BRANCH OF FISHERY BIOLOGY

ANNUAL REPORT FOR FISCAL YEAR 1957

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National Oceanic and Atmospheric Administration

Report of the United States Commissioner of Fisheries

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UNITED STATES DEPARTMENT OF THE INTERIOR, Fred A. Seaton, Secretary
FISH AND WILDLIFE SERVICE, Arnie J. Suomela, Commissioner

ANNUAL REPORT for FISCAL YEAR 1957
(JULY 1, 1956 through JUNE 30, 1957)

BRANCH of FISHERY BIOLOGY

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UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
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LAST ISSUE

FUTURE ANNUAL REPORTS WILL BE DISCONTINUED

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SECTION OF ANADROMOUS AND SHELLFISHERIES

Ralph P. Silliman
Washington, D. C.

The anadromous fishes are those which spawn in fresh water and spend part of their lives in the sea. Of these, the Pacific and Atlantic salmons, the Atlantic shad and striped bass are currently being investigated. Emphasis in the investigations depends on the use to which the data are to be put. In the Columbia River fish protection at dams and diversions is the primary outlet for application of research results; on the Atlantic Coast it is rehabilitation of the greatly depleted salmon and shad runs and better utilization of the striped bass; in the North Pacific it is the international conservation of a high seas resource.

Because part of their life is spent in streams the anadromous fishes are ones that we can "do something about". Stream conditions can be improved, pollution abated, fishways built and adequate spawning escapements permitted. All of the present research is designed to provide the knowledge needed to do these things successfully. Results will ultimately be measured in terms of the maintenance and rehabilitation of the runs.

The major lines of investigation under the section devoted to shellfish include studies of physiology, propagation, growth and fattening, ecology, experimental farming, protection against enemies and parasites, and biology and conservation of edible mollusks.

Investigations of specific problems are undertaken to obtain fundamental biological information which may serve as a basis for improving farming techniques or can be utilized by the federal and state regulatory agencies in formulating laws and regulations pertaining to the conservation and management of shellfish resources, the harvesting of crops and sale.

The keynote of the shellfish investigations is the adaptation of scientific knowledge accumulated through precise laboratory research to field studies which intend to provide practical solutions of various problems of cultivation, utilization of bottoms, protection against enemies. Because of a marked difference in ecological conditions within the ranges of distribution of the oysters and clams some of the phases of the investigation are carried out simultaneously at more than one research laboratory.

ATLANTIC SALMON INVESTIGATIONS

John B. Glude
Annapolis, Maryland

The cooperative research program of the Fish and Wildlife Service, carried out by the Atlantic Salmon Investigations and the State of Maine, centers on the Sheepscot River. During the past two years they have oriented their research toward a study of the nature and the degree of mortality of stocked salmon.

Counting weir.--An up-and-down stream counting weir has been operated in the Sheepscot River since May 18, 1956 to obtain estimates of the river and ocean survival of salmon. The smolt migration which was counted by the weir consisted of naturally spawned 2-year-old fish and both 1- and 2-year-old planted salmon, stocked in the fall of 1956 and 1955, respectively. The following table shows the pattern of migration:

Salmon smolts taken in the weir traps during the spring migration, 1957

Period	Wild 2-year-olds	Planted 2-year-olds	Planted 1-year-old
April 19-21	44	0	0
22-24	24	0	0
25-27	62	1	0
28-30	121	4	0
May 1-3	147	1	0
4-6	51	0	0
7-9	20	4	0
10-12	8	2	6
13-15	7	2	8
16-18	130	39	73
19-21	148	54	21
22-24	8	1	9
TOTAL	770	108	117

In addition to the numbers shown in the foregoing table, an estimated 150 smolts escaped uncounted when a freshet on May 21 loosened a board in the downstream trap.

Data collected in 1956 and in the first half of 1957 revealed the number of hatchery fingerlings planted in 1955 and

the number of fingerlings resulting from natural spawning in 1954 which survived to smolt migration. Of the 20,000 fingerlings planted in the fall of 1955, about 173 went to sea in 1956 as 1-year-olds and about 146 in 1957 as 2-year-olds. Practically all of the wild salmon, over 800, went to sea as 2-year-olds in 1957. Thus, the survival from the 1955 planting of 20,000 hatchery fingerlings was about 319 smolts or 1.6 percent.

Measurements of a representative sample of migrant smolts showed an average total length of 196 mm. for 2-year-olds of hatchery origin, 204 mm. for wild 2-year-olds and 159 mm. for 1-year-olds of hatchery origin. The wild fish were larger and more robust and vigorous than the planted ones.

Ecological investigations.--Information on the movements of salmon in the estuary is being collected by means of two fyke nets; one net was set about three miles below the weir at the upper limit of penetration by saline water, and the other about two miles below the first. Salmon smolts were taken in both traps within 48 hours after their release at the weir, in a ratio of about 8 for each 200 released. The presence of a substantial proportion of 1-year-olds in these estuarine traps indicates that this age group does move into salt water and not merely into the lower reaches of the river itself.

Observations on the food preferences of smolts in salt water were made on two fish transferred to the aquarium at Boothbay Harbor, Maine. Attempts were made to feed them a number of estuarine species which are abundant in the area and appeared to be potential food organisms. The most abundant organism, an amphipod, Gammarus tigrinus, was rejected. Sand shrimp, Crago, were seldom accepted. Killifish, Fundulus, were taken readily if smaller than about 1-1/2 inches while brit sea herring up to 2-1/2 inches long were pursued and eaten voraciously.

