# Fisheries Utilization Research—50 Years in Retrospect, Part I: Fishery Development

JOHN A. DASSOW

*It was early in the summer of 1937 when, as a young chemistry undergraduate, I first entered the Bureau of Fisheries building on Montlake Boulevard in Seattle, Wash. I reported with several others for a job, not in research, but as a temporary clerk to assist the statistician, Elizabeth Vaughan, in compiling reams of salmon data from stream observations in Alaska. I can still remember that the building smelled new, although it was 6 years old then, and had the odor of biological preservatives from a laboratory on the third floor near the library where I worked. After several months of rather dull compilation work I left, remembering the pleasant atmosphere of the building and staff.*

*About 3 years later I returned and reported to a tall, young, serious looking chemist, Maurice E. Stansby, as a laboratory aide under appointment with the Works Progress Administration, one of the depression-era Federal job agencies. This, then, was my introduction to fisheries utilization research and to methods for determining the freshness and spoilage of fish.*

*After a brief orientation, I was provided daily with coded cans of frozen salmon for determination of quality by various chemical methods. There were seemingly endless samples for analysis, and I enjoyed the work and the surroundings but left after several months for a dull though financially more rewarding job as an engineering aide in the Boeing Aircraft Company. A year of that was quite enough, however, and it was in November 1941, a month before the U.S. entered World War II, that I found myself on a freighter bound for Ketchikan, Alaska, and a position as junior chemist at the new Fishery Products Laboratory under chemist-in-charge, Maurice Stansby. This position proved to be my real initiation into fisheries utilization research and began an association that ended (at least actively) only when I retired in 1982 as supervisory research chemist at the Seattle Utilization Research Laboratory.*

*My review for this retrospection of 50 years of fishery utilization research has brought back keen memories. Also, with the help of six file drawers of reprints and laboratory reports, it has verified that it's been just as interesting, variable, and frustrating as I might have imagined as that freighter took me along the misty shores of the Inside Passage to Ketchikan during those three cold, rainy days in November 1941.*

## Introduction

Before embarking on this retrospective journey, I should explain the laboratory designations. The term "utilization research" is used currently to designate the divisions and laboratories; therefore I have used it most, although in past years the terms "technological," "industrial fisheries," "fishery products," and "food science" have been used also to designate laboratories or divisions. The goal has always been the same—to develop and apply the scientific and engineering information needed to encourage the best use of fishery resources for food and industrial products, within the national policy of conservation and wise use of marine resources.

At the beginning of our period in the late 1930's, there were two major laboratories for utilization research, one at College Park, Md. (the original Gloucester Laboratory in Massachusetts was closed and moved to College Park in 1935), and the other at Seattle, Wash. In 1947 a new laboratory was established in Boston which, in 1959, was moved to a new building in Gloucester, Mass., where it remains today. The College Park Laboratory was relocated to Charleston, S.C., in 1978.

The Seattle Laboratory has remained at the same site but moved into a new fishery research building in 1965. The Alaska Laboratory was in Ketchikan from 1940 to 1971, when it was moved to Kodiak. In 1958 a laboratory was established in Pascagoula, Miss., for regional utilization research, and in recent years it was designated the national laboratory for quality standards and research and administration of the Department of Commerce fishery inspection activities. Other fisheries utilization laboratories operated for shorter periods in Mayaguez, P.R., during the 1940's, in Terminal Island, Calif., during the late 1950's, and in Ann Arbor, Mich., during the 1960's.

In selecting the major topics for this survey of the past, I was mindful not only of the need to consider the changing web of research on fishery development and processing methods, but also of the basic fabric of research on quality, nutritive value, and product safety that has provided continuity in research planning for more than 50 years. The examples of specific programs are drawn from my experience as a researcher and supervisor in Pacific Coast and Alaska research and numerous field trips to the other laboratories over the years. The result is a somewhat biased review, despite my effort to include national research programs that involved two or more utilization laboratories. The focus is on the research—the problems, applications, accomplishments, and failures. To preserve that focus, few

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researchers are named; for those who wish to associate individual researchers with their accomplishments, however, the literature cited will serve as both an acknowledgment and a directory for further study.

In this article, the first of three, we look at fishery development of three species once considered underutilized—Alaska king crab, *Paralithodes camtschatica*; Pacific whiting, *Merluccius productus* (formerly called Pacific hake), and Alaska or walleye pollock, *Theragra chalcogramma*; and also at the major industrial fishery of the U.S. east coast and Gulf of Mexico—menhaden, *Brevoortia* spp. These species provide examples of long-term fishery development in which utilization research has been a significant contributor to the goal of optimum development for food and industrial products. The story is still unfinished, but it illustrates the integration of utilization research and engineering with the pioneers in private industry who frequently put their fortunes on the line to develop fishery resources and new products. Their vision and faith were often the basic ingredients for success. Later articles will explore the enduring themes of utilization research—the quality, nutritive value, and safety of fishery products—and the contribution of processing and engineering research in the continuing search for product diversification and improved processing methods.

John R. Manning in the Bureau of Fisheries Laboratory, Washington, D.C., about 1930.

## Role of Utilization Research in Fishery Development

How best to use a natural resource is basic to industry and government goals, as well as to the public interest in the conservation of that resource. In past years a major concern of utilization research has been those fishery resources that were little used and relatively unknown with respect to their harvest and product potentials. Usually the economic outlook was rated promising by the early pioneers of a resource development but dubious by the banks that lacked information on harvest costs and product development. Our research role emphasizes the species and product characteristics although the research on resource assessment, harvest variables, and market potential by other divisions is also important in our work and to the development goal.

