IN SEA AND RIVER

Research at the Bureau of Commercial Fisheries Biological Laboratory, Seattle, Washington 1966-68

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ABSTRACT

Primary emphasis of the research was on (1) salmon (genus *Oncorhynchus*) in the North Pacific Ocean and the Columbia River Basin and (2) groundfish on the Continental Shelf of the Pacific Northwest. Considerable progress was made toward showing how the distribution of salmon is related to the ocean environment. Biochemical techniques showed promise in pinpointing genetic and geographic differences in stocks of fish. To gather the data needed for managing the salmon stocks, integrated studies were made of ocean growth, mortality, maturation, and effects of gear on salmon. Research in the Columbia River Basin provided new information on how dams and reservoirs affect salmon and steelhead trout (*Salmo gairdneri*); studies were made to measure and to develop ways to counteract the losses of fish. Groundfish research disclosed differences in Pacific hake (*Merluccius productus*) stocks of Puget Sound and the Continental Shelf. Publications and staff of the laboratory are listed.

FOREWORD

Scientific fishery research of the U.S. Government in the Pacific Northwest was accelerated under the terms of the White Act of 1930. A 3-story research building was completed in 1931 on a 7-acre site at 2725 Montlake Boulevard East, Seattle, Wash., on Portage Bay south of the University of Washington. A new 4-story laboratory, connected to the "old" building by an auditorium-library, was dedicated in 1965 and provides 65,000 square feet of additional laboratory and office space. The Biological Laboratory shares the Montlake research complex with other Bureau of Commercial Fisheries agencies — the Exploratory Fishing and Gear Research Base, Food Science Pioneer Research Laboratory, Marketing Office, and Technology Laboratory.

The Biological Laboratory, with some 80 scientists, is the largest research organization in the Bureau. Under Laboratory Director Gerald B. Collins, our scientists conduct intensive research on salmon and groundfish of the eastern Pacific Ocean to accomplish the aims of the Bureau — to strengthen the American fishing industry and to conserve the fishery resources. Assistant Director Francis M. Fukuhara directs marine and coastal research on salmon and groundfish; Assistant Director Carl H. Elling supervises fresh-water and estuarine research. Of inestimable value is the Laboratory's close association with representatives of the fishing industry, government officials, educators, engineers, and scientists — locally, nationally, and internationally.

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FIGURE 1.–The research complex (center) of the Bureau of Commercial Fisheries in Seattle lies between Lake Washington (upper right) and Portage Bay on Lake Union (lower left) south of the University of Washington. Laboratories and offices of the Biological Laboratory occupy first and second floors of the larger new building. Small structure with tower (right center) is a laboratory for studies of fish behavior.

INTRODUCTION

As the 1960's draw to a close, man is focusing his attention on the resources of the sea. Although production of marine minerals is increasing, the world's fisheries still give the greatest economic yield from the sea.

Our country has less than 7 percent of the world population; we capture only 4 percent and consume about 12 percent of the world catch of fish. We are the world's largest market, but our vessels supply only 30 percent of the U.S. demand for fishery products. Demographers predict that the population of the United States will grow to 350 million by the year 2000. More food will have to come from the ocean. But increased harvests will be possible only if our fishing industry is strengthened and the resources, particularly underutilized stocks of fish, are developed.

Seventy percent of the world's continental shelves (where most fish are caught) lies in the northern hemisphere. And nowhere in the world is the use of ocean resources developing more rapidly than in the North Pacific Ocean. Here, also, stocks of fish that historically are bases for the fishing industry of the United States are under growing pressure from far-ranging fleets of foreign nations.

To protect and develop these economically important resources, the Biological Laboratory (figs. 1 and 2) is engaged in research to assess the potential yield of the resources, to furnish information for fishery management agencies, and to provide a factual basis for international treaty negotiations. This report summarizes progress of research in 1966-68.

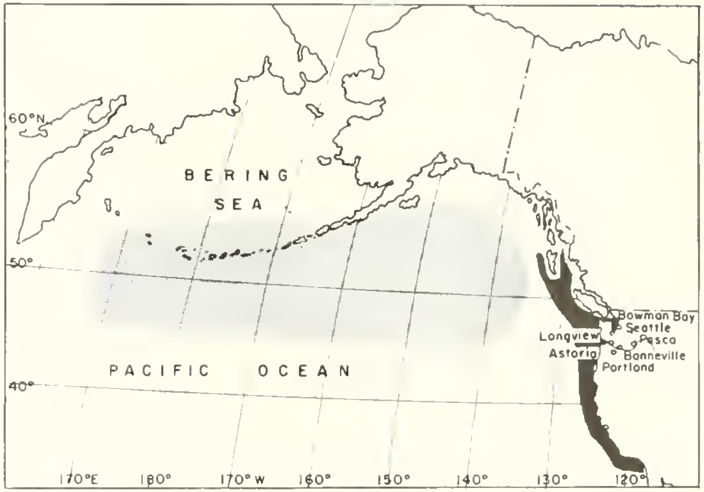

FIGURE 2.—Research at the Biological Laboratory covers a vast area of the North Pacific Ocean (shaded). Salmon are studied in the northern waters; groundfish research is carried out along the Continental Shelf. Work at six field stations and at various dams along the Columbia River is directed from Seattle.

THE FISH AND THE FISHERIES

Research of the Biological Laboratory focuses on two main groups of fish — Pacific salmon and groundfish. The fisheries for these groups have changed as technology has advanced and as the stocks have been subjected to increased fishing pressure. Man's modification of the salmon's freshwater environment has resulted in additional problems to be solved to maintain the salmon runs.

PACIFIC SALMON

The Pacific salmon (genus *Oncorhynchus*) are found in temperate and arctic waters of the North Pacific Ocean along the North American and Asiatic coasts. North America has five species: chinook (*Oncorhynchus tshawytscha*), chum (*O. keta*), coho (*O. kisutch*), pink (*O. gorbuscha*), and sockeye (*O. nerka*). Asia has a sixth species, the masu or cherry salmon (*O. masu*), found only in limited numbers. Most Pacific salmon have an anadromous life history; that is, they are born in fresh water, migrate to sea to grow and mature, and return to fresh water to spawn. The adults die after spawning.

Four nations — Canada, Japan, the United States, and the U.S.S.R. — have extensive salmon fisheries. Of the average annual catch of 200 million fish, Japan takes 34 percent, the U.S.S.R. 29 percent, the United States 26 percent, and Canada 11 percent. The predominance of particular species in the catches of each country varies; the species in order of total catch are pink, chum, sockeye, coho, and chinook.

From the time the first salmon cannery was set up on a barge at Sacramento, Calif., in 1864, the salmon industry of the western United States has developed to become a vital part of our fishery economy. Salmon is the second most valuable seafood canned in the United States.

U.S. fishermen take their silver harvest from coastal waters of the Pacific Northwest and Alaska. The mighty Columbia River, draining two-thirds of the Pacific Northwest, is the largest single source of chinook salmon in the world. Troll fisheries as far north as southeastern Alaska and as far south as northern California take chinook salmon born in the Columbia River and its tributaries. More sockeye salmon are caught in Alaska than anywhere else in the world — more than half originate in Bristol Bay rivers. Because the sockeye has the highest dollar value, the Bristol Bay fishery is the most important to the salmon industry of the United States.

Most salmon fishing was done in coastal waters until 1952 when Japan began high-seas fishing with mothership fleets in the North Pacific. Starting with 3 motherships and 57 catcher boats, the fleets expanded to 11 motherships and 369 catcher boats. Each day, 369 catcher boats can set enough nets to reach almost from Seattle to Tokyo.

Research has shown that the Japanese fleets take both North American and Asian salmon. Because the fleets harvest stocks of Bristol Bay sockeye salmon, which are caught inshore by U.S. fishermen, the management of the valuable fishery is a complex international problem.

COASTAL GROUNDFISH

The Continental Shelf of the northeastern Pacific Ocean is an area where groundfish are fished intensively in depths of 90 to 1,800 feet. Three kinds of fish — the flatfishes, rockfishes, and roundfishes — account for most of the landings by the United States and Canada, averaging some 140 million pounds annually. The flatfishes (flounders and soles) head the list in poundage and value; the rockfishes (ocean perch) and roundfishes (cod, hake, sablefish) are next in importance.

The coastal fisheries for groundfish date back to 1875. Rapid changes have been wrought recently by improvements in fishing gear, by wider markets, and by new techniques in filleting and freezing. Pacific Northwest trawl catches increased from 12 million pounds in 1940 to 140 million in 1965; catches reached an all-time high of 185 million pounds in 1966.

During exploratory fishing in the early 1960's (by the Bureau's Seattle Exploratory Fishing and Gear Research Base), large schools of Pacific hake (*Merluccius productus*) were discovered; a midwater trawling system was then devised for efficient capture. Although not valuable in the United States as a food fish because of its soft, bland flesh, the hake is 15 percent protein, equal in nutritional value to cod, salmon, and beefsteak. Other uses have been found for this previously undesirable scrapfish — animal food, fish meal, oil, and FPC (fish protein concentrate). FPC, which can be produced from many types of fish, has great potential as a protein additive to the diet of the world's undernourished people.

The commercial hake fishery began in 1965 with a few commercial vessels under BCF charter. In 1966, a modern plant was built at Aberdeen, Wash., to reduce hake to oil and high grade fish meal. But just as the fishery got underway, a huge Russian fishing fleet appeared off the Washington coast (fig. 3).

The Russians, who fished in international waters, took large quantities of hake and ocean perch. The fleet (comprising more than 100 vessels at times) caught over 286 million pounds of Pacific hake and about 22 million pounds of ocean perch. The U.S. fishermen, in their relatively small vessels, were preempted from the better fishing grounds and had trouble finding dense concentrations of hake.

In 1967, however, the U.S. fishery was more successful. The United States extended its jurisdiction to 12 miles from shore, which gave our fishing boats some area where they could operate unhindered. In 1968, for economic reasons, the United States Pacific hake fishery was nonexistent offshore although the Soviets continued to take large quantities.

The need for scientific information to protect U.S. fishing rights in international negotiations and to use for the rational management of our fisheries has given impetus to our research on groundfish.

FIGURE 3.—Russian fishing fleets are self-sufficient and operate great distances from their home bases. Here a trawler brings its catch to a ship that processes and stores the fish.

SALMON IN THE OCEAN

Until recently the movements of salmon and their relations to the environment in the vast expanse of the North Pacific Ocean were virtually unknown. Their lives were shrouded in mystery once the young fish left rivers and streams on the journey that would end in their return one to several years later as adults.

Since 1955, however, a store of new information has been gradually acquired during research on the high seas for the INPFC (International North Pacific Fisheries Commission). Techniques were developed to classify sockeye salmon as of "North American" or "Asian" origin. Scientists demonstrated that North American and Asian stocks intermingle at sea but were unable to define the factors that control fluctuations in the marine distribution of the salmon.

Knowledge for use in the management of salmon fisheries also has been increased. New facts have been revealed by research on salmon growth and mortality in the ocean, on effects of fishing, on physiology of maturation, and on more precise means to identify ages and stocks of salmon; these facts have direct application to efficient use of salmon stocks.

DISTRIBUTION AND ENVIRONMENT

In an effort to relate the distribution of salmon at sea to dynamic ocean characteristics, such as major currents, 14 major research cruises were undertaken in the North Pacific Ocean and Bering Sea during 1966-68. The research vessels *George B. Kelez* and *Miller Freeman* (figs. 4 and 5) and two charter vessels logged more than 108,000 miles, the equivalent of more than four trips around the world. Along the cruise tracks our scientists fished with gill nets of various mesh sizes (fig. 6) and collected data to sample salmon populations (fig. 7), define ocean domains, and measure biological productivity.

FIGURE 4.—The *George B. Kelez*, a converted military cargo ship, is 176 feet long, has a cruising speed of 11 knots, and carries 6 scientists and a crew of 14. The vessel was named for a scientist from the Biological Laboratory who lost his life in a plane crash while on duty in Alaska in 1954.

Research on the ocean distribution of salmon is designed primarily to fulfill the obligation of the United States to the INPFC and to measure the effects of foreign fisheries on U.S. salmon stocks. Under provisions of an international agreement, Japan agreed not to fish for salmon east of a provisional line established in 1952 along long. 175° W. Our research has concentrated on predictions of when and where Bristol Bay sockeye salmon are found, how available they are to the Japanese fishery, and what their abundance is inshore.

Unusual changes in the abundance of salmon usually accompany changes in water properties, structure, or flow. The abundance of sockeye salmon and of minute organisms is apparently related to the major oceanographic features in the Pacific Subarctic, south of the Aleutian Islands (fig. 8).

During the summer, immature sockeye salmon were caught south of Adak Island — in an area with no well-defined currents, or the Ridge Area, just south of the Alaskan Stream. During the winter, immature sockeye salmon were farther south in the extension of the Western Subarctic water. Maturing sockeye salmon, on the other hand, were found only in the Alaskan Stream and in the Ridge Area. Maturing fish apparently remain in more northerly waters in the winter before their spawning migration.

FIGURE 5.—Bureau's newest research vessel, the 215-foot *Miller Freeman* was launched in 1967. She carries 9 scientists and a crew of 28. Her cruising speed is 14 knots, and maximum range is 16,000 miles.

FIGURE 6.—Sockeye salmon caught by a gill net. In the water, fish are captured when they push their heads through a mesh opening. When the twine constricts them behind the gill covers, they find it difficult to escape.

Chum salmon apparently move with the Alaskan Gyre in late spring and summer and appear in the Subarctic Current in winter. Several species of salmon were caught in significant numbers in the strong Subarctic Current in the winter cruise of 1967, but apparently they were not south of the main axis of that current and only in small numbers in the Ridge Area to the north.

Summer cruises in 1966-68 examined the distribution of salmon in the central Aleutian Islands area in relation to oceanic features. The area has been an important site for obtaining indexes of the abundance of immature fish — in forecasting the run to Bristol Bay the following year.

In this sampling we are following the Bristol Bay sockeye salmon through one cycle of 5 years to evaluate the sampling site through years when both the abundance and the oceanic conditions vary.

Our biologists and oceanographers hypothesize that two populations of maturing Bristol Bay sockeye salmon exist in winter and early spring — one in the Alaskan Gyre (Gulf of Alaska) and the other in the western Subarctic Gyre (western North Pacific Ocean). Sockeye salmon from Bristol Bay presumably travel as far as the western end of the Alaskan Stream, which diverges near long. 170° E. One branch of the stream flows north into the Bering Sea, and the other flows south to merge with the Subarctic Current.

The purpose of the spring cruise in 1968 was to define the distribution of Bristol Bay sockeye salmon in relation to oceanic features at about the time the salmon started their migration inshore. A working hypothesis was tested: that maturing sockeye salmon are associated with certain ocean domains and that their migrations into areas fished by Japan are related to the Alaskan Stream. We were joined in this research by two Japanese research vessels.

FIGURE 7.–Salmon caught by research vessels are weighed (left), measured (above), and frozen for further study in the laboratory.