MIDDLE ATLANTIC FISHERY INVESTIGATIONS

Gerald B. Talbot
Beaufort, North Carolina

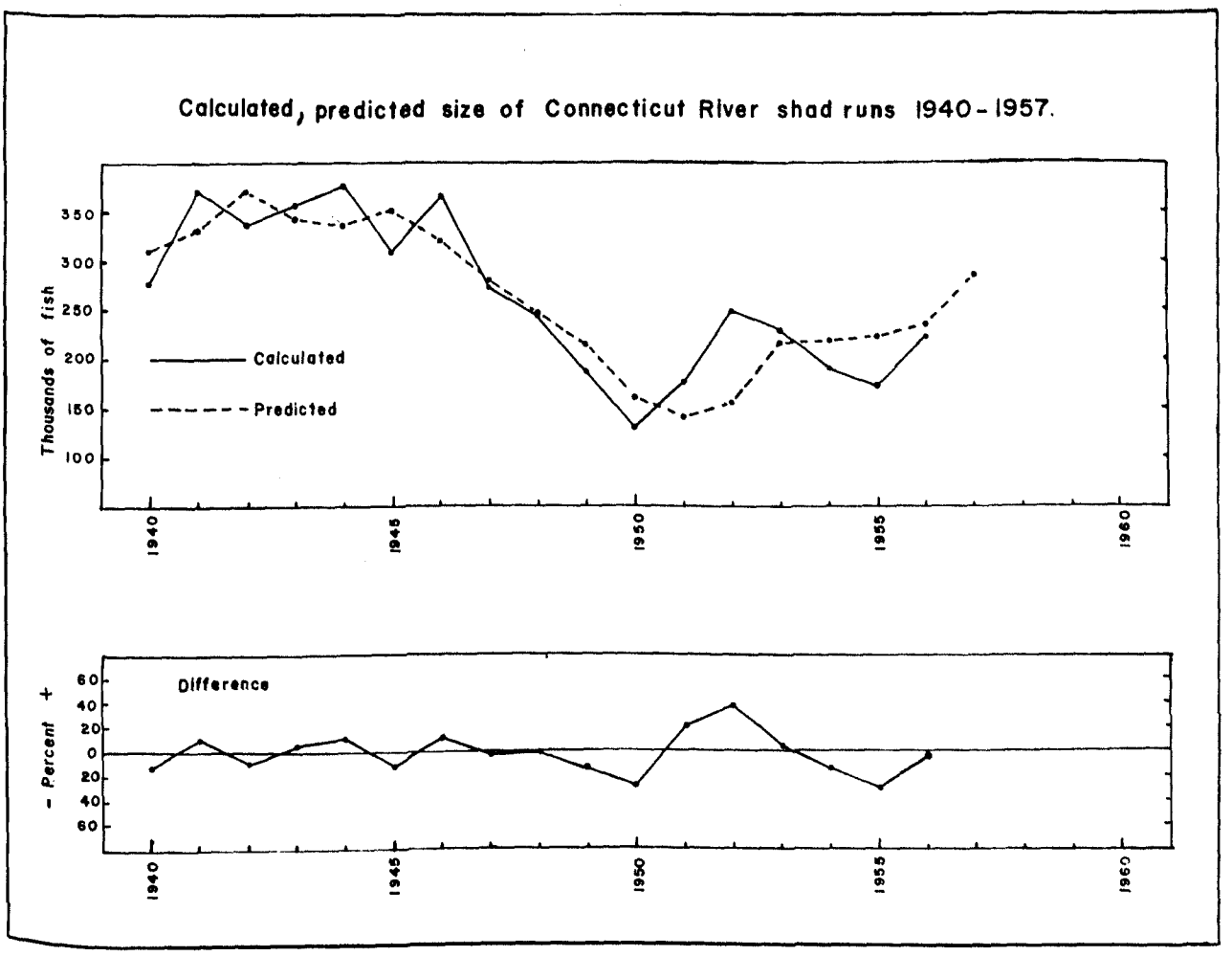
The Service, acting as the primary research agency of the Atlantic States Marine Fisheries Cmmission, has undertaken a coastwise investigation of declining shad stocks to determine the underlying causes of the decline, to determine conditions favoring recovery of the runs and to provide information for proper management to obtain a maximum sustained yield. Research is carried out in designated fishing areas each year since funds and personnel are not sufficient to permit simultaneous studies of all fisheries. During the period covered by this report the shad investigations centered on the Connecticut River, the Hudson River, the Delaware River and the St. Johns River.

Studies are being made also to better utilize the striped bass. The Middle Atlantic Fishery Investigations is conducting a large-scale tagging and recovery program at various points in Albemarle Sound, North Carolina, and collecting data on the types of fishing gear employed there. With the States of Virginia and Maryland, the Middle Atlantic Fishery Investigations is tagging striped bass in Chesapeake Bay to determine the percentage of striped bass spawned and reared through the first two years in the Bay that take part in the northern coastal migrations and to measure the rate of exploitation of Bay stocks by sport and commercial fisheries inside and outside the Bay. In addition to these studies, the Atlantic states--Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland and South Carolina--are making a coastal investigation of the striped bass. The Middle Atlantic Fishery Investigations is coordinating this program.

SHAD INVESTIGATIONS

Connecticut River.--Research on the shad runs of this river, first undertaken during 1951, showed that shad production depends upon the number of shad allowed to spawn. If overfishing occurs and the number of spawners is small, subsequent shad runs are small. When spawning populations are large, or at least adequate, subsequent runs are larger. The results of work done in 1951 have made possible predicting the size of the shad run one year in advance so that proper fishing regulations can be worked out to provide the proper escapement of spawners.

Since 1951 a tremendous sport fishery has developed on this river. The sport



catch was not important during the 1951 program and was treated as a constant. Additional research was conducted on the Connecticut River this year to re-evaluate both the sport and the commercial fishing so that proper management can be carried out; results of this work are being analyzed. Data from the 1956 shad records show the total run was 223,000 fish and the commercial catch 53,000 fish. A run of 285,000 fish was predicted for 1957.

During the 1957 season 8,845 fish were passed above Holyoke Dam by the new fish lift. This was an increase of 1,115 over those of last season.

Hudson River.--Results of work on this river in 1950 and 1951 showed that this run also is capable of management to produce maximum continuing yields. Since 1950 the fishing rate has lowered and the escapement of spawners has been higher. As a result, this run has increased tremendously and is nearing its previous high levels. Data for 1957 have not been compiled. In 1956, the total run was calculated to be 4,106,000 pounds and the commercial catch 1,807,000 pounds while in 1950 the total run was 1,398,-000 and the commercial catch 992,000 pounds. From data available in 1955 the size of the 1956 run was predicted to be 5,117,000 pounds which amount is less than 20 percent error. Since many male shad were thrown overboard because of a glut in the market, the actual run was probably higher than that calculated from the marketed catch. The run for 1957 was predicted to be 5,956,000 pounds.

There is no sport fishing on this river.

New Jersey Coast racial study.--Research on the Connecticut River and the Hudson River indicated that the large catches of shad made each year along the New Jersey

Coast and off Staten Island, New York, might affect the catches of shad in these rivers. This possibility was investigated in the spring of 1956 by tagging shad at several locations along the New Jersey Coast and at Staten Island to determine the river that these shad came from. Results have shown that 76 percent of them were from the Hudson River, 13 percent from the Connecticut River and 11 percent from other areas, such as the Chesapeake Bay and the Delaware Bay.