My experience with major fishery developments include work on the Alaska king crab, *Paralithodes camtschatica*, from 1947 to about 1965; Bering Sea groundfish from 1948 to the 1980's; pink shrimp, *Pandalus borealis*, off the Pacific Northwest coast and Alaska in the 1950's; Pacific (hake) whiting, *Merluccius productus*, in the 1960's and later; and Alaska (walleye) pollock, *Theragra chalcogramma*, in the 1970's. Shellfish resources of interest to me have included the Tanner or snow crab, *Chionoecetes* spp.; Alaska pinto abalone, *Haliotis kamtschatkana*; butter clam, *Saxidomus giganteus*; blue mussel, *Mytilus edulis*; geoduck, *Panope generosa*; weathervane scallop, *Pecten caurinus*; and deep-water clams such as the Alaska surf or pinkneck clam, *Spisula polynyma*. Other fishery studies in which I participated have included shark species of both the Pacific and Atlantic, little used species of rockfish, *Sebastes* spp.; sablefish, *Anoplopoma fimbria*; Alaska sheefish, *Stenodus leucichthys*; pomfret, *Brama japonica*; and whitefish, *Coregonus* spp., in Alaska lakes and streams. It's quite a diverse assortment from my 40-year background, but I think it illustrates well the breadth of laboratory interests in resource development during that period. Other long-term researchers could provide lists equally broad.

As can be seen from the dates, major fishery developments may require intermittent research for many years depending on the technological problems that develop as the fishery grows. In contrast, our studies of some minor fisheries, such as Alaskan abalone and scallops, required only a few months to provide the needed information. The objective in each fishery is similar, to provide information to government and industry on species characteristics and product potential as well as processing and quality control recommendations. Development of a major fishery, such as king crab and walleye pollock, establishes a need for biological and management research by the state and Federal agencies and a basis for continuing utilization research on product quality and process problems.

In a few cases, utilization studies have resulted more from the interest of the government than of industry. During World War II, in 1943, our departmental office in Washington, D.C., asked our Ketchikan Laboratory to investigate potential emergency sources of marine foods in case military activities in Alaska caused food shortages. We were already studying the availability and utilization of various groundfish and shellfish species; therefore, we added species not commonly used for food to our research program. One species selected was the Steller sea lion, *Eumetopias jubata*; another was sharks, including the Greenland or sleeper shark, *Somniosus pacificus*; the common dogfish shark, *Squalus acanthias*; and the salmon shark, *Lamna ditropis*.

The first task was to obtain a sea lion. Fortunately, we obtained the cooperation of the Coast Guard who deposited me along with a few crew men on an offshore rookery just west of Craig on Prince of Wales Island where a large male of about 1,200 pounds was killed on the rocks. I obtained the needed meat and liver samples, with the help of the crew to move the large carcass, placed the samples in refrigerated storage at a salmon cannery in Craig, and arranged for air transport back to Ketchikan. Both meat and liver of seal lion proved to be surprisingly palatable in our laboratory tests, especially if one were hungry and anticipated a food shortage.

Some years later, in 1951, we renewed our studies on sea lion utilization, this time for animal feed, as a result of fishermen's requests to reduce what they regarded as an overly large fish-eating sea lion population. About the same time the Alaska Department of Fish and Game undertook an extensive biological study of Steller sea lions, with later pilot tests of industry harvest for industrial products. The test results were discouraging on a cost basis, and that took care of the matter until the Marine Mammal Protection Act was passed in 1972 and laid the whole question to rest.

The early studies on the use of three species of shark for food indicated that for most people, consumption would definitely be as an emergency food. Dogfish and sleeper shark were fished commercially at that time for their livers, which were valuable for vitamin A. With our encouragement a fish processor arranged limited market tests of shark fillets that included a shipment of frozen sleeper shark fillets to Chicago. The negative consumer reaction to that shipment confirmed local ratings of doubtful palatability for sleeper shark. Fortunately the war passed with no need to market either sea lion meat or shark meat for food.

During the 1960's at the Seattle Laboratory, we made a more intensive study of the composition and palatability of various shark species from both the Atlantic and Pacific fisheries. We found a wide variation in the palatability of various shark species. Some, like the thresher and soupfin shark, are excellent table fare; some, like the salmon shark, are highly variable and appeal to only a few people; and some, like the dogfish, require such special treatment (e.g., marinating or smoking the flesh) to make them palatable that use as a table fish is not practical.

For a resource that is fully utilized and under conservation regulations, e.g., Pacific salmon, *Oncorhynchus* spp., and menhaden, our laboratory objectives emphasize processing improvements and solutions to quality problems that are recognized by both the industry and the government. The basic question that remains for every fishery resource is how to harvest, process, and market species to assure the optimum benefit to the economy, the consumer, and the future of the resource.

The answer is not easy for fully utilized natural resources under public management, and the "tragedy of the commons" (Hardin, 1968) is all too frequent as resources available to all suffer from serious depletion on both the national and international scales. Looking back, it's also easy to see that often conservation regulations were based on an inadequate understanding of species ecology and the effects of natural phenomena such as "El Niño" (warm water occurrences) along the Pacific coast.

In general, utilization research is not directly concerned with catch regulations but often has been concerned with regulatory changes that affect the species quality or process potential. For example, the use of privately owned salmon traps for harvesting salmon at fixed locations in Southeast Alaska was eliminated in 1959, the year Alaska became a state. The resulting change affected the quality and grading of the canned salmon pack because trap-caught fish were generally brighter, i.e., not so mature, sexually, as seine-caught fish.

When king crab were harvested by otter trawl in the early years (the late 1940's) of the developing fishery, there was a serious problem with dead and injured crab (including the protected female and undersized crabs) during fishing and handling operations. This was reflected in the poor condition of many crabs at the processing plant and in lower yield and quality of the crab meat. As pot fishing developed and became a legal requirement in more areas, the condition of landed king crab improved substantially. Regulations limiting the amount of fishing gear or landed fish not only distribute the fishing pressure, but also encourage better care and handling of the catch, especially with trawl-caught fish.