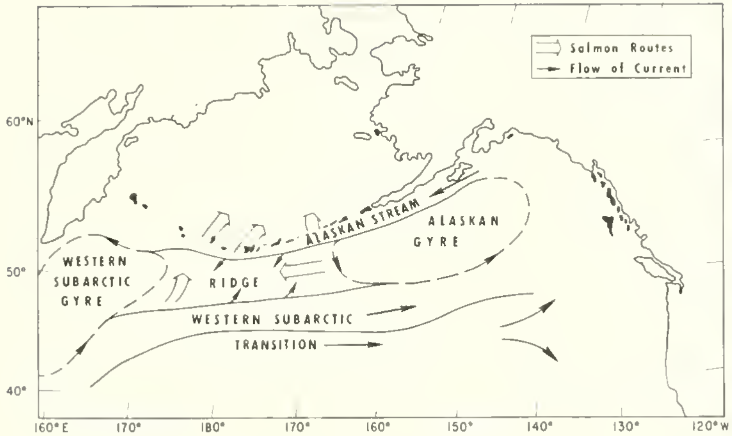

FIGURE 8.—Oceanographic features of the Subarctic region of the North Pacific Ocean. The Alaskan Stream flows strongly westward; the Ridge Area is a boundary between westward and eastward flow; the current in the Western Subarctic Area flows eastward; and the Transition Area, which has a weak eastward flow, is a mixture of Subarctic and Subtropic water.

The ultimate goal of our oceanographers is to forecast environmental conditions and their effect on the abundance and migration of salmon. The direction and size of major ocean currents appear to depend on the wind or barometric pressure. This type of water movement is called wind-stress transport. Transports calculated from meteorological data can indicate monthly, seasonal, and annual variations in circulation during periods of no direct observation. The oceanographers compare actual observations with circulations calculated from pressure distributions.

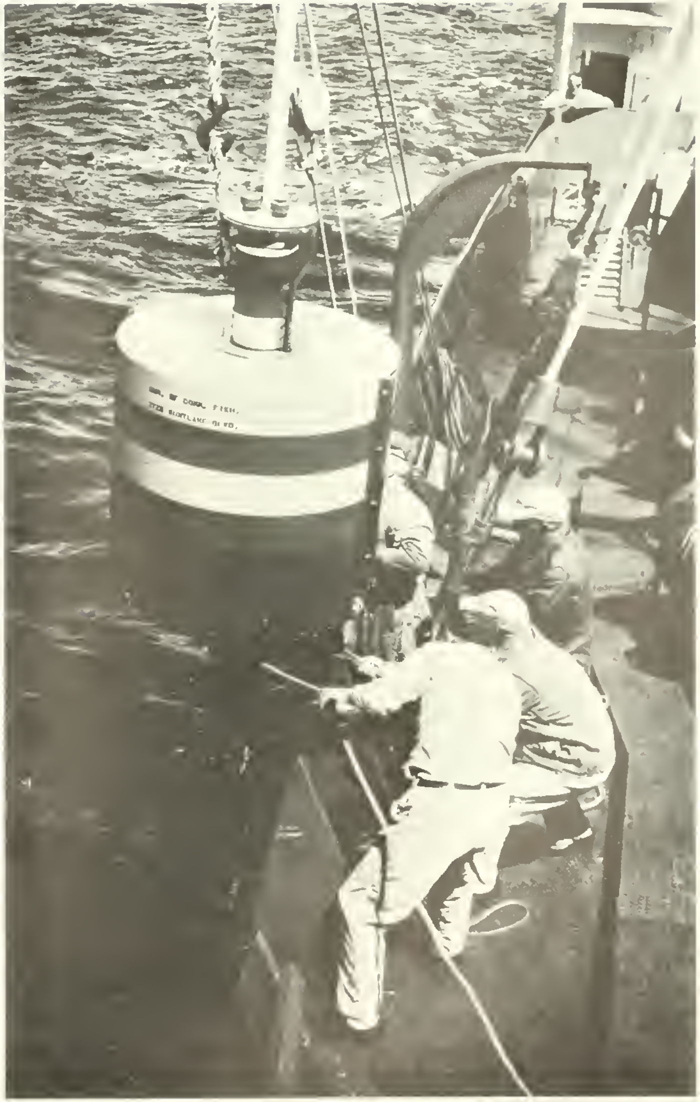

FIGURE 9.—One of the Laboratory's telemetry buoys being lowered in midocean. It measures temperature and salinity and can store the information.

Our oceanographers have proposed a network of drifting telemetry buoys. Such a network would provide a continuous picture of oceanographic conditions (fig. 9). Prototypes have been tested. These buoys, if released periodically in the western Pacific Ocean, would drift to North America, taking up to 2 years. They would transmit their data on locations, salinity, and temperature to vessels at sea, land stations, or even satellites (fig. 10). By 1969, satellites will be capable of relaying data from ocean stations. Our laboratory already has equipment to communicate with buoys via satellite signals.

Modern shipboard equipment greatly speeds the collection and analysis of oceanographic data (fig. 11). Nansen and other sampling bottles collect water for chemical analyses. Bathythermographs record the temperatures.

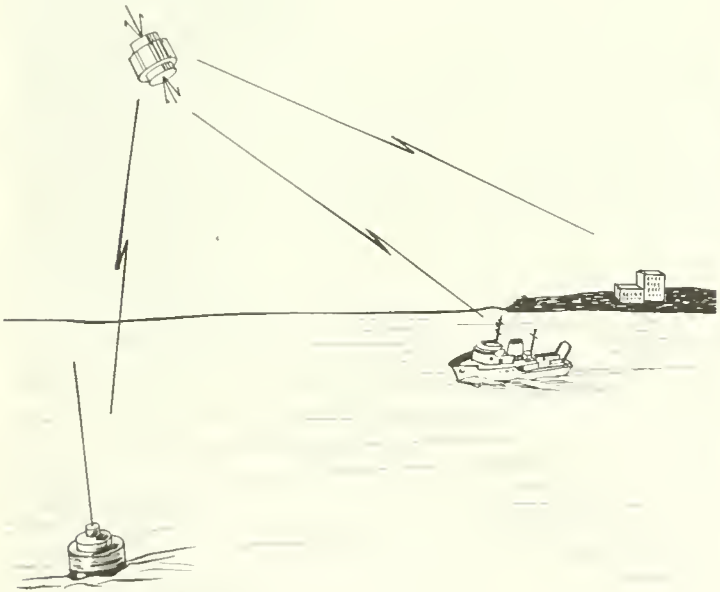

FIGURE 10.—Transmission of data from drifting buoys via satellites is under development. Monitor stations will trigger buoys to report oceanographic data and buoy locations.

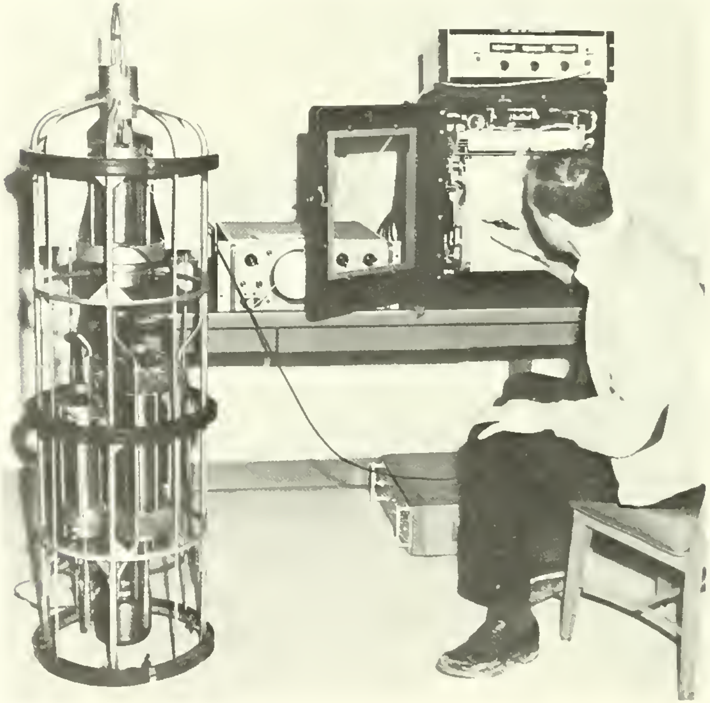

FIGURE 11.—Data from an automatic STD (salinity-temperature at depth) sensor (left) lowered from a ship are collected on a recorder (right) or may be processed immediately with a shipboard computer.

FIGURE 12.–Measurement of trace element content of sea water by atomic absorption spectrometry.

Chemistry of the Ocean

Studies of the chemistry of the ocean are fundamental for understanding the relations among chemical features, water masses, and life in the sea. Broad research includes basic studies to supplement information on the properties and movements of water masses. Also significant are the organic constituents of sea water and marine organisms.

Our marine geochemists have adopted new techniques for the determination of nitrate-nitrite and for analyzing carbohydrate. Accurate measurement of trace elements will increase their ability to identify water masses, to trace oceanic circulation, and to determine the processes that cause the distribution of elements. Use of atomic absorption spectrometry (fig. 12) permits large volumes of sea water to be examined for precise measurement of rare elements — at concentrations of a part per billion or less. These trace elements help identify the distinct water masses that may influence the movements of salmon.

FIGURE 13.–Biological oceanographer sorts zooplankton to identify species and determine their abundance.

Concentrations of sockeye salmon between the two opposing current systems south of the Aleutian Islands were examined to determine if their abundance could be attributed to differences in the availability of food organisms (fig. 13). Differences in relative abundance of phytoplankton and zooplankton in the Ridge Area and in the Alaskan Stream may have come about from different grazing rates or varying physical-chemical conditions. Large zooplankters are consistently abundant in the Ridge Area which corresponds to the area of known high concentrations of immature salmon in autumn.

Biological Productivity

How does the availability of food organisms affect the movement of salmon? Why is the production of organisms low in some parts of the ocean in spite of adequate vital nutrients? Research on biological productivity may provide the answers to these and other questions.

The most basic food organisms are the phytoplankton which are tiny single-celled plants. Produced continuously wherever light energy from the sun and nutrients are in the right combinations, phytoplankton may live only a few days or even a few hours but reproduce at fantastic rates. As they multiply, they exhaust one or more of the nutrients in the water. Phytoplankton also constitute food for grazers, the smallest of which (zooplankton) are consumed by small fish, which in turn become food for larger carnivores higher in the food chain.

The amount of chlorophyll contained in the phytoplankton is an index of the stock of phytoplankton. Productivity is the increase of the stock in relation to time. Our oceanographers measured basic productivity by injecting radioactive isotopes of carbon-14 into bottles of sea water. After a specified time, the samples were analyzed with a Geiger counter. The amount of carbon-14 assimilated by the phytoplankton provided an index of productivity.

Maximum productivity in 1966-67, as indicated by utilization of nutrients, was in the spring; minimum productivity was in the winter. Chlorophyll in the late winter south of the Aleutian Islands increased from north to south and was highest in the warmer, central Pacific Ocean. Productivity in summer was highest in the Alaskan Stream and on either side of the area of vertical upwelling (Ridge Area) which brought up nutrients from the ocean depths.

MANAGEMENT OF SALMON STOCKS

The efficient use of salmon stocks requires a knowledge of where, when, and how many to harvest. Is it more efficient to catch smaller, younger, more numerous salmon far out in the ocean before many of them die from natural causes or are eaten by predators? Or, is their growth and survival — between their exposure to high-seas and coastal fishing — such that the total weight of the stock is greater when larger, older, but fewer fish are caught inshore? How many salmon die after escaping from the gill nets of the Japanese fleet, and what is the effect of the physiological stress from their struggles? Biometric analysis, knowledge of the relative efficiency of nets, growth and mortality studies, physiological research, and techniques to identify races or stocks may furnish some of the answers.

Forecasts of Sockeye Salmon Runs

A system to estimate the numbers of sockeye salmon which will return to Bristol Bay each year is one of our primary goals. Both industry and management will benefit if the number of fish that will arrive 6 months to a year later can be predicted with reasonable accuracy. Such forecasts reduce costs of the U.S. salmon industry largely because the canning operations can be planned more effectively. The Alaska Department of Fish and Game also needs the forecasts when it sets regulations designed to utilize sockeye salmon runs fully and to assure the optimum number of spawners on the spawning grounds.

Predictions of sockeye salmon runs to Bristol Bay have been made by U.S. scientists since the late 1950's. The forecasts were based on counts of spawners and downstream migrants, surveys of distribution and abundance of salmon in the ocean, age composition (of fish at sea and in spawning streams), and estimates of the catches and fishing efforts of the Japanese vessels. Made in November each year, the forecasts are not yet highly reliable. We hope that our goal of accurate estimates may be reached when more information is available on the distribution and abundance of salmon in relation to the ocean environment.

Our biometricians have developed a method to predict the size of the run of Bristol Bay sockeye salmon 1 to 3 weeks before the fishing season. It is a complicated system that requires an adjustment for variations in the Japanese fishing effort and an estimate of the percentage of fish that have lived 2 years in the ocean. The new method is under evaluation.

Effects of Fishing

The response of fish populations to fishing is modified by the harvesting techniques and by the environment. To measure these responses, biologists have conducted fishing gear experiments in the ocean and controlled population studies in the laboratory.

Fish caught by gill nets but not enmeshed in the nets when they are brought aboard a vessel are called "dropouts." The effects of the loss of salmon from gill nets may have an important bearing on the management of fisheries. After escaping the nets, the salmon may die, be less able to evade enemies, or be more susceptible to disease than salmon never meshed in nets. Dead salmon also may drop out. The lost fish contribute nothing to man's food supply nor to the reproduction of stocks.

Experiments in 1966-67 on the high seas to measure dropout rates yielded interesting results. The gill nets set by research vessels were patrolled at night by small boats. Most of the time this work was difficult in a tossing boat and in darkness penetrated only by portable spotlights. During each patrol, the locations of gilled salmon were marked with colored pins, and the presence of salmon was noted on later patrols or when the nets were hauled.

Total dropouts ranged from about 11 percent (for fishing periods up to 1 hour) to as high as 64 percent (for periods up to 10 hours). Losses varied according to mesh size; losses were larger in shorter periods (2½ hours or less) in large-mesh nets and for longer periods (5-10 hours) in small-mesh nets.

Additional dropout experiments were carried out in 1966-68 at our Bowman Bay Marine Station on Puget Sound, Wash. (fig. 14). Up to 45 percent of the sockeye salmon escaped after being caught by gill nets, and 79 percent of these fish were dead within 20 days. All live fish that were removed from the nets died within 20 days, but only 1/10 of the fish not exposed to gill nets died. Thus, in a fishery, for every 1,000 fish enmeshed in a gillnet, 550 might have been landed and an additional 450 might have been landed if they had not dropped out. Of the 450 dropouts, only 94 might have lived to reach inshore fisheries.

FIGURE 14.–Floating enclosure at Bowman Bay for gill net experiments under controlled conditions. Marked salmon were exposed to gill nets in the larger area. Those that escaped from nets were transferred to the smaller area at left end and held with nonexposed control fish.

