charleston, South Carolina	1931-35	Cooperator with Bureau on metabolism of minerals in fish.
Rice, Olin	Temporary Assistant USBF	Reedville, Virginia	1929	Fish meal and oil project.
Ridlon, H. Joseph	Temporary Assistant	Reedville, Virginia	1926-29	Fish meal and oil project.
Robertson, Alfred (Dr.)	Fishery Technologist	Washington, D.C. Erie, Pennsylvania, and Reedville, Virginia	1927-29	Preservation of fish nets and fish meal projects.
Rockwood, E.N.	Temporary Assistant	Middletown, Connecticut	1881	Assisted W. O. Atwater on analyses of fish.
Sadler, W. R.	Microbiologist USBF	San Pedro, California	1919-20	Sardine canning under Lester Lingle.
Stevenson, Charles	Field Agent, USBF	Washington, D.C. and elsewhere	1889-1910	Voluminous writer especially on curing methods for fish.
Taylor, Harden F. (Dr.)	Assistant for development fisheries and for saving and using fish products, USBF	Washington, D.C.	1918-23	Later Division Chief.
Taylor, Robert S.	Technologist, USBF	Washington, D.C. and Reedville Virginia	1924-26	In charge of fish meal and oil investigation.
Taylor	Temporary Assistant	Washington, D.C.	1920	Assisted D. K. Tressler.

Table 2A. Continued.

Name	Position	Location	Approximate time	
Thompson, Clifford	Laboratory Mechanics, USBF	Washington, D.C.	early 1920s	Assisted D. K. Tressler.
Tolle, Chester D. (Dr.)	Chemist, USBF	Laboratory at Johns Hopkins University and later at Washington, D.C.	1928-30	Nutritive value of fish, salting of fish, and other problems.
Vilbarndt, F. C.	Professor, University of North Carolina	Temporary Bureau Laboratory at Brunswick, Georgia	1928	Cooperation with Bureau on project of drying of shrimp waste.
Voorhees, E. B.	Chemist, Wesleyan University	Middletown, Connecticut	1881	Assisted W. O. Atwater on analyses of fish.
Wells, Arthur W.	Chemist, USBF	San Pedro, California & Washington, D.C.	1920-27	Canning sardines, mineral content of fish, preservation of fish nets.
Woods, C. D.	Chemist, Wesleyan University	Middletown, Connecticut	1879-82	Did most of analytical work on fish under W. O. Atwater.
Wright, W. H.	Professor of Bacteriology, University of Wisconsin	Laboratory at Erie, Pennsylvania	1928-29	Bureau Cooperator on preservation of fish nets.

a U.S. Bureau of Fisheries
b U.S. Department of Agriculture

Table 2B.--Division chiefs, branch chiefs, and laboratory directors of the Bureau of Commercial Fisheries and predecessor agencies which were located in Washington D.C. 1888 to 1970

Title	Year	Name
Chief of Division of Industrial Research (and predecessor divisions)	1888-92[c]	J. W. Collins
	1892-97[c]	Hugh M. Smith
	1897-1903	C. H. Townsend
	1903-04	Barton W. Evermann
	1904-17	A. B. Alexander
	1917-22	Lewis Radcliffe
	1923-24	Harden F. Taylor
	1924-29	O. E. Sette
	1929-43	R. H. Fiedler
	1943-53	A. W. Anderson
	1953-57	H. E. Crowther
	1957-66	Charles Butler
	1966 to 1970	Joseph Slavin
Chief of Branch of Technology	1918-23	Harden F. Taylor
	1924-27	Harry Beard
	1927-30	Wallace Conn
	1930-40	John Ruel Manning
	1941-43	Roger W. Harrison
	1943-51	James M. Lemon
	1952-53	H. E. Crowther
	1953-57	Charles Butler
	1957-60	John Holston
	1960 to 1970	Harold Allen

c Although Collins was nominally Division Chief from 1880 to 1892, he was detailed to other assignments for almost the entire period, and Hugh Smith was acting chief.

Table 2C.--Directors of permanent laboratories of U. S. Government for Work on Fishery Food Science & Technology 1913-1970