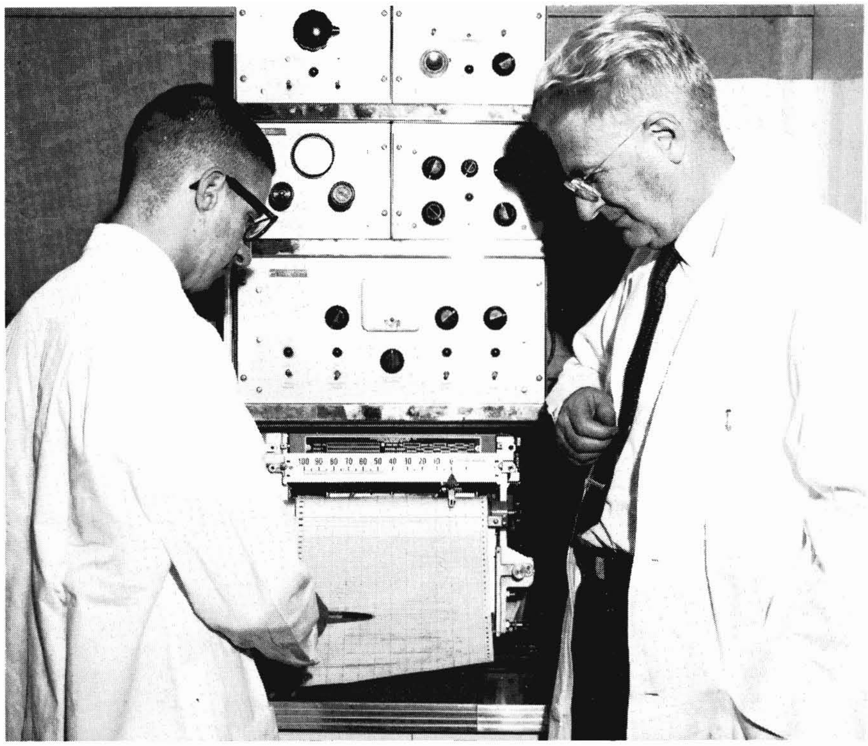
Processing improvements are a major factor in the development of resource potential and affect production economics as well as product characteristics. There were few technical personnel in the smaller and even some larger plants in the earlier years, and the utilization laboratories frequently were asked to assist in the technical and engineering aspects of processing changes that were common to a number of plants. Our personnel conducted plant and laboratory studies in the following examples.

In the 1950's the use of live wells and better handling methods for king crab aboard vessel and at the plant improved both meat yield and quality. During this same period the economics of king crab recovery were improved with the introduction of roller extraction to replace the air and water pressure blowing technique. In the southeastern Alaska shrimp fishery, conversion from the double cook-manual peeling process to the single cook-machine peeling process during the late 1950's changed both the production economics and the characteristics of the frozen cooked shrimp. I, along with most other consumers of the traditional Petersburg-Wrangell cooked shrimp, bemoaned the change to the moist mild-flavored machine processed product, but yield and labor costs improved with the new process and it stayed. The shrimp fisheries of Washington, Oregon, and central Alaska developed during the 1950's with the introduction of the machine peeler and new consumers of that product never knew any better.

Also in the 1950's the expanding offshore shrimp fishery in the Gulf of Mexico needed better technology for preserving shrimp aboard vessel. The potential for freezing shrimp at sea was demonstrated by utilization research in cooperation with the Gulf exploratory fisheries laboratory in Pascagoula, Miss. In the 1960's the Ketchikan laboratory cooperated with Alaska processors in a comprehensive plant study of methods and possible use of precook techniques to improve both yield and product characteristics of the machine-peeled pink shrimp. These studies at Ketchikan and later ones by the Seattle laboratory included the effects on quality and yield of pink shrimp held in crushed ice or refrigerated sea water before processing.

Another traditional concern of utilization research is the total use of the resource including the discarded fish and waste. If local volume is sufficient, a reduction process plant to produce fish meal and oil is common, but the economics are often not favorable. An extensive study of Alaska salmon cannery waste utilization in the 1940's at Seattle and Ketchikan was made in response to the problem of finding ways in which the solid waste, such as heads and viscera, could be used economically rather than being dumped into the bay. The study included the basic waste composition data, the potential for fish hatchery and animals feeds, new methods for production of edible salmon oil, and possibilities for chemicals and pharmaceutical products. The most immediate result was use of frozen salmon waste for hatchery and animals feeds.

The waste problem remained in many areas, however, and increased in ports like Kodiak with the development of the crab and shrimp fisheries and their waste problems. It was 25 years later in the 1970's that our research on fishery wastes was renewed because new Federal and state pollution regulations required screening and treatment of all effluent discharges into salt water. At that time neither we nor the industry had the data on efficient and economical methods of treatment of fishery effluents. Our work was completed once we and the industry developed the data and industry had the expertise in waste management.



Maurice E. Stansby (right) and Paul Robisch examine the results of gas liquid chromatography tests in the Seattle Laboratory, Bureau of Commercial Fisheries, 1970.

For a more detailed look at our role in fishery development, I have selected Alaska king crab, Pacific whiting, Alaska pollock, and menhaden of the Gulf and Atlantic coasts. The first three are major fisheries today but were underutilized resources with neglible landings by U.S. fishermen when our research began. The fourth, menhaden, has long been the major U.S. industrial fishery and of primary interest in our research on fish meal and oil in animal nutrition. In recent years menhaden has been the focus of research on use of fish oil as a food supplement and its potential as a food using the new surimi technology. Our first look is at king crab, a fishery close to me because I saw it grow from its first difficult year, 1948, to overwhelming success in the 1960's and a near-collapse after the peak production in 1980.