Sea lions, seals, sharks, and birds feed on salmon enmeshed in gill nets (fig. 15), but how they affect the catch rates is unknown. During the spring and summer cruises of 1968, freshly frozen salmon were attached to cork and lead lines of gill nets as decoys for predators. In the spring, after albatross were found feeding on salmon fastened at the surface, the decoys were fastened deeper to more nearly simulate fishing conditions. More than twice as many decoys were missing when nets were hauled in the summer (67 percent) than in the spring (29 percent). Losses were highest from sets where sea lions were observed along the nets; they were higher within 100 miles of shore (spring 48 percent, summer 82 percent) than beyond 100 miles (spring 17 percent, summer 39 percent). Higher total losses in summer were partly the result of more frequent fishing near shore in the summer compared to spring. Although the effect on catch rates is difficult to measure, the loss of decoys shows that predators could reduce the catch severely in certain areas.

Fish enmeshed in nets fight to break loose. Their struggles increase the lactic acid in their bodies, and high levels may cause death. Biochemists in 1965-66 examined the possible physiological stress caused in salmon by capture, tagging, and forced exercise. Maturing sockeye salmon, captured principally with longlines and purse seines in Bristol Bay and near the eastern Aleutian Islands, were tagged and held in shipboard tanks. Immature fall chinook

FIGURE 15.–A fur seal finds a ready-made banquet of a salmon taken from a gill net. Net floats in foreground (and weights under water) hold the net vertical.

salmon were transferred from hatcheries to salt-water ponds where they were handled, tagged, and chased to exhaustion.

Biochemists found the blood lactate concentrations of maturing sockeye salmon after stress were below concentrations that accompanied high mortalities of maturing coho and chinook salmon caught by troll gear in investigations by other scientists. The adult sockeye and immature chinook salmon did not die within several hours after subjection to stress, although their blood lactate increased. The immature chinooks did not suffer delayed mortality; the maturing sockeyes began dying after 2 days, however, possibly because of additional stress induced by shipboard handling.

Although actual mortalities are unknown, the number of salmon lost from dropping out of, and from predation in, gill nets in a fishery on the scale of the Japanese mothership operations could be tremendous. If more information is obtained about the secondary effects on salmon of being held and escaping from gill nets and if mortality could be measured accurately, management of the fisheries and the accuracy of forecasts could be improved.

Fisheries in Miniature

Not all investigations on the effects of fishing are done at sea. One project studies populations in the miniature world of the laboratory aquarium. Although not directly related to salmon, these experiments will provide knowledge that can be applied to all types of fisheries. The studies eliminate extraneous conditions such as weather and ocean currents that affect commercially fished populations and obscure the relations between populations and fishing. Fishing is simulated by selective removal of fish from aquaria.

One experiment with guppies and swordtails measured the effect of fishing on competing populations. The maximum sustainable yield was achieved when each species was fished at a rate of 10 percent per brood interval. The more vigorous reproduction and growth of guppies than of the swordtails eventually caused the disappearance of swordtails from the control population.

Two experiments with tilapia, a tropical pond food fish, are in progress. One is designed to determine the effect of space on the relation of catch to fishing. The other examines the genetic effects of selective fishing.

Ocean Growth and Mortality

One approach toward finding the potential yield from a salmon population is to evaluate their growth and mortality in the ocean. In 1964, laboratory biologists assessed the long-term growth of sockeye salmon from western Alaska; in 1968 they completed the investigations of seasonal (May-September) and long-term (between age groups) growth of chum salmon at sea.

The analysis of growth in chum salmon was based on body lengths and patterns of scale growth of fish caught by gill nets in the North Pacific Ocean and Bering Sea during 1955-56. Chum salmon of Asian origin were smaller and grew at a faster rate than those of North American origin, which suggested a shorter growing season for Asian stocks. Maturing and immature fish of the same age and stock grew at about the same rate. Growth was considerable from the time maturing fish left offshore areas until they arrived in coastal waters. Estimates of growth rates in the year before maturity of chum salmon that spent 3 years in the ocean (those most vulnerable to the oceanic fishery) indicated increases of population weight that considerably exceeded reasonable estimates of mortality. In other words a greater yield can be obtained from a coastal rather than an oceanic fishery.

Physiology of Maturation

The age at which salmon mature and the physiological processes that govern their maturation have been studied for several years. The ability to determine maturation at sea and to predict the year of spawning is necessary for accurate forecasts of runs and for efficient use of stocks. In salmon, the weight of the reproductive organs (gonads) is generally an index of maturity, but it is reliable only 2 or 3 months before spawning (fig. 16). Earlier detection of maturity — as much as 6 to 12 months before spawning — is now believed possible through biochemical techniques that examine the SM antigen in blood serum and the quantities of hormones in the pituitary gland.

FIGURE 16.–Biologist removing gonads of freshly caught salmon for weighing aboard ship.

SM antigen in blood serum. — During sexual maturation, new proteins appear in the blood of female salmon. These proteins are produced in the liver, carried by the blood to the eggs, and concentrated in the yolk. One protein, the SM antigen, is present in maturing females but absent in males, immature females, and spawned-out females.

Our physiologists studied more than 6,500 sockeye salmon between 1961 and 1968. They concluded that the presence or absence of SM antigen in the blood of oceanic female sockeye salmon (caught from late February or early March to time of spawning) separated most of the females that are maturing from those that are not maturing that year.

Pituitary hormones. — To determine if maturation can be detected earlier than by the SM antigen, we are investigating hormones from the pituitary glands (found at base of brain) of salmon. A marked difference in hormonal activity was found between immature and mature fish. The method is promising because of its sensitivity and potential reliability.

Identification of Ages and Stocks

Quick determination of the age and geographic origin of salmon caught at sea is required for effective management of the fisheries. A Pacific salmon captured in the ocean could have been born in either Asia or North America.

Because some species of salmon born in a given year do not all mature and return to fresh water after a specified time, fish of different age and geographic origin may be mixed in some catches. Thus, research on ocean distribution, abundance, and utilization of stocks must rely on good classification systems.

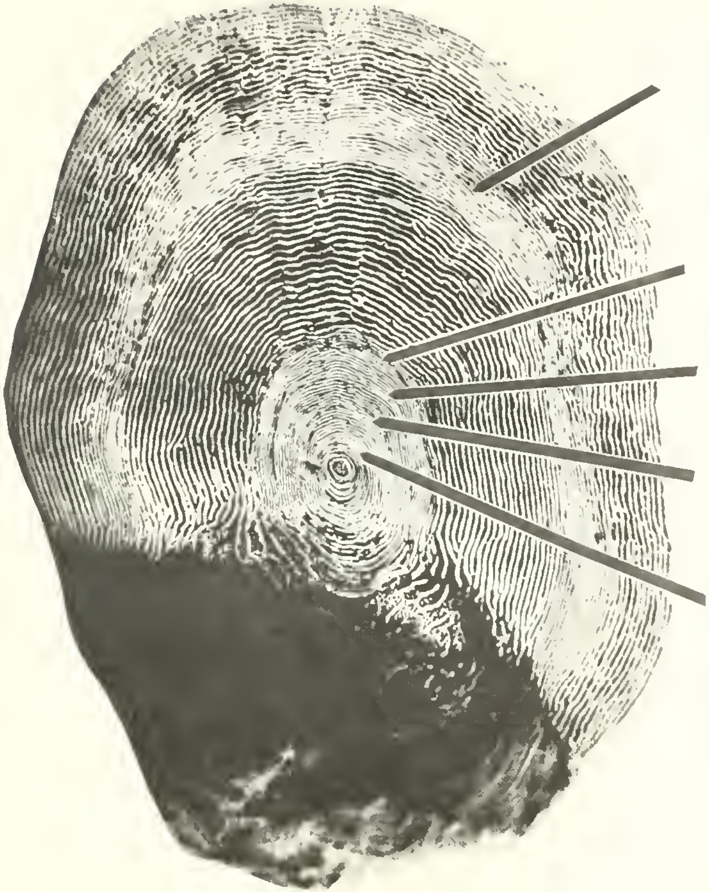

FIGURE 17.—Scale taken from steelhead trout caught in Gulf of Alaska. The four arrows pointing towards the center indicate fresh-water year marks (annuli). The fish went to sea in its fourth spring. The shorter arrow indicates the winter it spent in the ocean — the fish was 5 years old, going into its sixth year.

FIGURE 18.—Experimental operation of semiautomatic machine for reading fish scales. Image of scale under microscope (right) is fed to computer (center). The computer analyzes the light and dark areas of the scale and results are printed on teletype (left).

The scales of fish reveal details of the past much as growth rings tell the story of a tree (fig. 17). Data on scales, measurements of body structure, and biochemical "blood typing" were analyzed by computers to demonstrate the intermingling of North American and Asian stocks of salmon.

Each spring, scales of sockeye salmon caught by research vessels are rushed back to Seattle where technicians read the projected images to determine age. By a time-consuming process, features on the scales are measured to determine continental origin. The age composition and origin of the catches are then given to the biometricians to prepare their forecasts of sockeye salmon runs.

To speed the processing of fish scales and open new areas of research, the laboratory obtained a semiautomatic scale-reading machine (fig. 18). The machine, made to our specifications, is the first of its kind. Processing should be accelerated from the present rate of about one scale per hour to about one scale per minute; added benefits would be more information derived from each scale than was possible by human scale readers. The electronic scanning and computer capabilities of the machine should give an immediate print-out of age and a classification as to the origin of the fish.

Our biologists are searching for new clues to pinpoint racial distinctions of salmon. They are analyzing scales, bones, blood, muscles, and eye lenses for genetic or biochemical peculiarities. The chemical composition of scales and bones may reflect the mineral chemistry of waters where the fish were born. The patterns in which circuli are formed on scales during the ocean growth of salmon show promise as indicators of differences between maturing and nonmaturing fish. Blood sera of sockeye salmon have variable LDH (lactate dehydrogenase isozyme) patterns that are potentially useful as genetic "markers" to differentiate stocks (fig. 19).

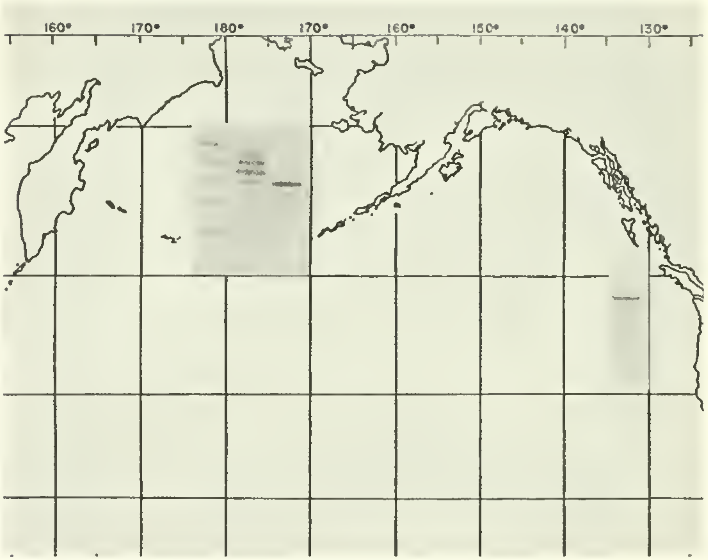

FIGURE 19.—Bands in starch gel illustrate different LDH patterns in sera of sockeye salmon. Fish from western Alaska or Kamchatka River in eastern Siberia have one of three different patterns (left), and fish from southern British Columbia or Washington State have only one pattern (right).

SALMON IN INLAND WATERS

Salmon migrating between the sea and their spawning areas have adapted to the estuarine and fresh-water environment over thousands of years. In the space of a few decades, however, enormous changes have taken place to threaten their survival. In our research on inland waters we anticipate the environmental changes that will be detrimental to fish. We attempt to develop methods to increase survival as the fish move between natural or artificial spawning areas and the sea. Our research has application nationally and internationally where water-use developments threaten the production and development of aquatic organisms.

THE CHANGING ENVIRONMENT

During the past three decades, changes in the environment of the Columbia River were mainly brought about by the construction of hydroelectric dams. These dams constitute physical barriers to migration and are gradually changing the river to a series of impoundments. The relations of salmon to their predators, competitors, diseases, and food organisms have been altered. Temperature regimes have been modified. Freshets and floods, which play a major role in migration, have been affected. Young salmon migrating to sea are often carried by water currents into turbines and are killed by the blades or other shear forces. Predators below the dams also cut down the number of survivors.

At the present rate of construction, all sites for economical production of hydroelectric power will have been utilized by 1985. When dams in the upper reaches in Canada are completed, the flow of the mighty Columbia will be almost completely controlled. Little or no water will spill over the dams. This change will influence the upstream migration of adult salmon and force most of the young fish to pass through the turbines.

THERMAL POLLUTION — A DEVELOPING PROBLEM

In the future, most electricity in the Pacific Northwest will be produced by thermal electric power plants (fig. 20). Twenty such plants — over 1,000 mw. (megawatts) each — are proposed for construction by 1990. The first will be a fossil fuel (coal) plant; the remainder will be thermal nuclear plants. Thermal plants use large volumes of water to cool the condensors. The temperature of the cooling water at the point of return to the river may be 15° to 20° F. higher than at the intake. A series of power plants could produce a severe cumulative effect. The proposed construction has stimulated a controversy over the disposal of waste heat from the nuclear power plants.

Our biologists have been aware of the problem for some years and have studied fish that have been subjected to the temperatures of anticipated thermal regimes; research has now been intensified.

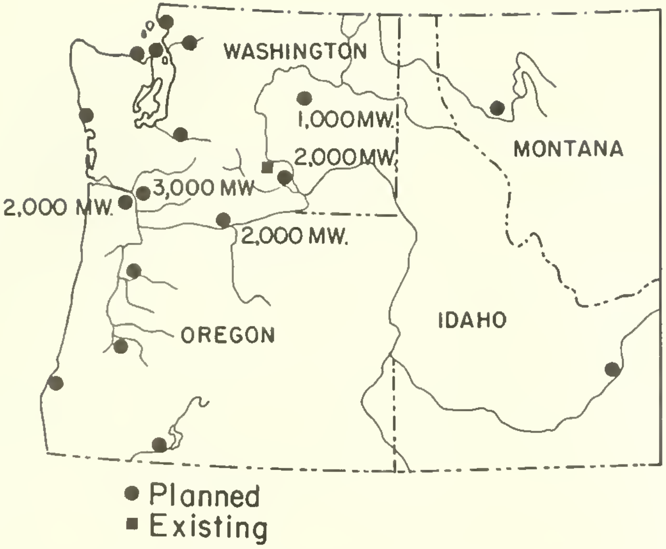

FIGURE 20.—Thermal electric power plants (planned and existing) in the Pacific Northwest.

Water Quality Survey

In July 1967, the Bureau began a survey of the water conditions of the lower Columbia River from the mouth of the Willamette River downstream to Puget Island. Two thermal nuclear plants have been proposed for this area — 2,000 mw. at the Trojan plant in Oregon and 3,000 mw. at Kalama in Washington.

Nuclear power plants protect their large screening facilities and condensers with chemical antifoulants which can affect the streams receiving the overflow. Thus we have been making chemical analyses of the area's water, along with studies of the biological and physical conditions.

The data collected in 1967-68 were compared with data from a survey of 1954-55 by R. O. Sylvester, Department of Civil Engineering, University of Washington. Water temperatures had increased during all months, whereas concentrations and saturation of oxygen had decreased (fig. 21). Although concentrations of oxygen are still in an acceptable range, the downward trend is one that bears watching — particularly in view of the anticipated industrial expansion.