Year	Name	Agency
1913-20[d]	Marry Pennington	U.S. Department of Agriculture, Bureau of Chemistry, Food Research Laboratory
1916-18	Ernest W. Clark	U.S. Department of Agriculture, Bureau of Chemistry, Fishery Laboratory, Seattle
1919-21	Lester Lingle	Bureau of Fisheries, San Pedro Lab.
1921-24	Harry Beard	
1931-35	James M. Lemon	Gloucester Technological Laboratory
1933-41	Roger W. Harrison	Seattle Technological Laboratory
1942-66	Maurice E. Stansby	"
1966 to 1970	Maynard Steinberg	"
1935-43	James M. Lemon	College Park Technological Laboratory
1943-46	Hugo W. Nilson	"
1946-48	Leslie Sandholzer	"
1948-50	Clifford Evers	"
1950-58	Hugo W. Nilson	"
1958-61	Frank T. Piskur	"
1961 to 1970	Donald Snyder	"
1940-42	Maurice Stansby	Ketchikan Alaska Fishery Products Lab.
1942-45	Lyle Anderson	"
1945-50	Harris W. Magnusson	"
1950-55	John Dassow	"
1955-57	Clarence Carlson	"
1957-60	Eyestein Einsett	"
1960-62	Jefferson Collins (acting-in-charge)	"
1962 to 1970	Murray Hayes	"

Table 2C.--Continued.

Year	Name	Agency
1940-44	Joseph Punocochar	Mayagez Puerto Rico Fishery
1944-45	William S. Hamm	"
1945-46	Pedro Roig	"
1947-54	Joseph Puncochar	Boston-East Boston-Gloucester Technological Laboratory
1954-60	S. R. Pottinger	"
1960-66	Joseph Slavin	"
1966 to 1970	John Holston	"
1958 to 1970	Travis Love	Pascagoula Technological Laboratory
1958-60	Hugo Nilson	Ann Arbor Technological Laboratory
1960 to 1970	Harry Seagren	"
1964 to 1970	Roland Finch	Terminal Island Technological Laboratory
1966 to 1970	Maurice Stansby	Food Science Pioneer Research Laboratory

[d] Period when fish was investigated.

APPENDIX

B - GOVERNMENT RESEARCH CARRIED OUT AT SEATTLE, WASHINGTON, BETWEEN 1966 AND 1983 ON FOOD SCIENCE AND TECHNOLOGY AS APPLIED TO FISH

INTRODUCTION

Although the body of this report has been compiled only up to the time when NOAA was formed in 1970, in this Appendix is included information on development at Seattle in the Utilization Research Division (formerly the Technological Laboratory) and the Environmental Conservation Division (formerly Food Science Pioneer Research Laboratory) of the Northwest and Alaska Fisheries Center up to 1983. The section entitled Technological Laboratory was written by John Dassow and gives details beginning in 1966 at which time there were major changes in programming.

TECHNOLOGICAL LABORATORY
1966 THROUGH 1981

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. Personnel and resources of the Technological Laboratory were assigned to either the Pioneer Research or the Technological Laboratory with a revised research program. Dr. Maynard A. Steinberg, formerly with the Gloucester Tedhnological Laboratory, was appointed Director of the Seattle Technological Laboratory as of August 1966.

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

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

During the 1970s, the laboratory was designated the Pacific Utilization Research Center (PURC) with Steinberg as director. The technological research in Alaska under Jefferson Collins was relocated to Kodiak in 1971 and assigned to Pacific Utilization Research Center after a somewhat confusing period of separate regional responsibility. Administratively this unification was very important in re-establishing field research in Alaska on problems of technological concern to the Northwest and Alaska fisheries. The budget increased to more than $900,000 by FY 1976; however, the staff remained then and at the end of 1976 at 35, including a scientific staff of three 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 products. In August 1979, Dr. Steinberg retired from the government. John Dassow was Acting Division Director until the new Director, John Spinelli, was appointed in February 1980 and Dick Nelson was appointed deputy director in May 1980. By early 1981, the total staff had decreased (with retirements in recent years of Tretsven, Dyer, Miyauchi, and Patashnik) to 29 total including three at Kodiak Utilization Research Unit--Jefferson Collins, Dr. Kermit Reppond, and Dennis Markey. In addition two NOAA Corps officer, Lt. Jim Conrad and Lt. Cdr. Allan Kissam, were on detail to the Division's Preservation Research Program.

In May 1982 John Dassow retired, and shortly thereafter Lt. Jim Conrad was reassigned to other duties in the NOAA Corps. Lt. Cdr. Allen Kissam resigned from the Corps in June of 1983. Currently the Utilization Research Division has 28 permanent staff members and has been organized to concentrate its research efforts in two major areas: resource utilization and product quality and safety. In the area of resource utilization, major projects include investigations on the processing and utilization of the bottom fishes of the Pacific Northwest and Alaska. Research in the product quality and safety area is primarily oriented towards the control of microbiological contamination of fishery products and the development of objective methods to assess the quality and safety of fishery products.