The effects of these catches on the runs to the Connecticut River and the Hudson River can be determined from these data. The coastal catches fluctuated with the size of the Hudson River run and were not responsible for changes in its size.

Meristic studies conducted along with the tagging studies showed that these counts could be used to separate these stocks of shad. These counts may be as effective as tagging and will cost less than the tagging programs.

Delaware River.--The research carried out in 1951 showed that pollution in the Philadelphia-Camden area was the primary cause of shad depletion in this river. The municipalities in this area are trying to reduce pollution in the river and recent studies show that it is slightly less polluted than previously. However, it is still far below the level needed for restoring the fisheries.

During the past year a conference was held with the Corps of Engineers in connection with the proposed Tocks Island Dam. The Middle Atlantic Fishery Investigations is helping to develop fishways for this dam and similar proposed dams and data are being obtained and studied for this purpose.

St. Johns River.--Shad catch and effort data have been obtained on this river each year since 1953 when the investigation of the fishery was begun. In 1957 the commercial catch was 261,000 pounds and the sport fishery 75,000 pounds.

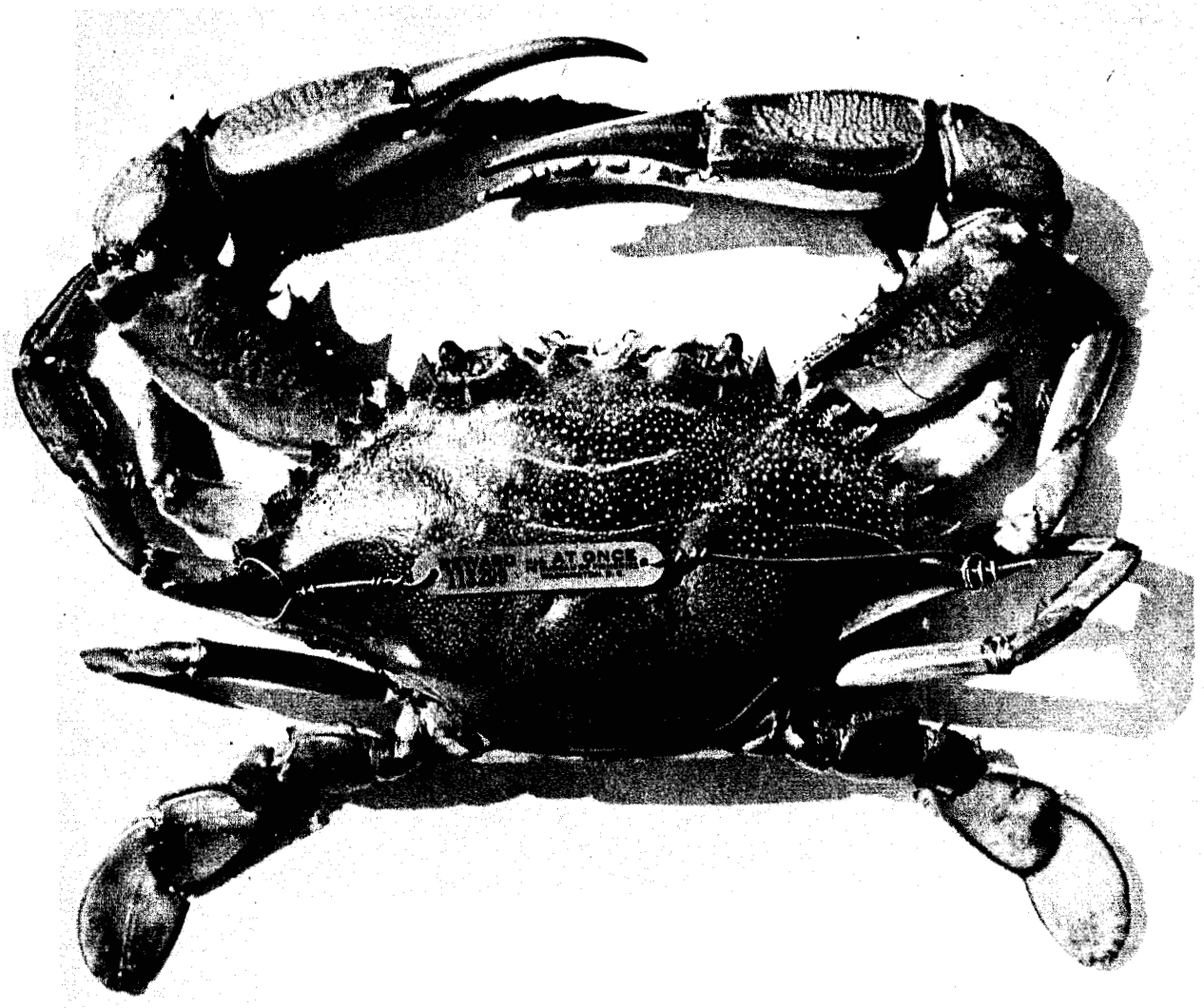
BLUE CRAB INVESTIGATIONS

In June 1957 the Fish and Wildlife Service awarded a contract to the Oyster Institute of North America, Annapolis, Maryland, to carry out research on the blue crab, Callinectes sapidus, of the Atlantic Coast. The Oyster Institute, which will conduct its research at the laboratory of the Middle Atlantic Fishery Investigations, will seek to provide information on the causes of fluctuations in abundance and methods of predicting such fluctuations, distributions of local stocks of crabs and yearly fluctuations therein and causes of the same. The Oyster Institute is recruiting a staff and work should begin shortly.

STRIPED BASS INVESTIGATIONS

North Carolina program.--Albemarle Sound, North Carolina embraces the greatest abundance of striped bass in the state. Present evidence indicates that the Roanoke River is the most prominant striped bass production tributary of the Sound. The construction of dams and increased pollution in the Roanoke River have recently threatened sustained abundance of the population. To resolve the problems confronting the fishery, a cooperative study for developing this river basin by scientific means became necessary. The U. S. Fish and Wildlife Service was directed in 1955 to participate in the study primarily because the Southeastern Power Administration, administered by the Department of the Interior, controls the sale of power generated by the John H. Kerr Dam, and needed information relative to minimum river flows required during the annual striped bass spawning migrations.

In carrying out this program the Middle Atlantic Fishery Investigations during the past two years has conducted a large-scale tagging and recovery program at various points in Albemarle Sound, and collected data on all types of fishing gear employed there. The purpose of this study is to determine the annual population magnitude and, hence, changes in size, related to alteration of river conditions in spawning areas. Catch and effort data have also been tabulated for two years since North Carolina recently abandoned its system of gear licensing. This was carried out by contacting dealers and fishermen throughout the Sound, and fixed gear was counted by airplane to check the validity of information obtained by direct contact with operators of this type gear. Commercial striped bass catches were sampled two to three times weekly for age and size class composition by gear. Two years' data relating to the above



ONE METHOD USED TO MARK BLUE CRABS TO DETERMINE MIGRATION AND FISHING MORTALITY

categories are being analyzed.