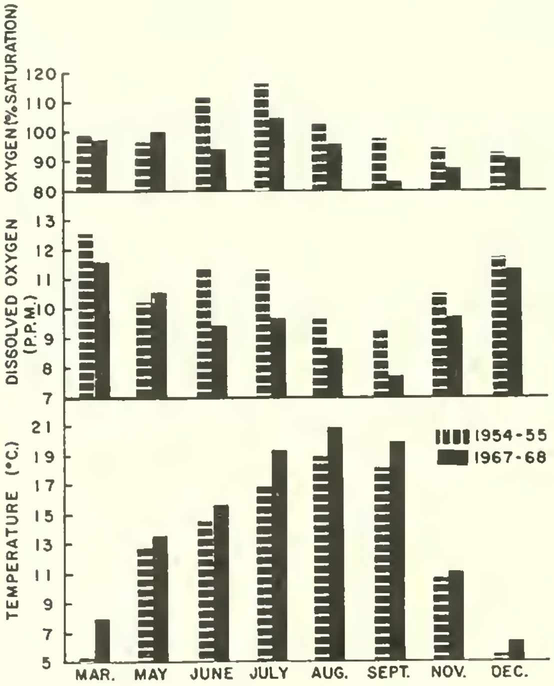

FIGURE 21.—Temperature-oxygen chart for lower Columbia River — a comparison of conditions in 1954-55 and 1967-68. Note increase in temperature and decrease in oxygen.

Thermal Enrichment

To offset the undesirable effects of thermal pollution, some electrical companies have announced their intention to install cooling towers. The water would then be recycled within the power plant and would not be discharged into the river.

Eventually (in salt water) the problem of thermal pollution may disappear into one of thermal enrichment, leading to extensive aquaculture. The matter is complex, however. Meanwhile, the Bureau is racing with time to save the cold-water species of fish from needless sacrifice.

MIGRATIONS OF ADULT FISH

Adult salmon and trout migrating upstream are confronted with many natural and manmade obstacles (fig. 22). Nearly every dam on the Columbia River has a fishway (or fish ladder) consisting of a series of stepped pools through which the fish can swim over the dam (fig. 23). Because fishways are costly to construct and because delays at dams can be harmful to the fish, our research seeks ways to improve the efficiency of fish passage. Some studies are made at dams and along the river; others are made with models in laboratories.

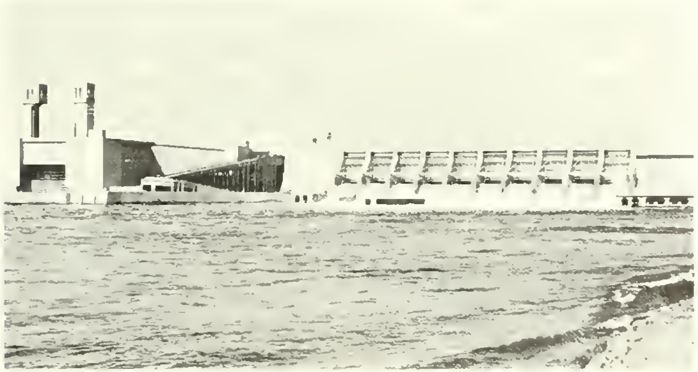

FIGURE 22.—Ice Harbor Dam on the Snake River. Some races of migrating salmon and trout must pass over many dams to reach spawning areas.

FIGURE 23.—Chinook salmon ascending the fish ladder at Ice Harbor Dam, Snake River.

In the Fisheries-Engineering Laboratory at Bonneville Dam, we made extensive studies on economical and efficient means of passing fish over dams (fig. 24). The investigations were financed by the U.S. Army Corps of Engineers.

The laboratory stands on a short bypass to one of the main fish ladders, from which migrating fish are diverted. Their behavior and performance are measured as they pass through experimental structures. Recent studies revealed how water temperature, types of flow, and light influenced the behavior and performance of adult salmon and steelhead trout within fish-passage facilities.

Response to Temperature

To test the response of migrating adult salmon and steelhead trout to different water temperatures, the fish were given a choice of entering either of two channels (fig. 25). In one channel, the water was at river temperature (50°-70° F.), to which the fish had been acclimated; in the other, temperatures ranged from 15° F. warmer to 7° cooler than the river temperature.

Although more fish entered the channel with water at river temperature, many fish voluntarily entered water up to 7° F. above or below that of the river. A few fish entered water as warm as 80° (15° F. warmer than river temperature), but none entered water above 80° F. When given a choice of entering water either 7° F. above or below river temperature, more fish entered the cooler water.

Attracting Fish

Ideally, water flow and other conditions at fishway entrances should attract the fish so they move past a dam with minimum delay and maximum ease. In their search for ways to speed the passage of fish, biologists tested various hydraulic and light conditions to attract fish into fishway entrances and into submerged orifices.

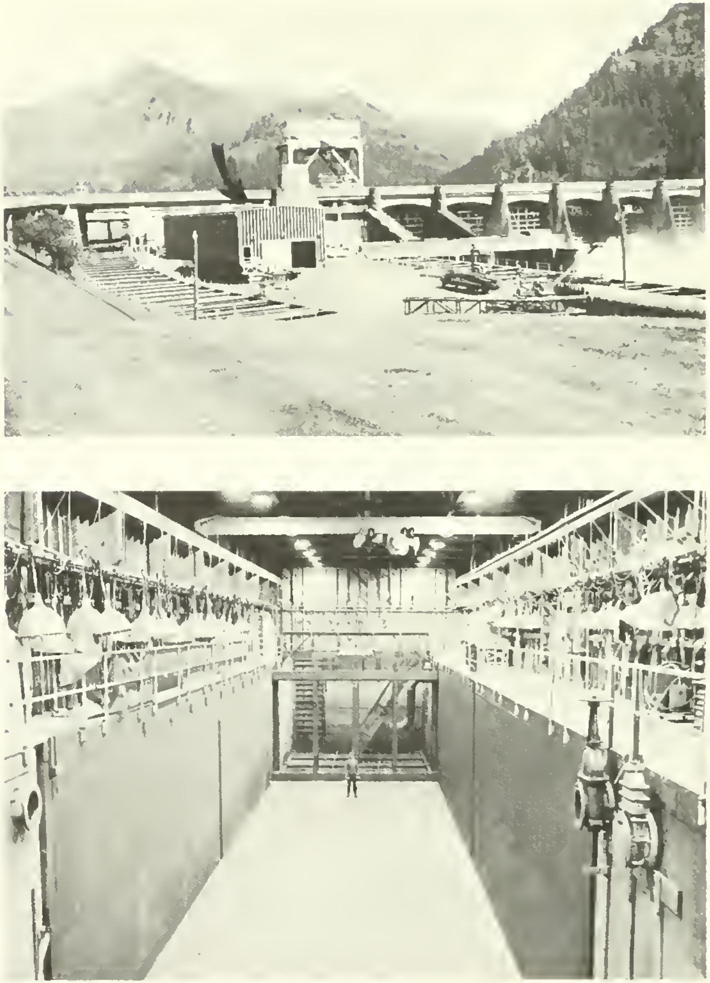

FIGURE 24.—TOP. The Fisheries-Engineering Research Laboratory (arrow) at Bonneville Dam on the Columbia River. BOTTOM. Drained test channel inside laboratory.

FIGURE 25.—Observers follow fish through the temperature test channels at Bonneville Dam. Heated or cooled water can be supplied to either channel by regulating valves from heaters and chillers without changing hydraulic conditions in either channel.

Into fishway entrances.—Because previous observations indicated that adult salmon may be attracted to stronger flows, tests were performed to determine if a high-velocity water jet might attract fish to fishway entrances. Adult salmon and steelhead trout were given a choice of entering either wide or narrow channels. It appears that fish may be attracted to high-velocity flows, but they might not enter a passageway if the entrance is too narrow.

Responses to different light intensities (fig. 26) and turbulence were also tested in the 5½-and 2-foot channels. Although the responses varied by species and with velocity of flow, the fish tended to avoid entering a channel with a dark entrance and were reluctant to pass through turbulence created by a screen of compressed air.

FIGURE 26.—TOP. Testing the response of fish to illuminated and dark channels at Bonneville Dam. BOTTOM. Fish were reluctant to pass through a screen of air bubbles.

Into submerged orifices. — Some fish arriving below a dam do not readily find entrances to fishways. Most dams on the Columbia River have a multientrance channel built into the powerhouse below the dam. Migrating fish enter the channel through submerged ports or orifices and are guided by currents to the fish ladders (fig. 27).

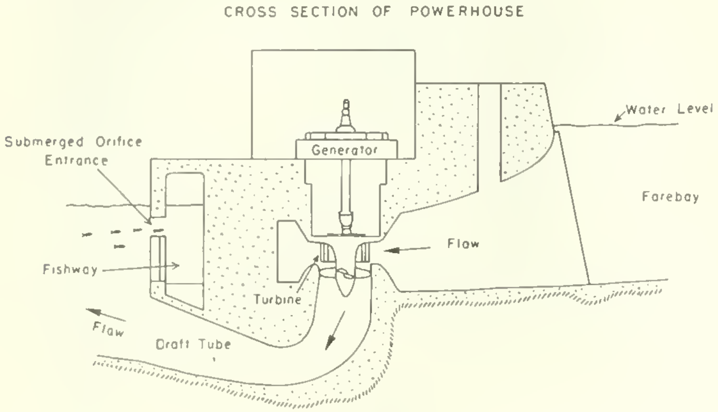

FIGURE 27.–ABOVE. Diagrammatic sketch of a typical powerhouse showing a submerged orifice entrance to the fishway. RIGHT. Some of the experimental orifices used in the laboratory at Bonneville Dam.

Our studies indicated that the relative attraction of a fishway entrance with a submerged orifice may be influenced by flow and light, relative brightness of the area, and the size of the orifice. Light appeared to be particularly influential. Fish adapted to light were reluctant to enter a dark orifice. If given a choice, a larger proportion entered the illuminated orifice regardless of flow or brightness of the surrounding area.

Many of the collection systems at dam powerhouses are so poorly illuminated that conditions possibly could be improved by lighting.

Tracing Movements of Salmon

Although much has been learned about passing fish over dams, some runs of salmon and steelhead trout slowly continue to decline; occasionally runs suffer drastic losses.

Unexplained losses of adult salmon and steelhead trout between certain dams have been as high as 46 percent and average 20 percent each year. Field studies in 1967-68 attempted to discover where and how delays and losses of fish occurred.

FIGURE 28.—Sonic tag being attached to 7-pound steelhead trout. One capsule contains mercury cell battery and 70-kHz transducer; adjoining capsule houses oscillator circuit components. Transmitting range is 1 to 2 miles in fresh water, or about 1 mile in salt water. Battery life is 10 weeks.

FIGURE 29.—A recently developed sonic tag is being inserted through the mouth and esophagus into the stomach of a chinook salmon. The procedure protects the tag and does not harm the salmon because it does not feed during its upstream migration.

To observe the effects of dams on upstream migration, more than 3,000 salmon and steelhead trout were tagged with miniature sonic transmitters (fig. 28) at Bonneville and McNary Dams. The sonic "tags," attached to the backs of the fish or inserted in their stomachs (fig. 29), sent out pulsed signals. As the fish moved upstream, the signals were recorded by automatic monitors (fig. 30) along shore and at the mouths of tributaries. Boat crews equipped with portable receivers made weekly surveys.

FIGURE 30.—Shore monitor which records passage of sonic-tagged fish. Data include date, hour, direction of passage, and repetition of tag pulses. Variations in the latter indicate where and when fish was tagged. Monitor is completely automatic; units need servicing only once every 7 to 10 days.

Among other findings, a temperature block to migration was revealed at the point the Snake River enters the Columbia. In the exceptionally warm summer of 1967, fish bound for the Snake River were delayed at the confluence for about 8 weeks — the river temperature was 7° F. higher than normal.

Future studies will use sonic tags to test the efficiency of collection systems at fish ladders, to measure fallback of salmon through spillways at dams, and to study behavior of salmon that encounter hot water discharges from thermal nuclear plants.

Sonic tracking was pioneered 15 years ago by our laboratory, primarily as a means of studying the behavior of salmon in their natural environment. Biologists within and outside the Bureau have since adapted similar equipment and techniques to the study of other aquatic animals — as diverse as lobsters, turtles, and whales.

MIGRATIONS OF JUVENILE FISH

In their migration from the spawning area to the sea, young fish face a harsh and dangerous journey. As they move downstream, their survival depends upon the availability of food, their ability to avoid large hungry fish, and finally the influences created by obstacles man has placed in the rivers. Each new dam and reservoir adds to the journey's hazards.

Our research on juvenile fish examined the effects of alterations of the physical and biological environment and developed methods to assist the fish in their migration and increase their survival. Young fish — wild and hatchery-reared — were captured, marked with a cold brand or magnetized wire tags, and released at various locations on the Snake and Columbia Rivers (fig. 31). As the runs moved downstream, the fish were recaptured in floating traps and other collection devices in the rivers and at dams. Near the end of their migration they were sampled by beach (fig. 32) and purse seines in the estuary. Evaluations of migration and survival were based on the numbers of marked fish recovered at various points. Biologists studied the effects of temperature and of excess nitrogen on juvenile fish. Turbine studies assessed losses of fish and devised systems to reduce mortalities. In other research, migrating fish were deflected by moving screens or transported around potentially dangerous areas.

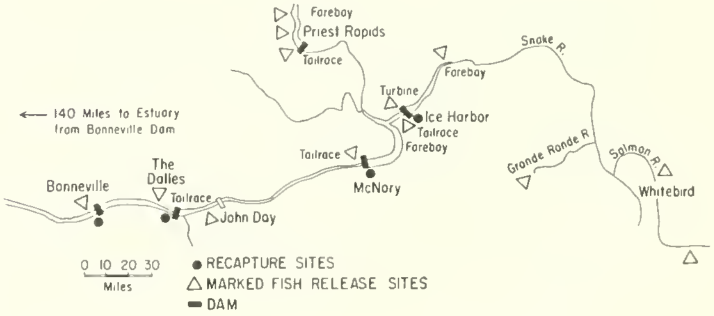

FIGURE 31.—Study areas in Columbia River system.

FIGURE 32.—Biologists collect young salmon with a beach seine.

Timing and Rates of Migration

Timing of migration of most juvenile salmon and steelhead trout through free-flowing and impounded stretches of the Snake and Columbia Rivers did not change appreciably in 1966-68. Since 1965, young chinook salmon have migrated from the upper Columbia River in July and August, but they moved from the Snake River in the more normal time of April-May. Sockeye and coho salmon and steelhead trout from both streams also migrated in April and May.

Our research revealed some variations in migration rates of young chinook salmon. Generally, the rate was directly related to water flows; the rate was 13 miles/day at low river discharge and 23 miles/day during moderate river discharge. Passage time through McNary and the newly formed John Day Reservoirs was three times longer than through other stretches of the Columbia and Snake Rivers. Our biologists predict that when all projected dams are installed on the Snake River, juvenile chinook salmon from the Salmon River will require 30 additional days to travel 415 miles to Bonneville Dam, the last obstruction on the Columbia River before the sea.