Chemistry of Fishery Products

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

It turned out that the recovery and separation of isopropanol, oil, water, and soluble proteins was a much more difficult problem at the pilot production plant than at the laboratory. John Dyer was detailed to study this problem with fatty fish species at the Aberdeen plant, but with the related problems in the extraction of the oil with fatty fish compared to the leaner hake, the engineering task became far too complex. For example, it was a major problem to eliminate the intractable and seemingly immovable emulsions that formed in the lines and heat exchangers, and this was essential to keep the process operating. Obviously a new engineering approach was needed for solution of the oil recovery problem with fatty species. 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. The cooperative research and liaison of the Seattle staff with the FPC plant was remarkably unproductive in terms of finished results in relation to our plans and expectations. In retrospect, the effort and experience led to new directions and productive research in the 1970s on other processes for fish proteins, modified proteins, and protein derivatives. In addition, the process difficulties and lower yields encountered provided a broader technological understanding of the limitations of the 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. Other chlorinated pesticides such as dieldrin were determined. The developing concern over polychlorinated biphenyls (PCBs) in the environment necessitated studies on its level in fish and shellfish of both the Atlantic and Pacific. With the continued cooperation of the menhaden industry, the laboratory obtained seasonal samples of the raw fish, meal, and oil for several years.

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

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

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

Preservation and Engineering

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

The field studies on preservation and handling of halibut at sea by Wayne Tretsven and Richard W. Nelson in the early 1960s and the detailed laboratory analyses on quality criteria by Max Patashnik had shown the real need for closely related vessel and laboratory experiments. A better understanding of the physical-chemical changes in the fish flesh during chilling and freezing was the result and this affected the continuing preservation research on other species. It is interesting to find in the laboratory's later research on the problem species such as Pacific hake and Alaska pollock that the technologists depended far more on the correlation of objective changes with the loss of desirable attributes of flavor and texture rather than spoilage changes. 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 was initiated with new studies on the techniques and application of mechanical flesh separation from skin and bone.

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

With the passage of 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 1970s. A primary goal of this research was to provide objective data on the characteristics and physical-chemical treatment of the effluents. The efforts included cooperative industry studies at a number of processing plants in the Northwest and Alaska and provided a base for liaison with EPA and advisory services with industry and local and state official's in environmental control. Active field research in effluent treatment was terminated in 1976.

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

Resource Development of Fish Protein Derivatives

The research on problems of FPC production in 1971-72 led to continuing protein studies under John Spinelli, culminating in the development of and a public patent to Spinelli 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 and Ruth Miller on the preparation and properties of chemically modified (acylated) fish proteins. The extension of this field to modified forms of protein by Spinelli and Koury also suggested the preparation of drum-dried proteins with optional pretreatment of the fish or use of cereals for co-drying with fish mixture. A major objective in this research continuing to the present is the development of aqueous pretreatments of minced flesh and drying techniques that minimize costs and eliminate solvent processes for protein production from lean species.

One aspect of these studies on the purified proteins was the recognition of the importance of the functional characteristics, such as the gel-forming and emulsification properties, not only to protein isolates but to the quality changes of fresh and frozen fish. This work in the 1970s clearly anticipated the importance of research in this now-active area in the laboratory. This research on functional proteins has resulted in two additional patents and 18 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 of the feasibility of radiation preservation of fresh fish and shellfish. With his background on the preceding research in measuring quality changes in fresh and chilled fish, David Miyauchi, the project leader, established a strong emphasis on the relationship of the sensory changes in the irradiated fish to the early chemical changes as shown in Spinelli's research on correlation of flavor loss to the decrease in level of inosine monophosphate. Research included chemistry and microbiology of the early and late changes in the freshness and spoilage of fresh fish, the measurements of acceptability by both subjective and objective criteria, the effects of prehandling and radiation at sea, the importance of packaging and quality control in extended storage and shipment tests, and the determination of preference at the consumption level. One of the final studies was the experimental installation and tests of a shipboard irradiator aboard the fisheries research vessel Miller Freeman. This research was conducted by Fuad

Teeny, who irradiated five species at sea in various stages of rigor. Teeny and Miyauchi demonstrated in the later quality and storage tests that the shelf life of irradiated pasteurized fish was significantly better for the pre-rigor fish in comparison with post-rigor fish. In addition to accomplishing the contract objectives, 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.

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

Radiation Preservation Microbiology

Early studies on the radiation pasteurization of fresh fish and shellfish and the profound effect on the survival and subsequent growth of the microflora led to a major investigation, supported initially by the AEC and currently by the U.S. Army Research Office, under 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 definitive research by Eklund and his small project staff on *C. botulinum* in relation to radiation pasteurization was applied in a most practical way to the problems of the hot-smoked fish industry. Of greatest importance was the need to show clearly the specific limitations of temperature, moisture, salt, and sodium nitrite in establishing safe processing guidelines for hot-smoked fish. Active support by the smoked fish industry of this phase of Eklund's research has assured the continuation of this project, complementing the continuing support by the Army Research Office on the basic factors in growth and toxigenicity of the various types of *C. botulinum*. The research staff for these various projects in 1981 included: Dr. Melvin W. Eklund, project leader; microbiologists, Gretchen A. Pelroy and Mark E. Peterson; food technologist, Frank T. Poysky; and scientific aides, Lamia Mseitif, Rohinee Paranjpye, and Eric Rolseth.