A study of sex ratios among Albemarle Sound striped bass was necessary to determine the effects of selectivity of gill nets on both sexes in spawning populations prior to their entry into the tributaries. This cannot be accomplished on striped bass by visual observation. Furthermore, this species is shipped out of state in the round, making internal inspection impossible. A new technique has been developed as part of this investigation to facilitate sex ratio studies which allows sex determination of fish in commercial catches without impairing market value.

Striped bass, weighing 20 to 40 pounds, were tagged at Oregon Inlet on the ocean in December 1956 to determine their relationship to Albemarle Sound populations or to those of other areas. Several of these fish have been recaptured in Albemarle Sound, Chesapeake Bay and off Sandy Hook, New Jersey, showing that in some cases there is a rather long-range coastal movement and that coastal populations are exploited by several Atlantic Coast states.

In the spring of 1957, a second year study of the Roanoke River population was made, encompassing an estimate of the size of run and a compilation of catch-effort

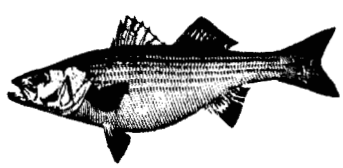
TAGGING OPERATIONS ON CHESAPEAKE BAY DURING COOPERATIVE STRIPED BASS TAGGING PROGRAM

data. Embryological and morphological studies were made of eggs and larvae under controlled laboratory conditions to test the degree of survival under varying river conditions and for facility in distinguishing larval striped bass from other related species.

Preliminary results from adult striped bass population data show that the spawning runs of 1956 and 1957 were almost identical in size. In 1957, however, there was a decrease in catch of approximately 10 percent and a decrease in fishing rate of approximately 1.5 percent.

Spawning ground studies have shown that the bulk of spawning in the Roanoke River takes place from river mile 60 to river mile 137, the upper segment being in the zone of heavy concentration of industrial and domestic sewage pollution. Striped bass use the entire river from its mouth to Roanoke Rapids Dam (mile 137) for either spawning or developing larvae. Post larvae have been collected as far downstream as river mile 6 in a polluted area heretofore believed to be avoided by young fish.

Chesapeake Bay program.--In February 1957 the Fish and Wildlife Service and the States of Virginia and Maryland organized a Chesapeake Bay striped bass investigation. The primary objectives are to determine the percentage of striped bass spawned and reared through the first two years in Chesapeake Bay that take part in the northern coastal migrations and to measure the rate of exploitation of Chesapeake Bay stocks by sport and commercial fisheries inside and outside the Bay.. The initial tagging program was begun as a one-year pilot experiment to obtain information as to availability of fish for study, to select the most satisfactory tag types and procedures, and to study striped bass movement both within and outside of Chesapeake Bay. The participating agencies have tagged 2,700 fish and 400 tags have been recovered. When analyses of the 1957 data are completed, a more detailed study of biological and fishing effects upon these populations will be possible.



PACIFIC SALMON INVESTIGATIONS

Clinton E. Atkinson
Seattle, Washington

In California and the Pacific Northwest, research on behavior patterns and survival of fish under extremes of environment is designed to understand fluctuations in abundance of the coastal stocks. Basic and developmental research is directed toward the safe passage of fishes at water-use projects. In the critical international North Pacific fishery involving Japan, Canada, the United States and, lately, the Soviet Union, some unique research tools are being developed to distinguish the Asiatic and North American stocks of salmon and determine their distribution and to learn the life history, distribution and abundance of the king crab in the Bering Sea. Major research is integrated with that of other organizations in the United States, Canada, Alaska, Hawaii and Japan through treaty, cooperation and contract.

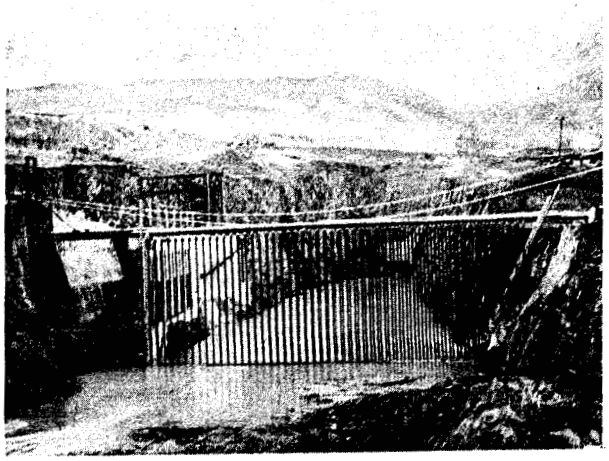
DEVELOPMENTAL RESEARCH AND GUIDING OF FISHES

Electrical stimuli have shown increasing success in efforts to guide fishes safely past dams. At Brownlee Dam, under construction on the Snake River in Idaho, an electrical barrier was installed, tested and evaluated to protect upstream migrating anadromous species of fish.

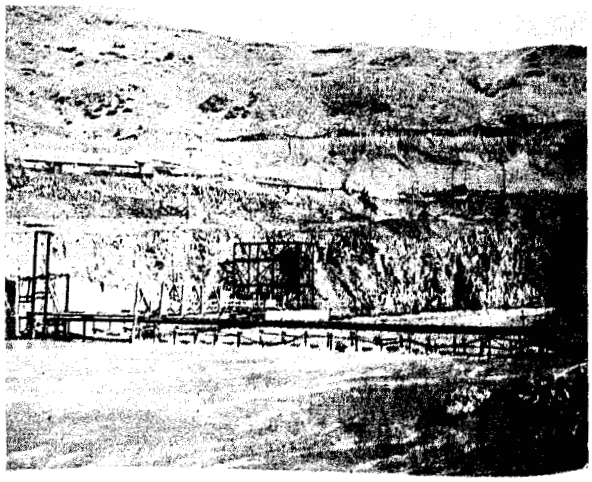
This barrier had to be capable of creating and maintaining desirable electrical fields in the water at all river discharges up to 40,000 second feet. This structure had to be flexible also so that desirable biological results could be obtained at minimum power consumption and maximum hydraulic efficiency.