Survival of Migrants

The number of salmon and steelhead trout migrating downstream in the Snake and Columbia Rivers varied in recent years. The variations reflect differences in sizes of runs of parent generations, in hatchery production, and in survival in the rivers.

The outmigration of juvenile chinook salmon from the Snake River was 2½ million in 1968, the lowest since our estimates started in 1964. By contrast steelhead trout, because of increased plantings of hatchery-reared fish in the Salmon River in 1967-68, had an outmigration of nearly 4 million in 1968 — about 1 million more than 1967 and 2½ million more than in 3 preceding years.

From the upper Columbia River, migrations of sockeye salmon declined abruptly from 4 million in 1966 to 1 million in 1967; chinook salmon increased significantly. Populations of coho salmon and steelhead trout remained nearly constant. Most salmon and trout from the upper Columbia are now reared in hatcheries; changes in numbers of sockeye and coho salmon outmigrants reflect the shift from rearing of sockeye to coho salmon at Leavenworth Hatchery, Wash.

The number of fish that survive to enter the ocean is not known, but the total mortality is high. Survival of juvenile chinook salmon between Ice Harbor Dam and The Dalles Dam, a distance of about 150 miles, remained at about 50 percent in 1966-68. Highest mortalities (27 percent) were near Ice Harbor Dam. By assessment of fish mortalities along other stretches of the river and at dams, we hope to learn why, where, and how great the losses are.

Survival of hatchery-produced fall chinook salmon from time of release of young from the hatchery to their return as adults may be as low as four out of each thousand. A systematic sampling of downstream migrants was begun in 1968 in the Columbia River estuary. The research was begun to learn whether changes in hatchery production techniques such as diet improvement, control of certain environmental factors, size and time of release, and training to avoid predators could increase the production and survival of hatchery fish.

In the estuary studies, beach seines were set on each shore and a purse seine was set at midchannel in the narrows above Puget Island (fig. 33). Fish from eight Federal and State hatcheries were marked before release; some releases were made several hundred miles upriver. Data indicated a 50-percent loss of fish migrating past Bonneville Dam, a 95-percent (total) loss past four other dams, and a 50-percent loss past an area of suspected pollution. An interesting discovery was that survival of yearling chinook salmon reared in ponds at the Rapid River Hatchery (Snake River system) was nearly twice that of those reared in raceways. Higher survival was attributed to larger size, better condition, and faster migration of pond-reared fish.

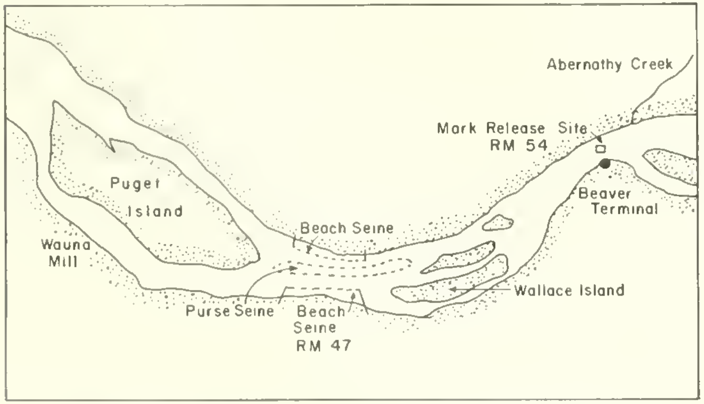

FIGURE 33.—Sampling site for capture of juvenile salmon and steelhead trout in the Columbia River estuary.

As a result of our 1968 work, the Fish Commission of Oregon has decided that all fall chinook salmon reared at two hatcheries above Bonneville Dam should be released below the dam. The Washington Department of Fisheries will transport all fish from Ringold Hatchery (near Pasco, Wash.) past three dams to Spring Creek Hatchery, some 175 miles downstream, and will intensify the study of suspected pollution. State and Federal agencies will have joint marking experiments in the spring and summer of 1969 to evaluate results of these measures.

Temperature Laboratory

In the fall of 1967, a covered barge (110 by 32 ft.) was moved to the lower Columbia River at Prescott, Oreg., to house research facilities for water temperature studies (fig. 34). The site was selected because thermal nuclear power plants are planned nearby on both sides of the river. By examining the physical, chemical, and biological features of the river before the plants are installed, biologists will have data to determine environmental changes that may occur after the plants are operating. In addition, native fish taken directly from the river can be held and tested in river water.

Juvenile salmon are known to have a temperature tolerance zone between 38° and 68° F., depending on age, condition, acclimation temperature, and other factors. Lethal zones at upper temperature levels are 56 to 77° F. Less thermal increase is required during summer than winter to reach lethal values.

In initial experiments, biologists investigated rapid death (within seconds) from thermal shock and slow death from exposure to heat beyond zones of tolerance. Juvenile chinook, chum, coho, and sockeye salmon died in 4 to 11 seconds at 90° F. Rapid death differed with species, size and condition

FIGURE 34.—The biological field station at Prescott, Oreg., houses biological and chemical laboratories plus two "wet" laboratories. Each wet lab has twenty-two 50-gallon tanks that can be individually supplied with heated or cooled water from the Columbia River.

of the fish, and temperature of the river water to which the fish were acclimated. Slow death of juvenile salmon from exposure to elevated temperatures over a long period has been described by other scientists, but our research is the first in which anadromous species of the Columbia River have been tested in their natural environment. In experiments at Prescott, about half the juvenile salmon held at 77° F. died within 1 week.

In other experiments, adult eulachon (*Thaleichthys pacificus*) from the Columbia River (fig. 35) were fairly intolerant to temperature increases and all died when the temperature was increased 11° F. Female eulachon failed to deposit eggs after the water temperature was increased a mere 5° F.

FIGURE 35.—Eulachon, or Columbia River smelt.

Turbine Studies

About half of the young salmon and trout (0-age and yearlings) now migrating down the Columbia River find relatively safe passage over the spillways of dams. The other half pass through the turbines, where 10 percent or more are injured or killed by the turbine blades. Most of the low-head dams on the Columbia River have Kaplan blades (fig. 36). Some of the survivors of turbine passage are disoriented or temporarily stunned, which sometimes makes them easy victims of predators.

Part of the survivors exiting with the turbine discharge are carried into comparatively slack water below nonoverflow sections of the dam. As many as one-third of these fish are eaten by herring gulls (*Larus argentatus*), northern squawfish (*Ptychocheilus oregonensis*), and other predators. The survivors enter the main flows and move downstream where velocities are too high for many of the predators. In a few years, however, the reservoirs now under construction will virtually eliminate spilling at Columbia River dams. All fish then will be forced to pass through the turbines.

To assess the losses, fish were released through hoses into intakes and passed through the turbines into specific parts of the tailrace below the dam (figs. 37 and 38). Other studies are underway to reduce these mortalities. Emphasis is being placed on a plan that takes advantage of several built-in structures of the dams. This method (developed jointly by the Bureau of Commercial Fisheries and the U.S. Army Corps of Engineers) calls for intercepting most of the fish headed for turbine intakes and diverting them into

FIGURE 36.—Blade of Kaplan turbine at Bonneville Dam. The blade has thick edges, but fish are injured where the clearance between the turbine blade and the turbine wall is minimal.

FIGURE 37.—Fish released into turbines at Ice Harbor Dam were collected below the dam. Comparisons were made of the survivals of fish that had passed through turbines and fish that had bypassed the turbines. The hose in the foreground carried the fish that were bypassed.

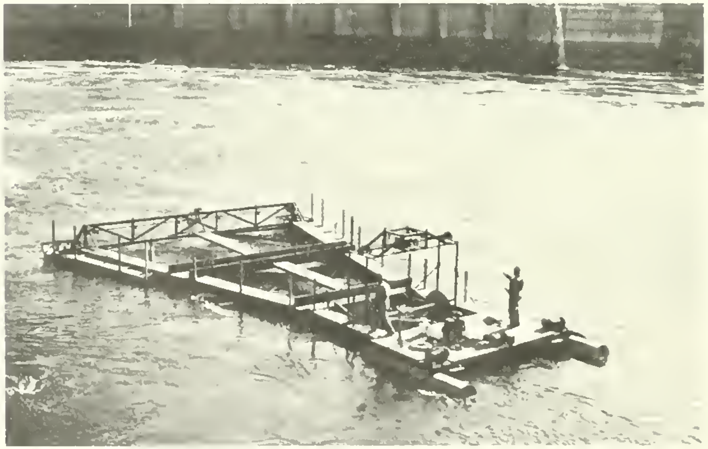

FIGURE 38.—Scoop (floating dipper) trap in operation to recover fish from predator-laden water below a dam.

open shafts called gatewells. The fish are then passed through openings in the wall into the ice sluice, which carries them to a safe location in the tailrace.

The Corps has equipped all 44 gatewells at McNary Dam with submerged portholes leading to the ice sluice and is providing funds for their evaluation. We expect to complete this phase of the research in 1969. Meanwhile, we are developing a traveling screen to divert the fish from intakes into gatewells. Placement of this guiding device within turbine intakes, rather than in the forebay, has two major advantages: (1) Trash racks across the mouth of the intakes, designed to protect turbines from large logs, also protect the guiding device and (2) the fish, as they are drawn deeper into the intake, tend to concentrate in the upper water mass along the ceiling, making it possible to divert greater percentages of the fish by screening smaller quantities of water. The prototype traveling screen will theoretically guide 70 to 80 percent of the fish into the gatewell-sluice bypass. Should traveling screens be placed in all turbine intakes of all 15 low-head dams planned for construction, the total cost would be about the same as the cost of fish facilities for adult salmon at only two of these dams.

Deflection of Migrating Fingerlings

Fishery biologists and hydraulic engineers have spent years trying to divert and collect migrating juvenile fish at hydroelectric and irrigation structures. To deflect fish, they have experimented with bands of rising bubbles, curtains of hanging chains, electrical stimuli, jet streams, light, louvers, and sound. Under certain conditions these systems worked but were never completely reliable. Vertically traveling screens caused losses or considerable damage to fish. A new development by our laboratory — the horizontally traveling screen — provides many practical solutions.

As the fish move downstream with the river current, they encounter the screen which is set diagonally to the current (fig. 39). The screen, made of interlocking panels, moves toward a bypass channel or collection point on the shore. Because the velocity of the screen matches that of the river flow, fish are diverted or impinged gently and led

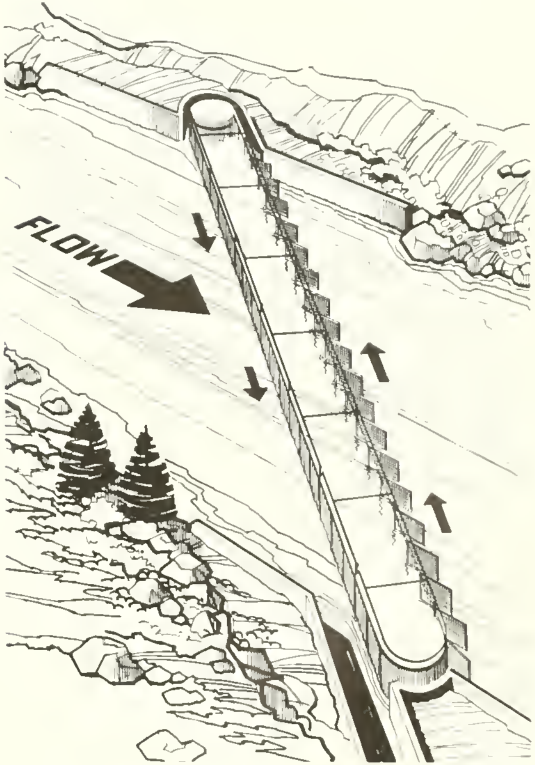

FIGURE 39.—An artist's concept of the traveling screen, Model VII, as it might appear within a river or canal.

around a potentially dangerous area. Nonswimming forms, such as eggs of striped bass and shad, can be collected on the screen and carried into the bypass.

The traveling screen has other advantages. Installation costs are reduced because of the simplicity of design; maintenance is minimized because all major operating parts are out of the water and panels can be easily lifted; and the screen does not appreciably alter river flow.

Since its conception, the traveling screen has been considerably improved. The latest prototype (Model VI), 85-ft. long, screening over 100 second feet of water at a 6-ft. depth, is being operated and tested on the Grande Ronde River near Troy, Oreg. A larger, improved model in the Leaburg Canal of the Eugene Water and Electric Board will have a screening capacity of 2,500 second feet.

Fish "Taxis"

If young salmon and trout could be collected in their seaward migration and carried around dams, many of the dangers to their survival could be bypassed. But the transportation of fish around areas through which they normally migrate might decrease their ability to return as adults to their home stream. Homing seems to depend partly upon a learned or hereditary capacity to recognize minute chemical qualities of the streams.

Transportation experiments were made to see whether survival could be increased and to learn if homing will be impaired (fig. 40). Wild spring chinook salmon were transported from Ice Harbor Dam on the Columbia River and released below John Day and Bonneville Dams. Their survival to the estuary was twice that of nontransported fish. Survival of hatchery-reared fish may be increased even more by transportation. In one experiment using fall chinook salmon reared in Ringold Hatchery, the survival of fish transported 160 miles around four dams was 20 times greater than that of fish migrating from the hatchery.

The transported fish were marked with magnetic wire tags so they can be identified when they return as adults. The magnetic tag eliminates the disadvantages of other marking systems and is the best tool for the job at present. The tags of stainless steel wire (4/100 inch long and 1/100 inch diameter) can be injected in the snouts of fingerlings at the rate of 1,000 per hour. As many as six colors allows a choice of thousands of combinations. After insertion, the tags are magnetized. When the adults return, the tagged fish will be separated from untagged fish by magnetic detectors and separating devices in fishways. We hope that enough adults will come back to give us an idea of how transportation affects homing ability.

FIGURE 40.—Truck used to transport fingerlings around dams. The 5,000-gallon tank truck has a refrigeration-aeration system and filter. Capacity is 400,000 fish, 2½-inches long.

Gas Bubble Disease

When excessive amounts of dissolved nitrogen are present, fish develop gas bubble disease (fig. 41). It causes bubbles under the skin, in the roof of the mouth, or in fin membranes; it also produces a "pop-eye" condition (hemorrhaging in the eye). Supersaturation of nitrogen occurs in turbulent water below spillways or where the water warms rapidly without adequate circulation. The condition is compounded by high water temperatures. Fish supersaturated with nitrogen have lower tolerance for higher temperature.

Potentially dangerous concentrations of dissolved nitrogen (over 110 percent) are reached in the Columbia River in spring and summer. Excessive numbers of juvenile salmon died in holding tanks at The Dalles Dam. The danger is not so great if the fish dive, but they are not always in an area with sufficient depth. One experiment showed that at nitrogen saturation of 130 to 140 percent, coho and chinook salmon must remain in more than 8 feet of water if they are to be free of the symptoms of gas bubble disease.

The disease could be reduced by control of spilling during downstream migration. When the river flow becomes almost completely controlled by dams, and spilling is nearly eliminated, the problem is expected to diminish.