## Alaska King Crab

Although a few Alaska fishery pioneers had tested the idea earlier, research on the potential of an Alaska king crab fishery began in earnest in 1940 when Congress appropriated $100,000 for a 1-year study by the U.S. Fish and Wildlife Service (FWS). The investigation was directed by Roger W. Harrison, who was the head of the Seattle Fishery Technological Laboratory. The study during 1940 and 1941 included biological, engineering, technological, and economic evaluations. The report, issued as a special number of *Fishery Market News* in May 1942, was favorable and presented considerable data on king crab


Industry and government participants in the Second Conference on the Technology of King Crab Processing, BCF Fishery Products Laboratory, Ketchikan, Alaska, 19-20 Oct. 1984. Participants included Galen Biery, Pacific American Fisheries, Bellingham, Wash.; James Brooker, BCF, Wash., D.C.; Marvin Brun, Seldovia-Port Graham Consolidated; Charles Butler, BCF, Wash., D.C.; Harry E. Carter, Alaska Dept. of Health and Welfare; Harlan Cheyne, Alaska Packers Assoc.; Jeff Collins, BCF, Ketchikan; Don Crosgrove, National Canners Assoc., Seattle; John A. Dassow, BCF, Seattle; James V. Dennis, Aleutian King Crab, Inc.; Pete Deveau, King Crab, Inc.; R. C. Estabrooks, Westgate California Corp.; Bob Egelkrout, Bob Egelkrout Shellfish; John Enge, Kayler-Dahl Fish Co., Petersburg, Alaska; Walter Estby, Nakat Packing Co.; L. G. Germain, American Can Co., Seattle; John Gilbert, Bumble Bee Seafoods; William Hardesty, Pacific Northern Airlines; Murray L. Hayes, BCF, Ketchikan; Fred F. Headlee, BCF, Ketchikan; J. Erwin Hube, Pacific American Fisheries, Bellingham; Charles Jensen, Alaska Dept. of Health and Welfare, Juneau; Ronald Jensen, Pan-Alaska Fisheries; Fritz Jermann, Bumble Bee Seafoods; Robert Jones, BCF, Ketchikan; Joe Juriab, King Crab Processors; James Kelly, Marco, Seattle; James Kirkwood, BCF, Auke Bay, Alaska; Marvin Kvernik, Pacific American Fisheries, Petersburg; Carl W. Lehman, Alaska Dept. Fish and Game, Petersburg; Rufus Littlefield, Seattle Seafoods; Hiram McCallister, Great Northern Fisheries; Don McLean, Pan-Alaska Fisheries; Tak Miyahara, Wakefield Fisheries; Ron Naab, BCF, Juneau; Dick Nelson, BCF, Seattle; Dave Ohmer, Alaska Glacier Seafoods, Petersburg; J. Richard Pace, Wakefield Fisheries; Richard H. Phillips, Pacific Fisherman; George Pigott, Geo. M. Pigott & Assoc. (Libby's); Roy W. Porter, BCF, Ketchikan; Guy Powell, Alaska Dept. Fish and Game, Kodiak; Warren Rathjen, BCF, Juneau; Dick Reynolds, Alaska Dept. Fish and Game; Bill Ritter, Pan-Alaska Fisheries; Lonnie Scroggs, Pan-Alaska Fisheries; W. H. Shook, W. E. Stone & Co.; Charles Turner, Kadiak Fisheries; Mel Vega, Alaska Packers Assoc.; Willard Wakeman, American Can Co.; Norman Yetterdahl, Nakat Packing Corp.; and Walter K. Yonker, National Canners Association. (Note: Not all participants are in the photograph.)

harvest areas, fishing gear, preservation, canning, and the industry potential, as well as a summary of the established Japanese fishery. The advent of World War II, however, delayed industry development until 1946.

Lowell Wakefield, who had conducted his own fishing and processing trials on king crab in the intervening years from the family herring plant near Kodiak, financed construction of a combination 143-foot trawler/processor, the *Deep Sea*, in 1946 and started off in 1947. A few other Alaskans, including Harry Guffey, Ellsworth Trafton, and William Suryan, geared up on a smaller scale and were joined in 1948 by the *S.S. Pacific Explorer*, then the biggest vessel to try processing king crab at sea. This was a government-sponsored commercial test of the feasibility of processing king crab and bottomfish at sea in the North Pacific and the Bering Sea.

The processing vessel, an 8,800 ton former freighter converted and renamed the *S. S. Pacific Explorer*, was operated by the Pacific Exploration Company and accompanied by a fleet of 10 fishing vessels. The ship had facilities for commercial production of frozen dressed and filleted fish and frozen and canned king crab and carried two FWS personnel to observe and advise on fishing gear, biology, and technology. Parallel with the commercial canned and frozen production, the FWS technologist aboard ship sampled the production and prepared an experimental series of canned and frozen king crab and frozen bottomfish fillets for evaluation by the Seattle Technological Laboratory. This extensive series of king crab samples was augmented with frozen king crab prepared earlier by biologist Joseph King aboard the FWS exploratory vessel *Alaska* and with samples received in 1948 from three of the pioneer commercial processors of Alaska king crab—Wakefield, Guffey, and Trafton. My assignment was to evaluate and determine the composition of the experimental samples and conduct further cooperative studies with the commercial processors to help develop the technology of king crab processing.

The experimental and commercial packs included both the canned heat-processed king crab and frozen packaged meat and frozen raw and cooked king crab legs. The canned crab commanded attention because the original interest of a few Alaskans in the 1930's was a domestic canned king crab to replace the Japanese imported Geisha[1] brand that dominated the national market for canned crab.

From 1935 to 1939, about 10 million pounds of canned king crab was imported from Japan. After the war the canned crab imports continued; therefore our first point of reference for quality and marketability of the 1948 canned king crab packs was the imported product. The best samples of the domestic and experimental packs compared favorably; the question was "What happened to the less desirable packs?" The answer appeared to be quality and handling problems of the meat before and during packing in the can, the proper acid addition, and good retort and cooling procedures. There was no obvious reason that precluded U.S. production of canned king crab as good as the Japanese import. A matter of quality control—sounds familiar, doesn't it?

Production of canned king crab grew steadily for 20 years. It peaked in the late 1960's, but declined as frozen king crab became more popular in the 1970's, and faded away with the decline in the landings after 1980. As king crab production peaked in 1966 in central Alaska and then shifted to the Bering Sea in the 1970's and 80's, the industry increasingly turned to the production of frozen and canned snow or Tanner crab, *Chionecetes tanneri*, a smaller cousin of king crab with similar processing characteristics but much higher production costs. Today, if you wanted canned crab you'll probably have to buy canned snow crab imported from Japan or Korea, since neither canned king nor snow crab is produced in any sizable amount domestically. So, as far as the consumer of canned crab is concerned, we're back to 1939.