The initial installation was two rows or electrodes anchored in a vertical position and spaced four feet apart with the electrodes two feet apart in the rows. A series of tests with fish showed that the spacing could be increased to six feet between elements in the rows.

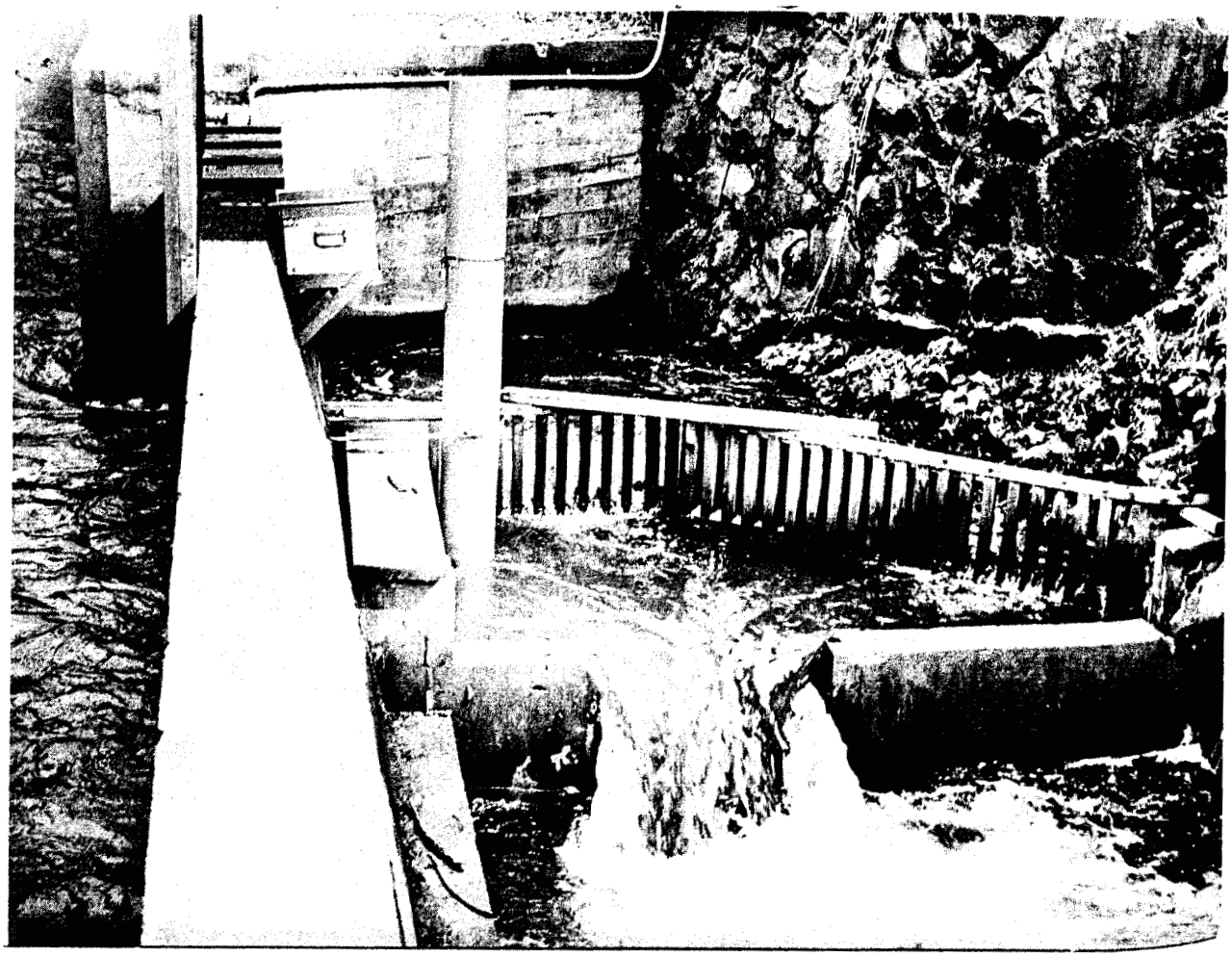
The electrodes were sequentially energized with square-wave pulses of direct current in a manner that created maximum voltage gradients on the long axis of any fish attempting to swim upstream.



ELECTRICAL BARRIER FOR THE PROTECTION OF UPSTREAM MIGRATING ANADROMOUS SPECIES OF FISH AT BROWNLEE DAM



ELECTRICAL BARRIER IN OPERATION



TRANSISTORIZED FISH COUNTER IN USE. THE ELECTRONIC APPARATUS IS HOUSED IN THE BOX IN THE UPPER LEFT AND IN THE VERTICAL PIPE. THE FISH ARE COUNTED THROUGH TUNNELS IN WEIR. POWER IS CARRIED TO COUNTER THROUGH CONDUIT FROM NEARBY LINE; HOWEVER, THE COUNTER CAN ALSO BE USED WITH DRY OR WET CELL BATTERIES. THIS INSTALLATION LOCATED AT BONNIE FALLS, SCAPOOSE CREEK, OREGON, "DISCOVERED" A FAIR RUN OF STEELHEAD THIS SPRING

Few adult salmon or steelheads were available at the time the Snake River was first diverted to flow through the electrical barrier. Therefore, preliminary biological tests were carried out with fine scale suckers, the only fish available in numbers. They were introduced into a large box-shaped net that was held against the electrodes. The two sides, the bottom and the downstream end were of dacron webbing. Fish could leave this net only by swimming upstream through the electrodes. In four tests involving 143 suckers, four escaped from the holding net when the power was on; they may have escaped from the net through holes torn in the web by debris. In two tests with the power turned off, one out of 120 suckers stayed in the holding net.

In a second series of tests, 2-year-old hatchery-reared steelhead fingerlings were forced through the electrical field to simulate the passage of downstream migrants. The most rigorous test conditions possible failed to produce any signs of lasting effects from exposure to the electrical shocks on the steelheads which were held 24 hours for observation.

Observations indicate that the electrical barrier is operating at an economical power consumption level and as an effective barrier. However, additional tests must be made to complete the evaluation.

Engineering research pertaining to fish guiding problems in general advanced also. Progress was made in the study of electrode geometry, the nature of the electrical fields created and in predicting the power demand of different electrode arrangements. Ways of simplifying and lessening the cost of construction of rather complex electronic pulse generating equipment were found while the efficiency and stability of the operations increased.