FISH BEHAVIOR

In their field studies, biologists often suspect that specific environmental conditions may influence the behavior or survival of fish. These conditions may be duplicated or altered in the laboratory. The responses to heat, light, pressure, shear forces, cavitation, and changes in flow as well as the periodic activities of fish were observed at our behavior laboratory in Seattle.

Heat

Fish migrating downstream could abruptly enter heated water from nuclear power plants and be unable to escape before being overcome by the high temperature. To simulate the effect of their contact with heated water pouring out of such plants, yearling coho salmon were subjected to sudden increases in water temperature. Test fish acclimated to 50° F. died within 50 seconds of exposure to 90°, believed to be close to the temperature of heated discharges.

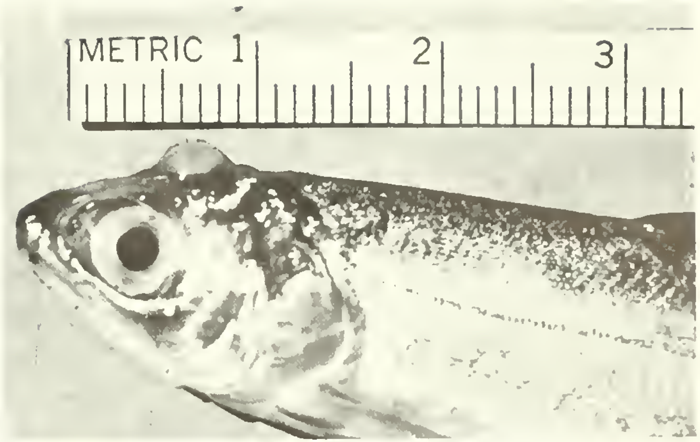

FIGURE 41.—Gas bubble in eye tissue of coho salmon.

Light

Lights placed near gatewells and near the ceiling of a simulated turbine intake caused more fish to enter the gatewells. The fish, like moths, seemed to be attracted.

Pressure

Responses to change in hydrostatic pressure were measured. Coho and sockeye salmon fingerlings swam actively upward when pressure increases were equivalent to depth increases of less than 2 feet (fig. 42). This behavior suggests that fish may be collected more readily by taking advantage of their tendency to compensate for change in pressure.

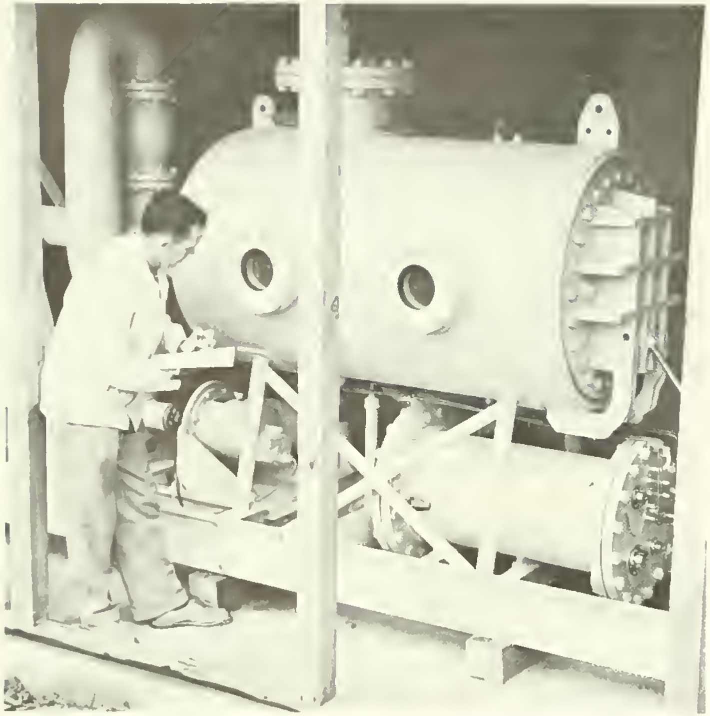

FIGURE 42.—Hydraulic chamber for studying response of fish to pressure changes.

Activity

An activity detector (fig. 43) measured the movements of juvenile fish during 24-hour periods. Coho and sockeye salmon were active from sunset till midnight, whereas chinook salmon were generally more active during daylight. Activity seemed to be regulated by biological clocks which told the fish when the sun rose and set even though they were in a darkened indoor tank.

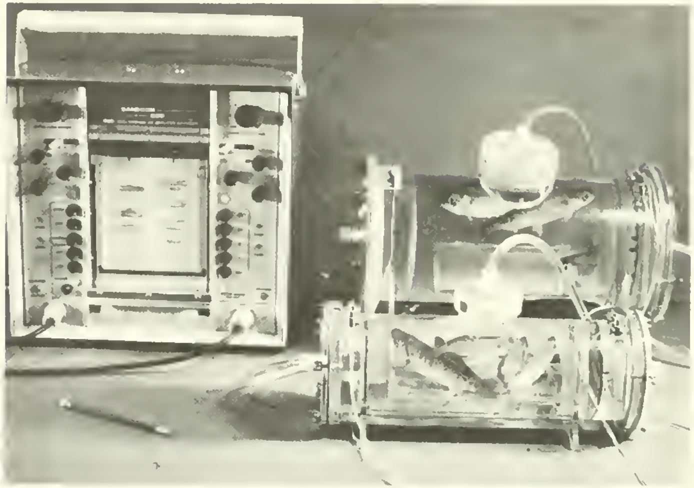

FIGURE 43.—Periodic activity of juvenile sockeye salmon being measured in laboratory apparatus.

Shear Forces and Cavitation

Hydraulic shear forces, at the margins of highly turbulent water, can be created by turbine blades at dams. In the laboratory, fish were killed by momentary contact (1/1,000 second) with differences in water velocity of 16 feet per second or higher. These sharp velocity differences may occur in small areas that measure less than 2 inches; fish have no defense against such forces. This action suggests that shear forces may be a major hazard to fish in turbines.

The sudden collapse of vapor pockets caused by cavitation in the highly turbulent water around moving turbine blades has been suggested as a major source of injury. Cavitation effects have been known to pit steel and erode concrete. In the laboratory, however, fish exposed to sudden collapse of simulated vapor pockets were unaffected by pressure changes of as much as 70 pounds per square inch occurring within thousandths of a second. These tests indicated that cavitation effects in turbines are probably harmless to fish.

Changes in Flow

Changes in the flow of water layers adjacent to the inner surfaces of a turbine intake may be a factor in guiding fish. In the laboratory, a series of expanded steel plates of different configurations were attached to the ceiling of a simulated turbine intake (fig. 44). The configurations modified the flow and velocity of the water in the vicinity of the plates. After the plates were installed in a model of a turbine intake, twice the average number of fish swam into escape ports. The modification has potential application at dams.

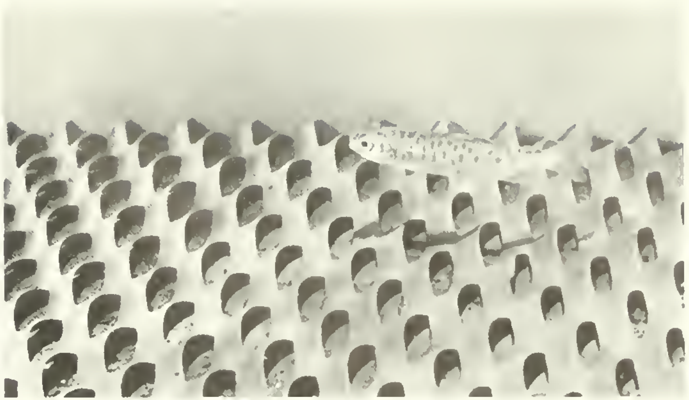

FIGURE 44.—Expanded metal plate attached to surface of horizontal conduit (in turbine intake model). The configurations of the plate change water flow and may enable fish to swim away from a turbine intake.

GROUNDFISH OF THE CONTINENTAL SHELF

Our biological studies of groundfish of the northeastern Pacific Ocean began in 1964. The studies had four purposes: (1) to determine the potential yield of stocks that are only partially fished; (2) to devise methods to forecast the abundance and availability of commercially important species; (3) to find the maximum catches that can be taken and yet maintain the stocks; and (4) to evaluate the effectiveness of conservation measures. Scientific information was needed to protect the fishing rights of the United States and for rational administration of national and international fisheries.

The immediate aim was to determine the maximum sustainable yield of Pacific hake off Washington and Oregon. At the same time, facts were gathered on the biological and ecological relations of hake to other species. Plans were made in 1966 for the investigation of ocean perch and sablefish (*Anoplopoma fimbria*) in cooperation with other agencies. The major effort in 1967-68 was on hake in coastal and inland waters (Puget Sound). Samples of hake were analyzed for age, length, maturity, sex ratio, and weight (fig. 45). This material provided a basis for the comprehensive study of the biology, population dynamics, and effects of fishing on hake stocks.

FIGURE 45.–Catch of hake aboard U.S. trawler. Samples for biological studies were taken from catches.

ABUNDANCE AND DISTRIBUTION OF PACIFIC HAKE

In summer, Pacific hake are found in comparatively shallow waters over the Continental Shelf from British Columbia southward to northern California. In winter, they move to spawning grounds off southern California.

In the spring of 1967, a survey was made to determine if hake spawn off the Pacific Northwest. The area surveyed for fish eggs and larvae covered Puget Sound and the coast from central British Columbia southward to the Oregon-California border. The research vessels *John N. Cobb* and *George B. Kelez* took samples up to 300 miles offshore. The *Miller Freeman* was sent on a 6-week cruise in February 1968 to the hake spawning grounds off southern California. The findings from the cruises support the hypothesis that no coastal hake spawn north of southern California waters.

Our understanding of the distribution and abundance of hake and other groundfish in relation to biological and physical factors in the environment is limited. Some measurements of primary productivity have been made by our oceanographers, and plankton samples have been taken on the coastal cruises. More sampling and analysis must be done before the gap in knowledge is closed.

At least one separate population of hake remains in Puget Sound throughout the year. This population was not fished commercially until November 1965, which gave our biologists an opportunity to gather data from the beginning of a fishery. Like the coastal hake, Puget Sound hake make spawning migrations but apparently over a limited distance. Our biologists found hake feeding and maturing in Saratoga Passage and other parts of Puget Sound during the summer and autumn. In winter and early spring the hake moved to Port Susan where spawning was at a peak in April.

MANAGEMENT OF GROUNDFISH STOCKS

Fisheries for coastal groundfish present a complex management problem; U.S. and foreign fishermen seek and catch the same stocks in international waters. The function of groundfish research is to supply information and analyses to guide decisions by management.

During the coastal hake fishing seasons of 1965-67, biologists sampled fishermen's catches as they were brought to the processing plant at Aberdeen, Wash. Additional fish were collected by a charter vessel in 1968. Biological data from several thousand fish collected from British Columbia to California through all seasons were processed by automatic data-processing equipment.

The data on ages of hake indicated that the population contained almost no fish born in 1962 and 1963. Because of the apparent absence of recruitment, a rather high rate of natural mortality, and heavy Russian fishing in 1966-67, biologists forecast a low abundance of hake off Washington and Oregon in 1968 unless a strong 1964 year class appeared. There was no U.S. coastal fishery for Pacific hake in 1968, but a proposed exchange of information with the Soviet Union will be useful in confirming this hypothesis.

Contacts between the Russian and United States governments led to meetings of scientists at our laboratory in July 1967 and in Moscow in October 1968. The discussions led to agreement on the current status of stocks of hake off Washington and Oregon and of ocean perch in the Gulf of Alaska. Plans were made for coordinated cruises and surveys, exchange of biological and catch data, and evaluation of models of populations.

Age Analysis and Genetics

As with salmon, improved techniques to distinguish ages and stocks are fundamental to studies of groundfish.

FIGURE 46.—Otolith (ear bone) from hake magnified about 4 times, age 8 years. Otoliths are better than scales for showing age of Pacific hake.

To standardize criteria for reading their ages from scales or otoliths (ear bones), a cooperative age-reading unit was established at the laboratory (fig. 46). Two Bureau biologists work part-time; the Washington State Department of Fisheries and the Pacific Marine Fisheries Commission each provide a full-time technician. The unit has completed age readings for more than 4,000 Pacific hake and Pacific ocean perch.

Biochemists have made considerable progress in the search for genetic markers that may be useful in racial studies. A protein in eye fluids, an iron-binding protein in blood, and LDH enzymes of the liver (fig. 47), tested in hake from Puget Sound and the Pacific Ocean, provided genetic evidence that the Puget Sound population is separate and isolated from ocean populations. Preliminary work has been done on genetic studies of three species of rockfish (*Sebastodes auriculatus, S. caurinus, S. elongatus*). The aim is to define biochemical differences among as many species as possible and to use these differences for species identification of larvae (positive identification is not successful with present methods).

Growth and Mortality

The most important discovery from groundfish research was made by comparison of ages and lengths of coastal and Puget Sound hake. Most of the fish in both areas were 4, 5, and 6 years old. The coastal hake were mostly larger (16-24 inches) than the Puget Sound hake (12-16 inches). Lengths of hake of like age in the two areas showed little overlap. Both length-frequencies and age-frequencies imply different growth and mortality in the two populations. The length-frequency and availability data provide strong evidence, supported by genetic evidence, that Puget Sound and coastal hake are racially distinct populations.

A study of age and growth of Pacific hake is in the final stages. Growth rates have been estimated from data on lengths and ages of the fish. A method of calculating growth from readings of otoliths is being developed.

FIGURE 47.–Technician preparing density gradients for ultracentrifugation to isolate enzymes.

FLOATING AQUACULTURE LABORATORY

Because aquaculture has a great potential for increasing food supplies in the future, the Biological Laboratory is developing plans for a major research program. Our floating laboratory, the *Brown Bear*, will be useful in these studies. The laboratory circulates fresh and salt water which can be modified by aeration, filtration, temperature control, and ultraviolet sterilization. The *Brown Bear* also has trays and tanks for culture of fish or shellfish (fig. 48) and excellent facilities for study of water chemistry (fig. 49).

One proposed phase of aquaculture would place a marine fish and shellfish laboratory in salt water adjacent to a thermal nuclear power plant and a primary sewage treatment plant. This situation would take advantage of nutrients and heated water that are byproducts of the plants. Basic food organisms would be nourished by the chemical nutrients, and cold waters could be warmed to improve the growth and production of fish and shellfish.

FIGURE 48.—Lummi Indian trainees examining trays of chinook salmon fry on board the *Brown Bear*. The trainees had spawned adult chinook salmon and raised the fertilized eggs to young fry.