The research on toxigenicity of *C. botulinum* includes the various forms of botulism of concern to public health and effects of the environmental factors in the products and 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 1980, 35 reports and scientific papers were published on the microbiology of radiated pasteurized fish and the continuing studies of C. botulinum outgrowth in other partially processed and preserved fishery products especially smoked fish and fresh fish stored in CO_2-modified atmosphere.

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

Fish Nutrition (Aquaculture)

The shortage and high price of fish meal during 1972-73 suggested the importance of technological research on alternative sources of feed proteins for use in developing aquaculture. To date, this study under John Spinelli has emphasized two aspects: 1) the problems and 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 established a new research area in salmonid nutrition. Continuing carotenoid research in 1980-1981 included evaluation of crayfish waste from Louisiana, a valuable carotenoid resource, and simple methods of extraction and concentration for feed use by use of soy oil. John Wekell was named project leader in 1980 and with Karl Shearer, fish nutritionist, and Dave Wieg has continued research on problems of essential trace element, particularly zinc, availability in relation to use of alternative feed proteins, soy and cottonseed meal, e.g., in which natural chelators occur. Ten scientific papers have been published on these studies since 1975.

FOOD SCIENCE PIONEER RESEARCH LABORATORY 1966-81

Organization and Programs

In 1965 Maurice Stansby, who had been director of the Seattle Technological Laboratory since 1942, received a PL 313 appointment. A group of scientists was transferred from the Technological Laboratory to work under

Stansby in a new laboratory for long-term, fundamental research. These other scientists included: Neva Karrick, Dr. Edward Gruger, Dr. W. T. Roubal, Dr. Donald Malins, Anthony Barone, and Paul Robisch. The major field of research of the new Food Science Pioneer Research Laboratory was the mechanism of oxidative deterioration in fish oils, especially while fish oils were present within the flesh of fish. A secondary project was concerned with the role of unusal lipids in sharks and porpoises, the latter in connection with sonar reception and transmission. The sonar work under Dr. Malins was conducted primarily by Dr. Usha Varanasi, who was funded by the Office of Naval Research. A third project, undertaken several years later, was concerned with nitrosamines and smoked fish.

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

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

Research on Lipid Oxidation

The research on oxidation of fish lipids within fish tissue was conducted partly at Seattle and partly by two of the Pioneer Research Laboratory personnel (Drs. Roubal and Gruger) stationed at the University of California at Davis' Food Science Department. In the latter investigations, Dr. Roubal determined the effects of oxidizing lipids in fish on proteins and established that polymerization of protein occurred. Dr. Gruger investigated the role of natural biological antioxidants, principally alpha-tocopherol, and reduced co-enzymes on the oxidation of fish oil polyunsaturated fatty acids in model systems. At Seattle, Dr. Roubal applied electron paramagnetic resonance spectrometry to study effects of trapped radicals in dry products such as fish meal, fish protein concentrate, and freeze-dried fish. It was shown that the free radicals, rather than oxidation products of the oil such as aldehydes, are primary agents responsible for deterioration of protein quality. Such oxidative activity was shown to take place slowly over extended periods of time when the dry products were stored.

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

Research on Other Projects

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

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

Because of published articles in the food science literature which suggested that nitrosamines having carcinogenic properties may form during processing smoked foods including fish, the U.S. Food and Drug Administration proposed limiting severely the amount of nitrates and nitrites that could be employed by the food industry. In the case of fish, the presence of considerable quantities of amines occurring naturally or as a result of early traces of spoilage indicated that on a theoretical basis, fish might be more vulnerable to nitrosamine formation than other foods. Research conducted at the Food Science Pioneer Research Laboratory by Malins et al. (1970) showed that at the storage temperatures used for smoked fish and at nitrate and nitrite levels and other conditions used by fish processors, no nitrosamines could form. In addition, Gruger showed that potential precursors for nitrosamine formation in fish flesh stored for long periods of time were either present at parts per million levels or were absent from the flesh. This work was also extended to possibilities that Alaskan salmon roe, which was preserved by nitrite and exported to Japan, might develop carcinogenic nitrosamines. The Japanese government had already tentatively banned importation of U.S. salmon roe preserved with nitrates for the subsequent season. Work performed by Dr. Roubal in the Washington, D.C. laboratories of the U.S. Food and Drug Administration showed decisively that nitrosamine formation did not occur. This work saved the multimillion dollar Alaska salmon roe industry.

Accomplishments

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

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

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