The initial studies in 1948-49 of the various frozen king crab samples, commercial and experimental, indicated that we all had a lot to learn about freezing king crab for an unknown market. There were significant quality differences in the frozen meat, such as a chalky fragile texture caused by use of dead or injured crab, poor meat color caused by rough handling in the extraction and washing of the meat, and poor appearance of the frozen meat from careless packaging or inadequate moisture protection. Other quality differences in flavor, texture, and appearance could not be related to obvious process differences, and it was only after further studies and sample preparation at cooperating plants that we realized the importance of the live crab handling, butchering, cleaning, cooking, and washing techniques for the preservation of the delicate crab flavor and texture in the final product.

During the 1950's, production and value of canned king crab increased at a greater rate than that of the frozen packaged meat, which was unfamiliar to the consumer and proved difficult to market. It wasn't until 1962 that frozen king crab meat production climbed from around 1-2 million pounds to 4.4 million pounds. With a market finally established, production expanded rapidly until consumer demand outstripped the supply in the late 1960's.

During the early period, the laboratory and field research emphasized study of the characteristics and composition of the raw and cooked crab in relation to problems of yield, bluing and discoloration of the meat, block-freezing variables, freezing and storage characteristics, and preliminary development of product specifications for the frozen meat blocks and frozen meat-in-the-shell. In 1962 and again in 1964 the industry managers, their technologists, and government researchers met at the Ketchikan Laboratory to review the state of the technology and to agree that frozen king crab was now a commercial success.

In fact, it was so much of a success

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

that in the 1970's pollution of the harbors at Kodiak and Dutch Harbor required serious attention from the state and Federal environmental agencies. The Seattle and Kodiak[2] laboratories helped the plants evaluate the characteristics and treatment of the effluents from the shellfish plants. King crab landings peaked in 1980 at 185 million pounds and then for reasons not fully understood dropped to a small fraction of that in recent years. Latest reports in 1987 indicate that the fishery may be recovering a little of its former glory; however, the history of many fisheries suggests that the bonanza of the earlier years is not likely to return. Fortunately, the momentum of the king crab fishery and the staggering investment in vessels and shore facilities were soon to be utilized in the development of Alaska groundfish and pollock, which is still proceeding rapidly.

Harold Barnett (left) and John Dassow examine Pacific whiting fillets during processing tests at the Seattle Laboratory, BCF, 1968.

## Menhaden

Menhaden is a herring-like fish about a foot long that abounds from the Gulf of Mexico to New England. It is bony and has a dark flesh surprisingly rich in oil and protein. The earliest references in colonial times mention its use as both food and fertilizer; however its flesh is too oily, bony, and strong-flavored for most consumers and its use as fertilizer won out. Actually, the raw menhaden is even too oily for use as a fertilizer, and in the early 1800's farmers hauled the wet cooked scrab from the early menhaden oil plants and used it as a fertilizer. The industrial production of oil and later meal and oil has been around for about 150 years, according to some records. The first Federal report on the menhaden fishery was a long 529-page memoir by G. Brown Goode (1877) issued by the U.S. Commission of Fish and Fisheries. Goode reported about menhaden as a table fish, "When perfectly fresh, they are superior in flavor to most of the common shorefishes, but if kept they soon acquire a rancid oily flavor."

One might think that after all this time utilization researchers and the industry must have learned everything that is needed to utilize menhaden for optimum benefit, but the answer is "Definitely not!" The basic problem is that, in terms of volume, menhaden constitutes an amazingly durable large resource; however, it has almost entirely been utilized for industrial oil and meal production during this long history. These are fine products of considerable importance, e.g., drying oils and animal feed ingredients, but they are of relatively low value compared with food products. Both the fishing industry and the NMFS Utilization Laboratory in the mid-Atlantic area, now at Charleston, S.C., have developed various ideas over the years for upgrading menhaden's product profile.

During the 1920's Roger W. Harrison (he transferred to the new Seattle laboratory in 1933) was a leader in the menhaden processing research and in 1931 published the definitive reports on the technology of menhaden oil and meal production, including the results of cooperative industry studies on process variables (Harrison, 1931a, b). Of great future importance was other early research by John R. Manning, Hugo W. Nilson, and others on the nutritive value of the oil, protein, minerals, and growth factors in menhaden meals used as ingredients in animal feeds. Early studies on the chemistry of menhaden oil and its refinement for specific industrial uses were undertaken at the time when there was great interest in use of refined menhaden oil as a drying oil in special paints, varnishes, and industrial products.

In 1949-50 the discovery of vitamin B-12 as a constituent in the animal protein factor of menhaden meal emphasized its importance as an ingredient in animal feeds. This and other observations on the nutritional value of menhaden mean provided the basis for comprehensive research by the Utilization Laboratories in the 1950's and 1960's, usually under contract with a university or research institution, on the significance of animal growth factors in fish meals.