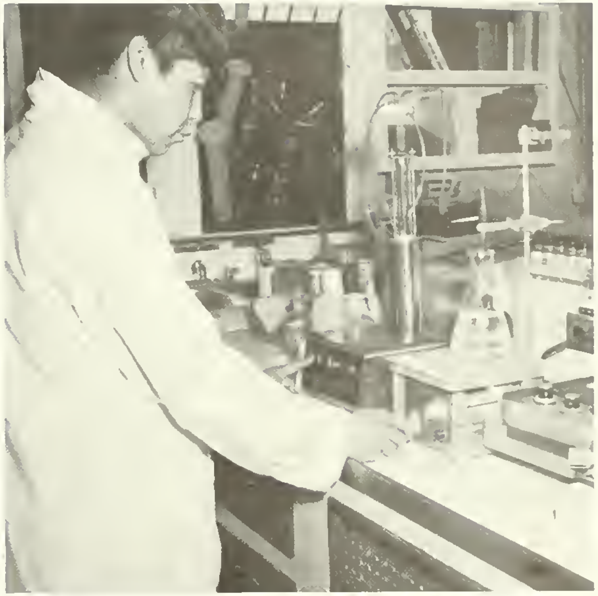

FIGURE 49.—A Lummi Indian trainee, working in the *Brown Bear's* water chemistry laboratory, measures dissolved oxygen in the controlled water supply.

DOWN TO THE FISHES' WORLD

Man's concept of the aquatic world in which fish live has been limited by his relative inability to penetrate that world. Working from a boat on the ocean to understand what occurs below the surface is similar to peering from an airplane to observe human behavior on land that is hidden by clouds. The Biological Laboratory now has the capability to observe sea life closely over an extended period.

A bathysphere capable of carrying two observers at atmospheric pressure to depths of 1,000 feet has been acquired (fig. 50). The mist-green "bell" is constructed of special steel plate more than ½-inch thick and has an inside diameter of 5½ feet. From their tight quarters, biologists will have excellent visibility through 16 plexiglass portholes. A hatch in the bottom of the chamber will permit divers to exit, after pressurization of the interior, to perform work outside. The Laboratory's self-propelled 104-foot derrick barge will raise and lower the bathysphere and provide telephone communication with a surface crew.

The bathysphere will be a tremendous asset to the Laboratory. From it, biologists will be able to observe the marine environment and the behavior of commercially important invertebrates. One of the first applications of the chamber will be a study of the natural behavior of weathervane scallops (*Patinopecten caurinus*) on commercial dredging grounds near Bellingham, Wash. The scallop seems to differ in its day and night behavior; it also seems to be able to evade fishing gear. Our observers hope from observations on behavior to explain the inconsistency of scallop catches. Future observations will be on rockfish and flatfish and may take the bathysphere onto the Continental Shelf.

FIGURE 50.—The Laboratory's new bathysphere is about 8 feet high and weighs nearly 8,500 pounds (including 2,500 pounds of ballast).

BIOMETRICS INSTITUTE

The scientific capabilities of the Bureau were enlarged in 1968 by the establishment of the Biometrics Institute in the Biological Laboratory. Organized from the existing staff of biometricians, the Institute assumed new national responsibilities in the Bureau's research program.

The Institute has three primary roles: (1) to conduct fundamental research on biostatistical theory and methods, experimental design, and mathematical models of fish populations for application to fishery investigations throughout the Bureau; (2) to analyze fishery and biological statistics for fish stocks in which the United States has vital interests and which present problems in international fisheries; and (3) to provide consultation and training to fishery scientists of this laboratory and to staffs of other Bureau laboratories.

The Institute avails itself of renowned specialists in population theory or mathematical statistics from the United States and foreign countries as consultants and lecturers. To speed data processing and the solution of complex problems, the Laboratory's IBM 1130 computer is connected directly to a larger computer in Washington, D.C.

PUBLICATIONS -- 1966-68

Scientific research at the Biological Laboratory in 1966-68 was reported in 123 publications, which are available upon request. Staff members are listed in bold type.

AMES, WARREN E.
1967. Studies on maturity of sockeye salmon. **In:** Investigations by the United States for the International North Pacific Fisheries Commission—1966. Int. N. Pac. Fish. Comm., Annu. Rep. 1966: 98-99.

AMES, WARREN E., R. M. CONDIE, and B. POLLARA.
1966. A method for intravascular injection and bleeding of fishes. Trans. Amer. Fish. Soc. 95: 317-318.

AMOS, MURRAY H.
1966. Commercial clams of the North American Pacific coast. U.S. Fish Wildl. Serv., Circ. 237, iii + 18 pp.

ATKINSON, C. E., J. H. ROSE, and **T. O. DUNCAN.**
1967. Salmon of the North Pacific Ocean – Part IV. Spawning populations of the North Pacific Ocean. 4. Pacific salmon in the United States. Int. N. Pac. Fish. Comm., Bull. 23: 43-223.

BABB, Albert L., WILLIAM P. MILLER, WILLIAM E. WILSON, Jr., GENE L. WOODRUFF, and **ANTHONY J. NOVOTNY.**
1967. Neutron activation analysis of stable dysprosium biologically deposited in the bone of chinook salmon fingerlings. Trans. Amer. Nucl. Soc. 10: 449.

BAKKALA, RICHARD.
1966. Salmon research cruises planned for summer 1966. Commer. Fish. Rev. 28(7): 40-41.

BENTLEY, WALLACE W., and **HOWARD L. RAYMOND.**
1968. Collection of juvenile salmonids from turbine intake gatewells of major dams in the Columbia River system. Trans. Amer. Fish. Soc. 97: 124-126.

BJORNN, T. C., **D. R. CRADDOCK,** and D. R. CORLEY.
1968. Migration and survival of Redfish Lake, Idaho, sockeye salmon, *Oncorhynchus nerka.* Trans. Amer. Fish. Soc. 97: 360-373.

BROCK, VERNON E., and **RALPH P. SILLIMAN.**
1966. Report of the working group on bigeye tuna. **In:** Thomas P. Manar (editor), Proceedings of the Governor's Conference on Central Pacific Fishery Resources, Honolulu, Hawaii, pp. 36-38.

CHILLER, J. M., **H. O. HODGINS,** and R. S. WEISER.
1968. Characteristics and application of the Jerne test in studies of the immune response of rainbow trout *(Salmo gairdneri).* (Abstract). Fed. Proc. 27: 1551.

COLLINS, GERALD B., and **CARL H. ELLING.**
1966. The accelerated Fish Passage Research Program of the U.S. Bureau of Commercial Fisheries – Summary of progress through 1964. U.S. Army, Corps of Eng., Third Progress Report on Fisheries Research Program (Portland, Oregon), pp. 107-124. (Processed.)

CRADDOCK, DONOVAN R., and **W. JAMES INGRAHAM, JR.**
1967. Winter salmon distribution and oceanographic conditions studied by *Kelez* scientists. Commer. Fish. Rev. 29(7): 21-23.

DARK, T. A., **K. N. THORSON,** and G. K. **TANONAKA.**
1967. Ocean growth and mortality. **In:** Investigations by the United States for the International North Pacific Fisheries Commission – 1966. Int. N. Pac. Fish. Comm., Annu. Rep. 1966: 96-98.

DAY, DONALD S., and WILLIAM G. PEARCY.
1968. Species associations of benthic fishes on the continental shelf and slope off Oregon. J. Fish. Res. Bd. Can. 25: 2665-2675.

DUNCAN, RICHARD N., and IVAN J. DONALDSON.
1968. Tattoo-marking of fingerling salmonids with fluorescent pigments. J. Fish. Res. Bd. Can. 25: 2233-2236.

DUNN, J. R.
1966. Results of salmon research cruises, summer 1966. Commer. Fish. Rev. 28(12): 15-16.

DUNN, J. R., and **D. F. SUTHERLAND.**
1968. "Freeman" studies salmon distribution and environment near Adak Island. Commer. Fish. Rev. 30(12): 46-49.

DURKIN, JOSEPH T., and **DONN L. PARK.**
1967. A purse seine for sampling juvenile salmonids. Progr. Fish-Cult. 29: 56-59.

EBEL, WESLEY J., and CHARLES H. KOSKI.

1968. Physical and chemical limnology of Brownlee Reservoir, 1962-64. U.S. Fish Wildl. Serv., Fish. Bull. 67: 295-335.

EBEL, WESLEY J., and ROGER E. PEARSON.

1968. Are Columbia upriver salmon stocks doomed? Fish Bus. 3(11): 8.

FAVORITE, FELIX.

1966. Bering Sea. **In:** Rhodes W. Fairbridge (editor), Encyclopedia of Oceanography, Encyclopedia of Earth Sciences Series, Vol. 1, pp. 135-140. Reinhold Publ. Corp., New York.

1966. Oceanography. **In:** Report on the investigations by the United States for the International North Pacific Fisheries Commission – 1964. Int. N. Pac. Fish Comm., Annu. Rep. 1964: 101-105.

1967. The Alaskan Stream. Int. N. Pac. Fish. Comm., Bull. 21: 1-20.

1967. Oceanography. **In:** Report on the investigations by the United States for the International North Pacific Fisheries Commission – 1965. Int. N. Pac. Fish. Comm., Annu. Rep. 1965: 94-98.

FAVORITE, F., and W. B. McALISTER.

1966. Fluctuations of subarctic circulation in relation to sockeye salmon fishery. (Abstract.) Proc. 11th Pac. Sci. Congr., Tokyo, 2 (Abstracts of papers related with oceanography: Changes in ocean, atmosphere and marine resources in the Pacific, with their predictions): 8.

1968. Fluctuations of subarctic circulation in relation to sockeye salmon fishery. (Abstract.) Jap. Soc. Fish. Oceanogr., Tokyo, Advances in Fisheries Oceanography, No. 2: 10.

FAVORITE, F., W. B. McALISTER, W. J. INGRAHAM, JR., and D. DAY.

1967. Oceanography. **In:** Investigations by the United States for the International North Pacific Fisheries Commission – 1966. Int. N. Pac. Fish. Comm., Annu. Rep. 1966: 89-96.

FREDIN, R. A.

1966. Population dynamics. **In:** Report on the investigations by the United States for the International North Pacific Fisheries Commission – 1964. Int. N. Pac. Fish. Comm., Annu. Rep. 1964: 124-126.

FREDIN, R. A., G. HIRSCHHORN, and S. MURAI.

1967. Population dynamics. **In:** Report on the investigations by the United States for the International North Pacific Fisheries Commission – 1965. Int. N. Pac. Fish. Comm., Annu. Rep. 1965: 123-128.

1967. Population dynamics. **In:** Investigations by the United States for the International North Pacific Fisheries Commission – 1966. Int. N. Pac. Fish. Comm., Annu. Rep. 1966: 111-116.

FRENCH, ROBERT R.

1966. Salmon distribution and abundance studies. **In:** Report on the investigations by the United States for the International North Pacific Fisheries Commission – 1964. Int. N. Pac. Fish. Comm., Annu. Rep. 1964: 91-101.

1968. U.S., Japan to hunt salmon routes. Nat. Fisherm., May: 9-C.

FRENCH, ROBERT R., and RICHARD BAKKALA.

1968. U.S. and Japan conduct successful salmon research cruise. Commer. Fish. Rev. 30(12): 57-61.

FRENCH, R., D. CRADDOCK, R. BAKKALA, J. DUNN, and K. THORSON.

1967. Ocean distribution, abundance, and migrations of salmon. **In:** Investigations by the United States for the International North Pacific Fisheries Commission – 1966. Int. N. Pac. Fish. Comm., Annu. Rep. 1966: 78-89.

FRENCH, R. R., D. R. CRADDOCK, and J. R. DUNN.

1967. Distribution and abundance of salmon. **In:** Report on the investigations by the United States for the International North Pacific Fisheries Commission – 1965. Int. N. Pac. Fish. Comm., Annu. Rep. 1965: 82-94.

FRENCH, ROBERT R., and ROY J. WAHLE.

1966. Study of loss and delay of salmon passing Rock Island Dam, Columbia River, 1954-56. U.S. Fish Wildl. Serv., Fish. Bull. 65: 339-368.

FULTON, LEONARD A.

1968. Spawning areas and abundance of chinook salmon (*Oncorhynchus tshawytscha*) in the Columbia River Basin – past and present. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 571, 26 pp., 6 color maps.

GAULEY, JOSEPH R.

1967. Effect of water velocity on passage of salmonids in a transportation channel. U.S. Fish Wildl. Serv., Fish. Bull. 66: 59-63.

GAULEY, JOSEPH R., CHARLES R. WEAVER, and CLARK S. THOMPSON.

1966. Research on fishway problems May 1960 to April 1965. U.S. Army, Corps of Eng., Third Progress Report on Fisheries Research Program (Portland, Oregon), pp. 29-66. (Processed.)

GILL, CHARLES D., and **DONALD M. FISK.**

1966. Vertebral abnormalities in sockeye, pink, and chum salmon. Trans. Amer. Fish. Soc. 95: 177-182.

GODFREY, H., D. D. WORLUND, and **H. T. BILTON.**

1968. Tests on the accuracy of ageing chinook salmon (*Oncorhynchus tshawytscha*) from their scales. J. Fish. Res. Bd. Can. 25: 1971-1982.

GRONLUND, WILLIAM D., HAROLD O. HODGINS, RAYMOND C. SIMON, and **DOUGLAS D. WEBER.**

1968. Blood lactate concentrations and mortality in sockeye and chinook salmon (*Oncorhynchus nerka* and *O. tshawytscha*) after exercise. J. Fish. Res. Bd. Can. 25: 473-484.

GROVES, ALAN B., GERALD B. COLLINS, and **PARKER S. TREFETHEN.**

1968. Roles of olfaction and vision in choice of spawning site by homing adult chinook salmon (*Oncorhynchus tshawytscha*). J. Fish. Res. Bd. Can. 25: 867-876.

HIRSCHHORN, GEORGE.

1966. Effect of growth pattern and exploitation features on yields of pink salmon in the northwestern North Pacific. Trans. Amer. Fish. Soc. 95: 39-51.

HODGINS, HAROLD O., RUSSELL S. WEISER, and **GEORGE J. RIDGWAY.**

1967. The nature of antibodies and the immune response in rainbow trout (*Salmo gairdneri*). J. Immunol. 99: 534-544.

INGRAHAM, W. JAMES, JR.

1967. Distribution of physical-chemical properties and tabulations of station data, Washington and British Columbia Coasts, October-November 1963. U.S. Fish Wildl. Serv., Data Rep. 21, 117pp. on 2 microfiche.

1968. The geostrophic circulation and distribution of water properties off the coasts of Vancouver Island and Washington, spring and fall, 1963. U.S. Fish. Wildl. Serv., Fish. Bull. 66: 223-250.

INGRAHAM, W. JAMES, JR., and **F. FAVORITE.**

1968. The Alaskan Stream south of Adak Island. Deep-Sea Res. 15: 493-496.

JASKE, ROBERT T., and **GEORGE R. SNYDER.**

1967. Density flow regime of Franklin D. Roosevelt Lake. Amer. Soc. Civ. Eng., J. San. Eng. Div. 93(SA3), Proc. Pap. 5272: 15-28.

JOHNSON, JAMES H.

1966. Fallback of adult chinook salmon at Ice Harbor Dam spillway, May 1964. U.S. Army, Corps of Eng., Third Progress Report on Fisheries Research Program, (Portland, Oregon), pp. 67-90. (Processed.)

JOYNER, TIMOTHY.

1966. Trace elements in sea water — some approaches to analysis for oceanographic research. (Abstract.) Proc. 11th Pac. Sci. Congr., Tokyo, 2 (Abstracts of papers related with oceanography: Chemical elements and isotopes in the Pacific waters including organic substances): 6.