Electrical stimuli are used also to control the squawfish, Ptychocheilus oregonensis, a salmon predator in the Columbia River. The data from laboratory tests indicate that practical electrical trapping devices for controlling squawfish predation can be constructed. Testing in the laboratory demonstrated that adult squawfish will respond and orient to direct current and can be led by sequentially pulsed direct current fields through an electrode array into a trap. The frequency of the square-wave pulses of direct current and the voltage were the two most critical characteristics of the electrical field for controlling squawfish movements.

In developmental research, electrical fish counting is rapidly advancing toward better counters through improved modifications of the present instruments and increased field experience. Counters have been installed in Bristol Bay, Alaska; at Lake George, Minnesota and on Scapoose Creek, Oregon. Installations are planned for Mill Creek, California; Eagle Creek and Sandy River in Oregon; Coweman River and Rock Island Dam in Washington; and at Little Port Walter, Alaska. These installations are part of a testing program carried out in cooperation with four state agencies and two other branches of the Fish and Wildlife Service. In Alaska, it was found that properly designed installation can by a statistical means correct errors resulting from multiple passage to high levels of accuracy.

Modifications and additions to the original transistorized version have made it versatile and have simplified operation. These innovations, which are available through manufacturers, include modified dry cells, a voltage tester for easier balancing of the instruments, various sizes and shapes of tunnels, a charger for wet cells, a remote tally, a time-of-count recorder and two special testing instruments.

Projects were started in which electrical fish counters were used for large numbers of fish. One project is for Alaska and may lead to the elimination of counting weirs and towers on large red salmon, Oncorhynchus nerka, streams. The second project is at Rock Island Dam in Washington and may supplement the current system of sample counts at Columbia River dams.

One of the most useful developments in recent fisheries research is the sonic fish tag. It is approximately three inches long and one inch in diameter. Smaller tags are being developed; the ultimate goal is a tag approximately half an inch in diameter and one inch in length. Such a tag will reduce to a minimum the effects of the tag while attached to the salmon. The effects of tagging with the tag now in use has been studied in the field and the laboratory. The results indicate that salmon in spawning condition recover within an hour while

THE SONIC TAG USED IN FISH TRACKING EXPERIMENTS IS SHOWN HELD BY THE MODIFIED PLIERS USED FOR ITS ATTACHMENT TO THE FISH

salmon at a stage of spawning maturity require a longer period of time.

Tracking experiments were conducted in Portage Bay, Seattle, Washington. Adult salmon carrying sonic tags were tracked for periods up to eight hours. They tended to follow the shoreline. The maximum swimming speed was two miles per hour.

The Pacific Salmon Investigations cooperated with the Washington State Department of Fisheries in studying the vertical distribution of adult sockeye salmon, Oncorhynchus nerka, in Baker Lake. Through use of the sonic tag and equipment, the researchers found the majority of sockeyes at depths between 20 and 40 feet.

BEHAVIOR, SURVIVAL AND FLUCTUATIONS IN ABUNDANCE

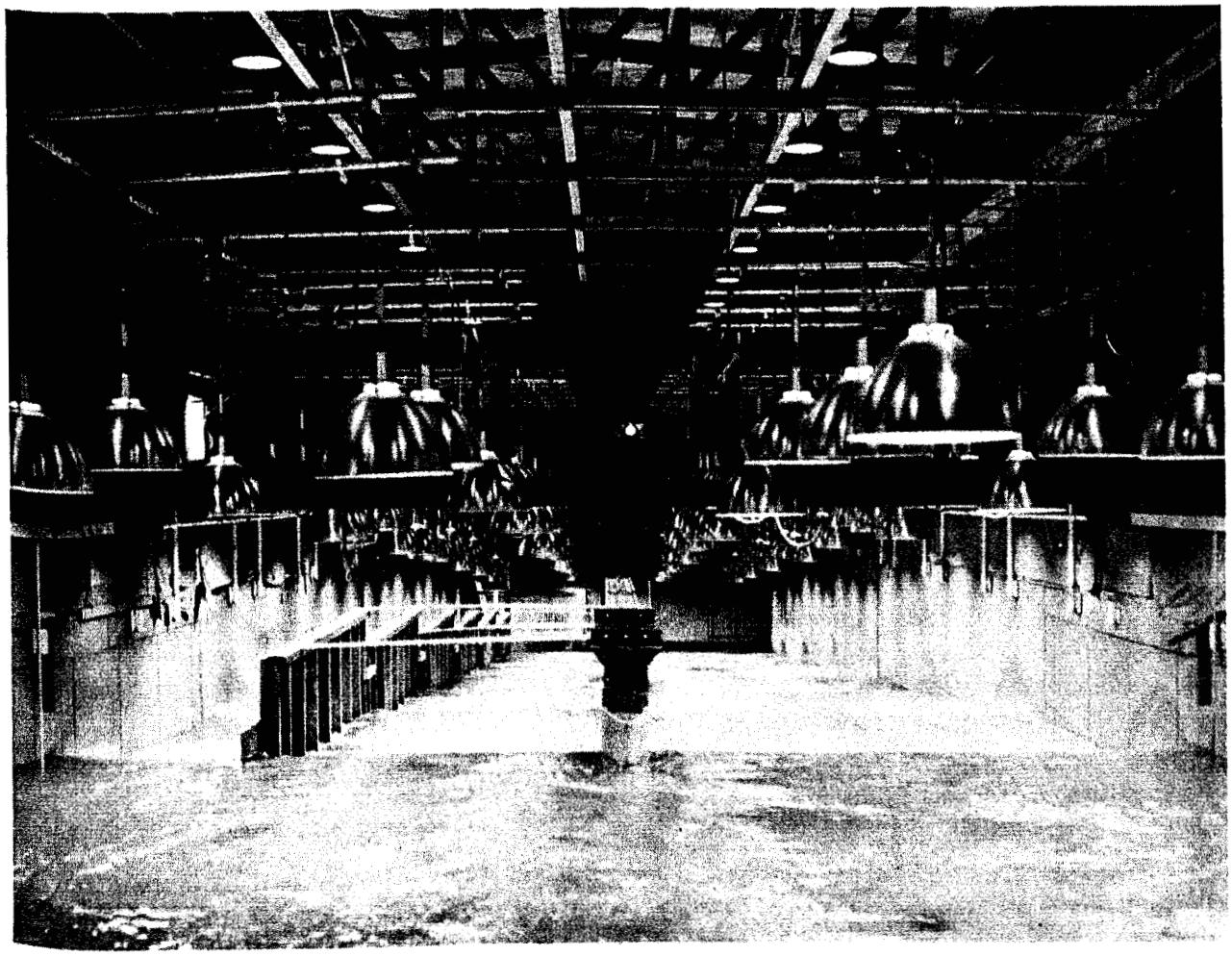
The reactions of over 10,000 adult salmon and steelheads were measured at the Fisheries-Engineering Research Facility at Bonneville Dam during 1956 to find more economical methods of providing safe passage of fish over dams. These fish were diverted from one of the main fishways into the laboratory where their performance in full-scale fishway situations was recorded.