Concurrent with the expansion of

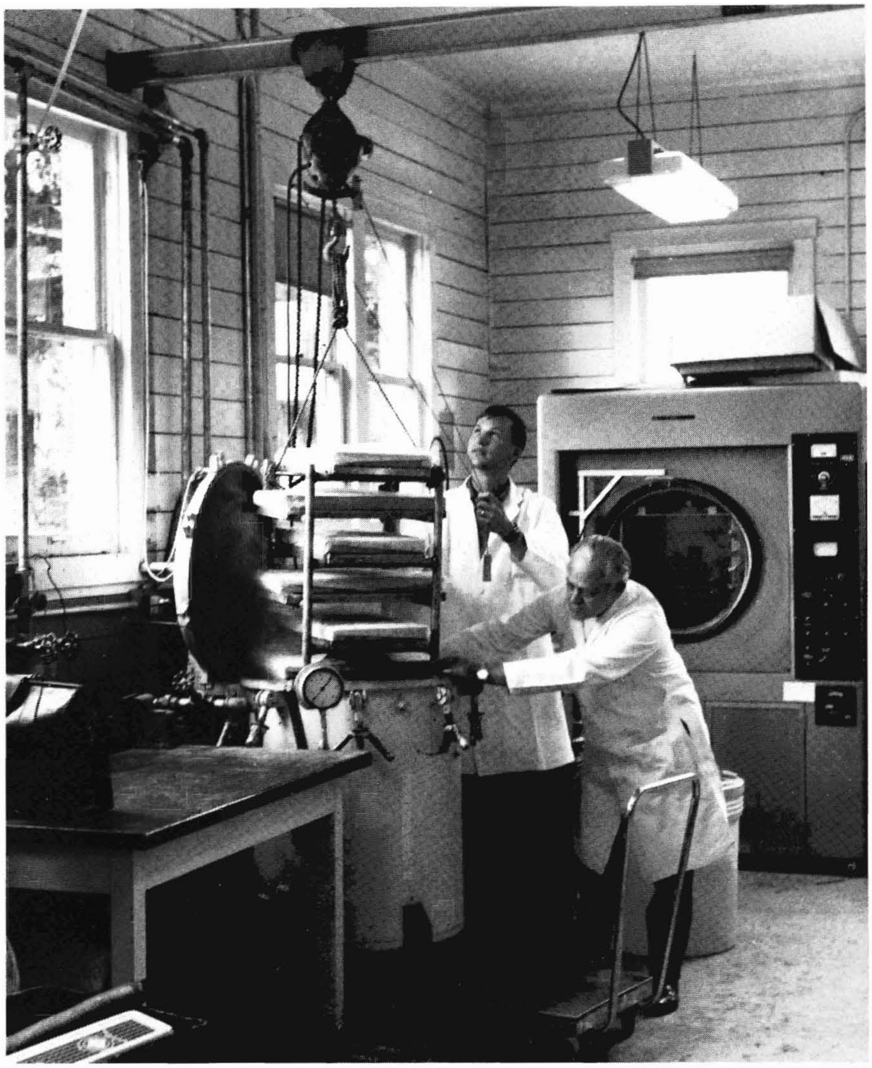
[2]The Ketchikan Laboratory was closed and relocated in Kodiak in 1971.

the large-scale poultry industry and mass production feeding methods, this research proved to be timely since it demonstrated the nutritional values of menhaden and other fish meals as ingredients in poultry feeds. Other research included nutritive value of raw and processed fish and fish meals in pig and mink feeds. During this period and to the present, menhaden meal normally comprises over 80 percent of the domestic fish meal production.

Menhaden has enormous potential as a human food source. Together, the Atlantic and Gulf menhaden averaged 2.7 billion pounds in annual landings during 1981-85. During the 1960's major emphasis in menhaden food research revolved around the concept of producing fish protein concentrate (FPC) as a stable and nutritious protein additive for food used anywhere in the world.

The separation and purification of the functional (muscle) proteins from fish in aqueous media was studied by John Spinelli and his group at the Seattle Laboratory in the 1970's. Their work indicated promise for use of seafood protein as an ingredient in processed and "engineered" foods. Another potential food use for menhaden, use of the deboned and washed flesh as a protein ingredient in processed meat foods, was studied briefly by the Seattle Laboratory in the surimi research during the early 1970's and in more detail later by the Charleston Laboratory. Recent research at Charleston and by food science researchers at North Carolina State University are promising for use of modified menhaden flesh as an ingredient in surimi seafood analogs. Since the surimi process and the FPC research are concerned with a number of species, I have discussed them in more detail under Part III, "Processing and Engineering."

Refined and hydrogenated menhaden oil has long been used in margarine and related human food products in other countries but not in the United States, because of the abundant supply of vegetable oils and restrictions preventing the use of fish oil in processed foods. However, the research in the 1970's and 1980's on the significance of fish oils in the human diet and the biomedical importance of the omega-3 fatty acids present in fish oils indicate there is a major potential for use of edible grade menhaden oil or oil fractions as either food ingredients or as direct dietary supplements[3]. After 150 years of the menhaden industrial fishery, there are finally several real possibilities for putting a substantial share of that huge 2.7 billion pounds of menhaden into the U.S. food basket. The research to do so is proceeding in industry and government laboratories and includes cooperative medical studies.



Steam cooking tests of Pacific whiting in pilot plant of the Seattle Laboratory, BCF, 1969, with Max Patashnik (right) and an unidentified laboratory assistant.

[3]See the separate article in this issue on the history of fish oil research by Stansby (1988).

## Pacific Whiting

Pacific hake or whiting is a skinny, cod-like fish and one of 11 species of *Merluccius* around the world. In the United States, it was commonly ignored until 1964, when our Exploratory Fisheries division at Seattle initiated survey studies from northern California to Puget Sound. Fishermen regarded hake as worthless because of its soft flesh and poor keeping quality. Early indications were that the size of the Pacific coast resource was huge, about 1.5 billion pounds, and there was discussion about developing a hake fishery for fish meal and animal feed production. With all the talk about the increases in world population and the need to look ahead for expanding fisheries for our own population, it was obvious that we needed research on hake composition and potential for food as well.

We conducted field studies aboard the research vessel *John N. Cobb*, including icing and freezing trials at sea and laboratory evaluation and composition studies. At its best, the fish was quite good when fresh, very mild and tender, with good appearance as a fresh and frozen fillet. Flesh composition was similar to cod, about 16 percent protein and 1.5 percent oil content. So far so good. The worst of the fish, however, convinced us that the fishermen were right. The flesh was streaked with dark blotches and became mushy shortly after the fish was landed, or turned mushy within hours.

Comparative tests showed that fillets of mushy-prone fish had good texture if cooked quickly after catch, indicating that a proteolytic enzyme was responsible. Much additional study, including microscopic examinations, showed that many of the hake were infected with a myxosporidian parasite, *Kudoa* sp., also related to mushy texture in other species. Extensive sampling over several years of the Pacific hake populations from California to British Columbia and in Puget Sound demonstrated that the parasite was endemic but the occurrence varied widely, from 20 to 100 percent infected fish in various samples. It was obvious from our research that processing of Pacific whiting into marketable food products depended upon quality control to determine parasite incidence and rapid processing and freezing of them at sea or ashore.