JOYNER, TIMOTHY, and **ROBERT C. CLARK.**

1968. Two legs of "*Oceanographer's*" global cruise. Commer. Fish. Rev. 30(2): 32-37.

JOYNER, TIMOTHY, and **JOHN S. FINLEY.**

1966. The determination of manganese and iron in sea water by atomic absorption spectrometry. Atomic Absorp. Newslett. 5(1): 4-7.

JOYNER, TIMOTHY, M. L. HEALY, D. CHAKRAVARTI, and T. KOYANAGI.

1966. Preconcentration for trace analysis of sea waters. In: Preprints of contributed papers, Symposium on Trace Characterization — chemical and physical, Gaithersburg, Md., Oct. 3-7, 1966, pp. 544-554. Dep. Commer., Nat. Bur. Stand., Inst. Mater. Res., Washington, D.C.

1967. Preconcentration for trace analysis of sea waters. Environ. Sci. Technol. 1: 417-424.

LANDER, R. H., **G. K. TANONAKA, K. N. THORSON,** and **T. A. DARK.**

1966. Ocean mortality and growth. **In:** Report on the investigations by the United States for the International North Pacific Fisheries Commission — 1964. Int. N. Pac. Fish. Comm., Annu. Rep. 1964: 105-111.

LANDER, R. H., K. N. THORSON, R. C. SIMON, T. A. DARK, and **G. K. TANONAKA.**

1967. Ocean mortality and growth. **In:** Report on the investigations by the United States for the International North Pacific Fisheries Commission — 1965. Int. N. Pac. Fish. Comm., Annu. Rep. 1965: 99-106.

LANDRUM, BETTY J.

1966. Bilateral asymmetry in paired meristic characters of Pacific salmon. Pac. Sci. 20: 193-202.

LANDRUM, BETTY J., and THOMAS A. DARK.

1968. The distribution of mature western Alaskan and Kamchatkan sockeye salmon (*Oncorhynchus nerka*) in the North Pacific Ocean and Bering Sea. Int. N. Pac. Fish. Comm., Bull. 24: 1-110.

LONG, CLIFFORD W.

1968. Diel movement and vertical distribution of juvenile anadromous fish in turbine intakes. U.S. Fish Wildl. Serv., Fish. Bull. 66: 599-609.

LONG, CLIFFORD W., and WILLMAN M. MARQUETTE.

1967. Research on fingerling mortality in Kaplan turbines. Proc. 6th Bienn. Hydraulics Conf., Moscow, Idaho, Oct. 18-19, 1967, pp. 11-36. Wash. St. Univ., Pullman. (Processed.)

McALISTER, WILLIAM BRUCE.

1966. Circulation and mass transport in the eastern North Pacific Ocean. (Abstract.) **In:** A. P. Vinogradov (editor), Second International Oceanographic Congress, 30 May - 9 June 1966, Abstracts of papers, Abstract No. 283-SIb, pp. 247-248. Publ. House "Nauka", Moscow.

1968. Buoy telemetry for environmental prediction in fisheries research. Proc. Int. Telemetering Conf., Los Angeles, Calif., Oct. 8-11, 1968, Vol. 4: 650-657.

MAJOR, RICHARD L., and JAMES L. MIGHELL.

1967. Influence of Rocky Reach Dam and the temperature of the Okanogan River on the upstream migration of sockeye salmon. U.S. Fish Wildl. Serv., Fish. Bull. 66: 131-147.

1968. Egg-to-migrant survival of spring chinook salmon (*Oncorhynchus tshawytscha*) in the Yakima River, Washington. U.S. Fish Wildl. Serv., Fish. Bull. 67: 347-359.

MARGOLIS, L., F. C. CLEAVER, Y. FUKUDA, and H. GODFREY.

1966. Salmon of the North Pacific Ocean. Part VI. Sockeye salmon in offshore waters. Int. N. Pac. Fish. Comm., Bull. 20, 70 pp.

MARRIAGE, L. DEAN, and RICHARD N. DUNCAN.

1968. Fish survive pumping plant. U.S. Dep. Agr., Soil Conserv. 33: 173-174.

MASON, JAMES E.

1966. The migrant dipper: a trap for downstream-migrating fish. Progr. Fish-Cult. 28: 96-102.

1966. Sockeye salmon scale studies. **In:** Report on the investigations by the United States for the International North Pacific Fisheries Commission — 1964. Int. N. Pac. Fish. Comm., Annu. Rep. 1964: 117-118.

1967. Sockeye salmon scale studies. **In:** Report on the investigations by the United States for the International North Pacific Fisheries Commission — 1965. Int. N. Pac. Fish. Comm., Annu. Rep. 1965: 108-116.

1967. Scale studies of sockeye salmon. **In:** Investigations by the United States for the International North Pacific Fisheries Commission — 1966. Int. N. Pac. Fish. Comm., Annu. Rep. 1966: 99-108.

MAXFIELD, GALEN H.

1967. Pacific salmon literature compilation — 1900-59: Instructions and index. U.S. Dep. Commer., Clearinghouse Fed. Sci. Tech. Inform. PB 174 101, 20 pp. (Processed.)

1967. Pacific salmon literature compilation — 1900-59. U.S. Dep. Commer., Clearinghouse Fed. Sci. Tech. Inform. PB 174 102, 645 microfiches (42,341 pp.)

MONAN, GERALD E.

1966. Aids to fish tattooing. Progr. Fish-Cult. 28: 57-59.

MONAN, GERALD E., JOHN R. PUGH, and JIM R. SMITH.

1967. Efficiency of a combined electrode and louver array in guiding juvenile steelhead trout (*Salmo gairdneri*). Trans. Amer. Fish. Soc. 96: 422-423.

MOSHER, KENNETH H.

1968. A photographic atlas of sockeye salmon scales. U.S. Fish Wildl. Serv., Fish. Bull. 67: 243-280.

NEAVE, FERRIS, TERUO ISHIDA, and SUETO MURAI.

1967. Salmon of the North Pacific Ocean — Part VII — Pink salmon in offshore waters. Int. N. Pac. Fish. Comm., Bull. 22: 1-39.

NICKERSON, RICHARD B., FRANK J. OSSIANDER, and GUY C. POWELL.

1966. Change in size-class structure of populations of Kodiak Island commercial male king crabs due to fishing. J. Fish. Res. Bd. Can. 23: 729-736.

NOVOTNY, ANTHONY J., and DIPTIMAN CHAKRAVARTI.

1966. A versatile force-feeding system for experimental use with small fish. Progr. Fish-Cult. 28: 108-112.

PARKS, N. B.

1968. "*Miller Freeman*" proves fine research ship. Commer. Fish. Rev. 30(12): 44-46.

PATTEN, BENJAMIN G.

1967. An abnormally colored C-O sole, *Pleuronichthys coenosus*. Underwater Natur. Aquatic Rep. 1(1): 40.

1968. Abnormal freshwater fishes in Washington streams. Copeia 1968(2): 399-401.

PATTEN, BENJAMIN G., and **CHARLES C. GILLASPIE.**

1966. The Bureau of Commercial Fisheries Type IV electrofishing shocker — its characteristics and operation. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 529, 15 pp.

PEARSON, ROGER E.

1966. Number of circuli and time of annulus formation on scales of pink salmon (*Oncorhynchus gorbuscha*). J. Fish. Res. Bd. Can. 23: 747-756.

1966. Pink salmon scale studies. **In:** Report on the investigations by the United States for the International North Pacific Fisheries Commission — 1964. Int. N. Pac. Fish. Comm., Annu. Rep. 1964: 118-124.

1967. Pink salmon scale studies. **In:** Report on the investigations by the United States for the International North Pacific Fisheries Commission — 1965. Int. N. Pac. Fish. Comm., Annu. Rep. 1965: 116-123.

1967. Scale studies of pink salmon. **In:** Investigations by the United States for the International North Pacific Fisheries Commission — 1966. Int. N. Pac. Fish. Comm., Annu. Rep. 1966: 108-111.

PETERSON, ALVIN E.

1966. Gill net mesh selection curves for Pacific salmon on the high seas. U.S. Fish Wildl. Serv., Fish Bull. 65: 381-390.

RALEIGH, ROBERT F.

1967. Genetic control in the lakeward migration of sockeye salmon (*Oncorhynchus nerka*) fry. J. Fish. Res. Bd. Can. 24: 2613-2622.

RALEIGH, ROBERT F., and **WESLEY J. EBEL.**

1968. Effect of Brownlee Reservoir on migrations of anadromous salmonids. Amer. Fish. Soc., Proc. Reservoir Fish. Resour. Symp., Athens, Ga., Apr. 5-7, 1967: 415-443.

RAYMOND, HOWARD L.

1968. Migration rates of yearling chinook salmon in relation to flows and impoundments in the Columbia and Snake Rivers. Trans. Amer. Fish. Soc. 97: 356-359.

RIDGWAY, GEORGE J., HAROLD O. HODGINS, and **GEORGE W. KLONTZ.**

1966. The immune response in teleosts. **In:** R. T. Smith et al. (editors), Phylogeny of immunity, pp. 199-207. Univ. of Florida Press, Miami.

RODMAN, DUANE T.

1966. Sound production of the African cichlid *Tilapia mossambica*. Ichthyologica 38: 279-280.

SCAROLA, JOHN F.

1968. Cladocera and copepoda in McNary Reservoir, 1965-66. Northwest Sci. 42(3): 112-114.

SCAROLA, JOHN F., and **JEFFREY H. GIBERSON.**

1967. A device for sorting bottom organisms. Progr. Fish-Cult. 29: 242.

SCAROLA, JOHN F., and **ANTHONY J. NOVOTNY.**

1968. Folsom plankton splitter modified for enumeration of Entomostraca. Limnol. Oceanogr. 13: 195-196.

SHIPPEN, HERBERT.

1966. Bering Sea king crab investigations. **In:** Report on the investigations by the United States for the International North Pacific Fisheries Commission — 1964. Int. N. Pac. Fish. Comm., Annu. Rep. 1964: 126-127.

1966. Pacific hake fishery: a progress report. Pac. Mar Fish. Comm., 18th Annu. Rep. 1965: 36-37.

SHIPPEN, HERBERT H., and **MILES S. ALTON.**

1967. Predation upon Pacific hake, *Merluccius productus*, by Pacific dogfish, *Squalus acanthias*. Calif. Fish Game 53: 218-219.

SILLIMAN, RALPH P.

1966. Estimates of yield for Pacific skipjack and bigeye tunas. **In:** Thomas A. Manar (editor), Proceedings Governor's Conference on Central Pacific Fishery Resources, State of Hawaii, Honolulu, pp. 243-249.

1966. Plan for an assessment of abundance and yield of Pacific tunas. **In:** Thomas A. Manar (editor), Proceedings Governor's Con-

ference on Central Pacific Fishery Resources, State of Hawaii, Honolulu, pp. 231-242.

1967. Analog computer models of fish populations. U.S. Fish Wildl. Serv., Fish. Bull. 66: 31-46.

1968. Interaction of food level and exploitation in experimental fish populations. U.S. Fish Wildl. Serv., Fish. Bull. 66: 425-439.

SIMPSON, ROBERT R., and HERBERT H. SHIPPEN.
1968. Movement and recovery of tagged king crabs in the eastern Bering Sea, 1955-63. Int. N. Pac. Fish. Comm., Bull. 24: 111-123.

SMITH, JIM ROSS, JOHN R. PUGH, and GERALD E. MONAN.
1968. Horizontal and vertical distribution of juvenile salmonids in upper Mayfield Reservoir, Washington. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 566, 11 pp.

THOMPSON, CLARK S., WILLIAM SPENCER DAVIS, and EMIL SLATICK.
1967. Response of migrating adult salmonids to vertical and horizontal rectangular orifices at two depths. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 547, 8 pp.

THOMPSON, RICHARD B., and DENNIS F. TUFTS.
1967. Predation by Dolly Varden and northern squawfish on hatchery-reared sockeye salmon in Lake Wenatchee, Washington. Trans. Amer. Fish. Soc. 96: 424-427.

THORSON, KENNETH N.
1967. A new high-speed tagging device. Calif. Fish Game 53: 289-292.

THORSON, KENNETH N., and RAE R. MITSUOKA.
1967. The *Miller Freeman*. U.S. Fish Wildl. Serv., Circ. 261, 7 pp.

TREFETHEN, PARKER S.
1968. Fish-passage research: Review of progress, 1961-66. U.S. Fish Wildl. Serv., Circ. 254, 24 pp.

TREFETHEN, PARKER S., and DOYLE F. SUTHERLAND.
1968. Passage of adult chinook salmon through Brownlee Reservoir, 1960-62. U.S. Fish Wildl. Serv., Fish. Bull. 67: 35-45.

UTTER, FRED.
1967. Serology. In: Report on the investigations by the United States for the International North Pacific Fisheries Commission — 1965. Int. N. Pac. Fish. Comm., Annu. Rep. 1965: 106-108.

UTTER, FRED M., and WARREN E. AMES.
1966. Salmon serology. In: Report on the investigations by the United States for the International North Pacific Fisheries Commission — 1964. Int. N. Pac. Fish. Comm., Annu. Rep. 1964: 111-114.

UTTER, FRED M., and GEORGE J. RIDGWAY.
1967. A serologically detected serum factor associated with maturity in English sole, *Parophyrys vetulus*, and Pacific halibut, *Hippoglossus stenolepis*. U.S. Fish Wildl. Serv., Fish. Bull. 66: 47-58.

1968. Cross-reactive properties of certain antisera prepared in rabbits by stimulations with teleost vitellins. U.S. Fish Wildl. Serv., Fish. Bull. 66: 203-207.

UTTER, FRED M., GEORGE J. RIDGWAY, and JAMES W. WARREN.
1966. Serological evidence for inbreeding of Lahontan cutthroat trout, *Salmo clarkii henshawi*, in Summit Lake, Nevada. Calif. Fish Game 52: 180-184.

VANDERWALKER, JOHN G.
1967. Response of salmonids to low frequency sound. In: Marine bioacoustics. Proc. Second Symposium on Marine Bio-acoustics, New York, Apr. 13-15, 1966, vol. 2: 45-58.

VAN DYKE, CRAIG.
1966. Oceanographic observations south of Adak Island, summer 1963. U.S. Fish Wildl. Serv., Data Rep. 12, 60 pp. on 1 microfiche.

VOLZ, CHARLES D.
1967. A/D multiplier/divider UJT as relaxation oscillator. Electron. Des. 15(19): 124, 126, 128.

VOLZ, CHARLES D., and CHESTER O. WHEELER.
1966. A portable fish-tattooing device. Progr. Fish-Cult. 28: 54-56.

WALDRON, KENNETH D.
1968. Early larvae of the canary rockfish, *Sebastodes pinniger*. J. Fish. Res. Bd. Can. 25: 801-803.

WEBER, DOUGLAS D.
1967. Growth of the immature king crab *Paralithodes camtschatica* (Tilesius). Int. N. Pac. Fish. Comm., Bull. 21: 21-53.

WEBER, DOUGLAS, and GEORGE J. RIDGWAY.
1967. Marking Pacific salmon with tetracycline antibiotics. J. Fish. Res. Bd. Can. 24: 849-865.

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