Tests with a short 6-pool segment of a fishway indicated that a 1:8 gradient fishway with pools 8 feet long and with a 1 - foot rise between pools can pass fish as well or better than a 1:16 gradient fishway with a similar rise between pools. Further tests will be made to find out if this holds true in longer fishways. The studies in 1:8 gradient fishways with a rise of 1.5 feet and 2 feet between pools suggest that these jumps may be excessive for chinook salmon but not for steelheads. Unstable water conditions (i.e., changing hydraulic patterns from plunging flow to streaming flow) seriously interfere with fish passage in a pool-type fishway. The introduction of human odor into a fishway also interferes temporarily with fish passage. Experiments to measure fishway "capacity" or the maximum number of fish that can be passed through a fishway per unit time showed that large numbers of fish were not reluctant to enter and pass through a fishway of restricted width. In recent tests, up to 40 fish (averaging 14 pounds) a minute passed through a pool-type, 1:16 gradient fishway that was only four feet wide.

Studies on the reaction of adult salmonoids to a variety of water velocities indicate that large chinooks and steelheads tend to select higher water velocities when given a choice in the range of two to eight feet per second. The rate of fish movement relative to the test channel in these experiments appeared to be independent of the velocity of the water.

Upon completion of modifications to Rock Island Dam fishways in 1952 a tagging experiment was initiated to study the efficiency of the fishways. The field phase of this study was completed during the summer of 1956. Last year 885 chinooks, 1,174 bluebacks and 23 steelheads, totaling 2,082, were tagged and released above and below the dam. The percentage recoveries on the spawning grounds were 19.0 for chinooks, 30.1 for bluebacks and 17.4 for steelheads.

Although fish count records showed that only 10 to 17 percent of the fish used

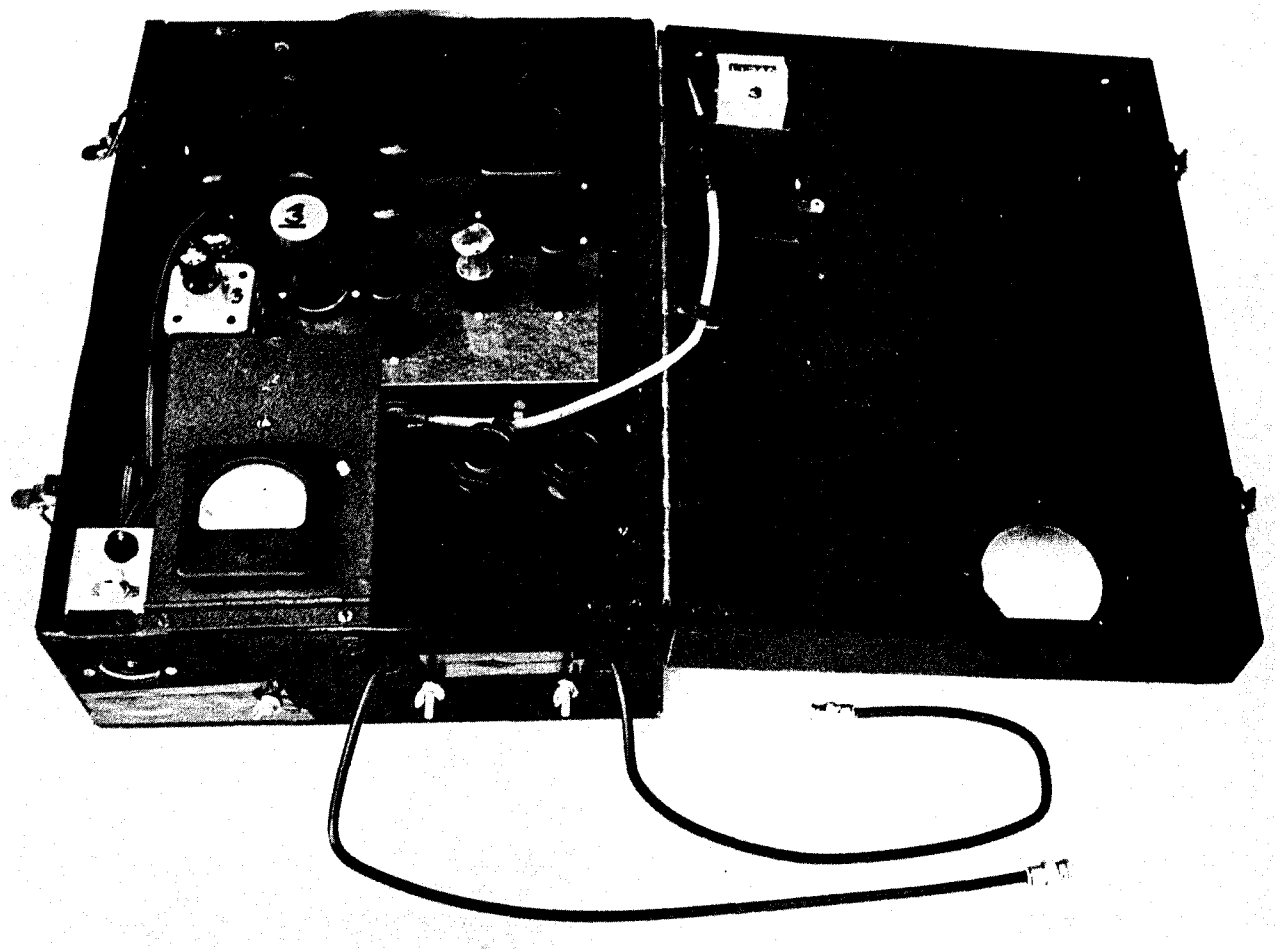


INTERIOR OF THE FISHERIES-ENGINEERING FACILITY AT BONNEVILLE DAM PRIOR TO A FISHWAY EXPERIMENT. THIS FACILITY IS ALSO USED TO CONDUCT EXPERIMENTS ON A FISH'S REACTION TO KNOWN VELOCITIES OF CURRENTS

the right bank fishway, tag observations at the dam indicated that the fish which did not find and use the ladder experienced no deleterious effects. The majority of the tagged bluebacks observed passed by way of the left ladder and 69.0 percent of right bank releases and 76.0 percent of left bank releases passed by way of the left and center ladders. Of the tagged bluebacks observed at the right ladder 12.3 percent were of right bank releases and 11.6 percent of left bank releases. Left and right bank releases passed the dam in equal time periods after tagging. The peak "days out" occurred on the third day after tagging bluebacks and summer run chinooks. Spring run chinooks passed the dam earlier after tagging, peaking after one "day out".