Initial hake/whiting surimi studies in 1968-69 indicated a possible alternative for future diversification in production. The process would involve the mechanical recovery and washing of deboned flesh, treatment to inhibit or inactivate proteolytic enzymes, production of surimi, and a final process into reformed heat pasteurized foods now known as surimi analogs. All this is not as simple as it sounds, and it's only been in the past year (1987) that the Seattle Laboratory (URD) has demonstrated a good quality Pacific whiting surimi analog, imitation crab meat, that is competitive in quality to the comparable product from walleye pollock surimi.

After Soviet freezer trawlers fished off the Pacific coast in 1966 and later years and filled their freezers with whiting, we thought they might clean out the infected population and improve the whole situation. Sampling and tests in later years showed no change, however. In the early 1970, with government assistance, U.S. fishing vessels harvested considerable whiting for a new fish meal plant in Aberdeen, Wash., and for processing into fish protein concentrate (FPC) at an experimental FPC plant built by the government nearby. The fish meal plant proved unprofitable and the experimental FPC plant expired for lack of an additional appropriation to continue the full-scale study of FPC production. Both plants were dismantled and sold in a few years, leaving valuable experience behind but no solution to the development of a domestic whiting fishery.

A new outlook developed for the Pacific whiting fishery after the U.S. declared the 200-mile exclusive fishing zone in 1976. A joint venture U.S.-Soviet operation was soon formed to exploit the offshore Pacific whiting resources, and U.S. trawl fishermen gained considerable experience and cash income fishing whiting for sale to the Soviet freezer ships under this operation, which continued through the 1987 season.

It was during this period the industry gained government approval of the "Pacific whiting" designation for the species. The experience of U.S. fishermen in harvesting and handling whiting under the joint venture operations and the increasing demand for economical fillet fish have contributed to a growing market for quick-frozen whiting fillets. Laboratory research on improved process methods for Pacific whiting is continuing with the goal of a U.S. fishery that processes it into products suitable for both the domestic and export market.

## Alaska Pollock and the Surimi Development

The Alaska or walleye pollock occurs from the Pacific Northwest coast to the Gulf of Alaska and the Bering sea, where it is the dominant species. What makes pollock so interesting is the huge size of the resource and its potential for both old and new products. From the beginning of the pollock studies in Seattle and Kodiak, utilization research envisioned the best use of the pollock resource in Alaska as a diversified U.S. fishery producing a variety of food products, from frozen fillets to precooked frozen foods and surimi analog products. This concept is still a challenge in the fastest developing fishery of the 1980's. The problem for both research and industry management is the need for product diversification and improved cost structure as the industry expands.

Meanwhile, this rapid-paced and "high tech" development of pollock for surimi and food analogs is taking place at the same time that consumer demand for basic "fresh fish" is unprecedented. The demand for fresh fish of almost any species is a major change in marketing and consumer attitudes rather than improved technology, with prime examples being west coast flounders, rockfishes, and sablefishes.

I noted recently on a fish display sign at a modern supermarket in the Seattle area, "Alaska starry flounder fillets, $4.99 lb." Many old-timers remember when the starry flounder, *Platichthys stellatus*, was considered a scrap fish, harvested mainly for mink feed in Alaska. The fish is still the same but the market and consumer perception are much different. Another example is Pacific rockfish, *Sebastes* spp., of which numerous species were ignored commercially only 15-20 years ago. Today widow rockfish, *S. entomelas*, of the Oregon coast, little heard of in early years, is a major food fish and contributes over 20 million pounds a year to the 100-million-pound rockfish landings. During the same period, sablefish, *Anoplopoma fimbria*, a fine food fish once considered underutilized but difficult to market, became an immensely popular fish, with 1986 landings of over 85 million pounds. This new market acceptance is being repeated with not only Pacific groundfish but species of all areas as U.S. consumers discover the virtues of fish consumption.

The walleye pollock is a member of the gadid or cod family and is a long skinny fish like the Pacific whiting. Fishermen scorned it, too, for many years as being soft and relatively worthless. My introduction to pollock was in 1943, on my first trip out with a trawler in Alaska. The trawler was one of several Seattle boats scouting for inside trawling grounds in southeastern Alaska because of the wartime restrictions offshore. After a few days of dragging the net in various bays and straits near Ketchikan, the trawler had little fish and a lot of torn webbing from the rough bottom, which seemed to be loaded with rocks and soggy logs.

To a commercial fisherman the catch was a sad looking assortment, mostly small rockfishes and flounders with a fair number of this skinny cod-like fish that I identified from the fish manual as walleye pollock. The fishermen used a much earthier term for them and assured me that they were fine for mink feed but no good for humans. Nevertheless, I took some back to the laboratory, along with the flounders and rockfishes, for our studies on foods for hungry Alaskans. After suitable taste tests and composition analyses, we concluded that the pollock and the small rockfishes were both good and nutritious. The flounders, incidentally, were arrowtooth flounder, *Atheresthes stomias*, and after cooking were mushy, a characteristic that is not uncommon in this species and definitely limits its food use.

The Seattle trawlers returned to Puget Sound, not finding Southeast Alaska a profitable trawling area. We then found sources of supply for the groundfish utilization studies among the local trawlers who supplied fish for feed at the mink farms in the Kechikan and Wrangell-Petersburg areas. The pollock were generally small, about 1-2 pounds each, but were obtained fresh and proved entirely suitable for the initial studies on composition and freezing characteristics. In 1948, the Seattle Laboratory received samples of frozen pollock with the commercial and experimental samples of groundfish processed aboard the vessel *S. S. Pacific Explorer* during operations in the Bering Sea. These included whole pollock and packaged fillets, and were used for a comparison of the quality of fillets frozen at sea and those prepared ashore from whole fish frozen at sea and later thawed and filleted.

George Kudo determines the texture (resilience) of kamaboko, a Japanese-style fish cake, prepared from Pacific whiting in the Seattle Laboratory, BCF, 1969.

The evaluations showed that pollock fillets in both cases were entirely acceptable and, except for the smaller fillet size, were quite comparable to Pacific cod, *Gadus macrocephalus*, in flavor, texture, and freezing and storage characteristics. The reputed soft texture and poor flavor of pollock appeared to be no problem if the fish were processed and frozen at sea as either packaged fillets or dressed or whole fish for later processing ashore.

The indications were favorable for pollock utilization in our tests in the 1940's and 1950's, but the U.S. companies showed little interest in pollock production for more than 25 years. This was a period, of course, when the fresh and frozen fillet industry of the Pacific Northwest was developing. In the interim, the fisheries and biological data accumulated and showed that pollock in the Bering Sea and Gulf of Alaska constituted the largest resource of bottomfish species in the northeast Pacific. Foreign fleets, particularly those of Japan and the U.S.S.R., harvested the Bering Sea pollock heavily in the 1970's, averaging over 1.5 million tons annually during 1971-75. Japan's harvest was primarily for production of surimi, the frozen blocks of washed, separated, and stabilized flesh that are processed into kamaboko and other reformed and flavored fish-paste products that are immensely popular foods there.

At the Seattle Laboratory, our interest in the Japanese process for surimi and kamoboko developed in the late 1960's as we began to realize that such a process for mechanically recovering and utilizing the flesh of smaller or less desirable fish species could provide a basic new process industry for U.S. fisheries. Two requirements were clear in the beginning: 1) Large-volume fishery resources not already used for food production are necessary and 2) the technology and economics of the production and marketed products must be based on pilot plant studies and product development to match the preferences of U.S. consumers.

The first requirement was satisfied by the potential of the Pacific pollock resource and by the possible use of other bottomfish species, such as Pacific whiting and Atlantic hake, *Urophycis* spp.; menhaden; jack mackerel, *Trachurus symmetricus*; sharks, and just about any other species that wasn't a fully developed food resource. The second requirement took more than 10 years of work by our laboratory, the gradual developmnt of interest by industry, and extension of the research to other laboratories with governmental support.

The laboratory research on production of surimi with Pacific Coast fish was initiated at the Seattle Laboratory in 1967 with the arrival of Minoru Okada, a biochemist and expert in surimi technology at the Tokai Fisheries Research Laboratory in Tokyo. I had talked to Okada at the Tokai Laboratory in 1966 about our interest in the surimi and kamoboko technology, and arrangements were made by our agency for a 10-month detail of Okada to Seattle. This proved extremely fortuitous on both sides. We needed advice and assistance from an expert chemist on the surimi technology, and Japan wanted information on the potential use of our Pacific Coast species for surimi production.

After the initial research on suitability of various species for surimi, we investigated the possible use of both the treated and untreated fish flesh as a protein ingredient in a variety of products, including processed meats and engineered foods including snack-type foods and extruded products. Serious domestic interest in pollock development began to develop after 1976, when the United States declared a 200-mile fishery conservation zone off its coasts. To develop cost and operating data, the need for government-subsidized production of surimi from pollock in Alaska was clear. A plant was established in Kodiak in 1982 by the Alaska Fisheries Development Foundation, through Federal, state, and industry support to provide the data for industry expansion into surimi.

At present the primary production plants are shore-based in Alaska, but development of U.S. surimi processing vessels is well underway. To date, pollock surimi from both Japan and domestic producers has been used most successfully for production and marketing of imitation crab meat, owing to the shortage and cost of the genuine crab. Other products like shrimp and scallop analogs are available, but the real product potential for a variety of ready-to-eat foods and snack items from pollock surimi is still in the development stage. Continued research in our utilization laboratories and various university food science departments is most important to provide the data and recommendations for quality control, nutritive value, product safety, and diversification of surimi products in this new fishery industry. An essential part of the research should be the problems and applications of the surimi process to other available fishery resources as the industry expands.

### Did Research Help?

A frequent question for government research administrators from the budget reviewers is, in simple terms, "Did research help?" If you answer "Yes," then the next question for resource development studies is "Can you prove it in terms of economic benefits to the economy?" I have wrestled with both questions many times as a research administrator and never had any problem with the first question. The answer is always "yes" because in research the objective is usually not to prove a particular point but to determine the facts. Therefore, negative information is as valuable in one sense as positive information. This logic doesn't get you off the hook on the second question, however.

Typically, one can answer the first question in detail by citing numbers of inquiries, publications, favorable comments from industry, and attendance at industry meetings. I remember one time when we even kept track of phone queries as evidence of industry or public interest in the utility of our research. Sooner or later, however, you have to deal with the question number two—the present or future economic benefits of utilization research in relation to the government expenditures during the period selected. In former years this was usually referred to as the benefit-cost ratio or indicator. If the research cost $1 million and yielded $10 million in measurable economic benefits, one has a benefit-cost indicator of 10, a good return on any research investment.

The real problem develops when you estimate not only the economic benefit of the development but the percentage that can be credited specifically to the research. For example, take the development of the king crab fishery. Lowell Wakefield once told me that he figured it was 15 years from the time he started in 1947 before he regarded his company as an economic success. If we take the period from 1947 to 1962, we find that king crab increased in landings from 753,000 pounds to almost 53 million pounds and in landed value from $32,000 to $5.3 million. Note in these figures that although the landings increased 7,000 percent in 15 years, the value of landed king crab, i.e. ex-vessel value, went from less than 5 cents per pound to about 10 cents per pound, an increase of 100 percent. Comparable figures for the weighted average wholesale price of king crab are $0.101/pound in 1947 and $0.238/pound in 1962. The total wholesale value of landed king crab was $111 million for the 15 years, 1947-62.

My rough estimate of the amount of government expenditures for the king crab utilization research during the period is $1.5 million. This would indicate that the economic benefit, as measured by the wholesale value, was 70 times the research investment. What you would really like to know, of course, is what the value of the fishery would have been for the period if the government had conducted no research. The difference would be the figure that shows the contribution that research made. One can spend a lot of useless time on this question or variations of it, in my opinion. My solution is to take a reasonable percentage, say 10 percent of the value, and claim that as the difference that research made in dollars. In our example, this would yield a benefit-cost indicator of 7, well on the positive side. But more important in my memory are the times when Lowell Wakefield and others said "Thanks, you've been a lot of help."

In Part II I will explore the enduring themes of utilization research—the quality, nutritive value, and safety of fishery products.

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