Tag returns upstream from below-dam releases were slightly less than from above-dam releases; however, for the sample sizes obtained the difference was not statistically significant. Thus, no significant loss could be attributed to the dam or, specifically, to a failure of fish to find and use the right ladder. The above-dam releases arrived at upstream points two to three days earlier than the below-dam releases. This difference in arrival time between the two lots corresponded to the time period required for the majority of the fish to pass Rock Island after tagging, and was termed the delay offered by the dam.

Above Rock Island Dam, on the Wenatchee River system, a study is in progress in relation to the proposed Chelan County Public Utility District hydroelectric power project. This research is being directed



"THE ALASKA FISH DETECTOR" IS USED IN FISH COUNTING TO RECORD THE NUMBER OF FISH PASSING THROUGH ONE SPECIFIC TUNNEL

toward ascertaining the magnitude, the timing and the spawning areas of anadromous fish runs into the system and the timing of the downstream migration of the young fish. The studies on the adult phase of the program will continue during 1957.

During 1956 approximately 2,400 chinooks, 26,000 bluebacks and 400 steelheads were counted through the Tumwater fish trap bound for the spawning areas in the upper river system. During the spring of 1957 an unprecedented run of spring chinooks passed Tumwater Dam. By June 30, over 2,900 chinooks were tallied, with two months of the counting season remaining. This large chinook run will be observed to determine its distribution over the spawning areas.

Spawning surveys were made last summer on all of the tributaries and the main stem of this system. The surveys have shown the spawning areas now utilized by salmon in relation to the areas to be inundated by the impounded waters. Under the present Public Utility District plans some spawning areas in the main river used by chinook salmon and steelheads will be inundated.

Another fishery research project partially financed by the Chelan County Public Utility District concerns the Rocky

Reach hydroelectric project on the Columbia River. Chinook salmon of the late summer or fall run were tagged at Rock Island Dam to determine their spawning areas in relation to the Rocky Reach Dam site. Surveys of all tributaries resulted in no recoveries from this lot. In contrast, recoveries of tagged spring and summer run chinooks from every experiment occurring from May to August at Rock Island were made in the various tributaries. Therefore, by inference, these late run chinooks may be Columbia River or main stem spawners.

Spawning ground surveys were conducted on all tributaries above Rocky Reach. It was determined that, aside from the Columbia River, no major spawning areas will be inundated by impounded waters resulting from the new dam. Spawning areas were determined for chinook and blueback salmon. Because of high waters during the spring the spawning areas utilized by steelheads could not be determined.

This spring saw the largest run of spring chinooks ever recorded over Rock Island Dam and their distribution on the spawning grounds will be observed.

In addition to the previously mentioned Chelan County Public Utility District impoundment projects, the Grant County Public Utility District is constructing the Priest Rapids Dam on the Columbia River and proposes to build the Wanapum Dam upstream from Priest Rapids. The University of Washington, under contract to the Fish and Wildlife Service, is investigating the water quality of the Columbia and Wenatchee River systems which the new impoundments will affect.

Physical and chemical water quality data have been collected during the past year from five stations on the Columbia River between Chelan Falls and McNary Dam, from the mouths of the Snake and Yakima Rivers and from Crab Creek which collects the return flow from the Coulee Irrigation system. Data have also have been collected from six stations on the Wenatchee River system.

Instrumental in understanding salmon biology is determining the number of young fish surviving from a season's spawning run to migrate to the sea and form the next generation. A study involving chinook and silver salmon was begun this spring on the Yakima River, a major salmon spawning tributary of the Columbia River.

A trapping station was established at the Prosser Canal bypass, Prosser, Washington, and was operated from early April until the end of June. A daily and a seasonal trend of migrating fingerlings was established by operating the trap 24 hours daily. Approximately 40,000 chinook fingerlings were tallied at this trap with the peak occurring at the end of April. Periodically, at various water flows, samples of fingerlings were marked by tattooing and released above the canal intake. This was done to determine a ratio of the number of fingerlings trapped and the number swimming freely down the river. The production of young salmon from a specific year's spawning run may be determine in this way.

Studies on the survival of the Columbia River blueback salmon, Oncorhynchus nerka, have been under way for several years. The majority of these salmon spawn in the Okanogan and Wenatchee River systems in Washington and at Redfish Lake in Idaho. In 1956, the spawning escapements for these areas were 26,000 fish in the Wenatchee River; an estimated 40,000 in the Okanogan River system; only 1,381 of the 10,000 bluebacks available to the Snake River reached the Redfish Lake weir. The adult migrants in the Okanogan and lower Snake Rivers encountered excessive high water temperatures.

In the area of the Okanogan flood control project, heavy spawning occurred in the newly channelized sections of the upper river. Construction was permitted in the river below Oliver, B. C., Canada, during the winter to allow completion of the project by July 1, 1957. The egg cartridges planted last year and recovered this spring and the fry trapping operation indicate a successful hatch of eggs and emergence of fry. Large numbers of migrating fry were in the river from April 1, 1957 to May 10, 1957.

The downstream fingerling migration was sampled below Lake Osoyoos by means of a newly developed fyke net. At Redfish Lake the fingerling migration was enumerated at the weir. Data from these areas on the age and the size of the fingerlings at the time of migration are being compared. Columbia

River blueback smolts migrate seaward in their second year. This year's data show almost 100 percent of the Okanogan migrants in the second year, whereas 44 percent of the Redfish Lake migrants were in their third year. In comparison of length and weight, the Okanogan fingerlings fall midway between the Redfish Lake 2's and 3's.

The fingerling migration study conducted at Bonneville Dam terminated on June 30. Species, age and size and migration, time of migration, numbers of marked fish and identity of marks are some of the information collected during the ten-year period that this study was conducted.

Several experiments were conducted during the course of the program. An example was an attempt last year to test the effectiveness of the fingerling bypasses in conducting fish downstream from the auxiliary water chambers at the dam. One thousand small chinook salmon were tattooed and introduced into the auxiliary water pits ahead of the bypasses. The recovery of 1 to 8 percent of the fish in the bypass traps indicated that the other fish either swam out of the area into the spillway forebay or remained in the pit area or escaped through defective screens in the pits.

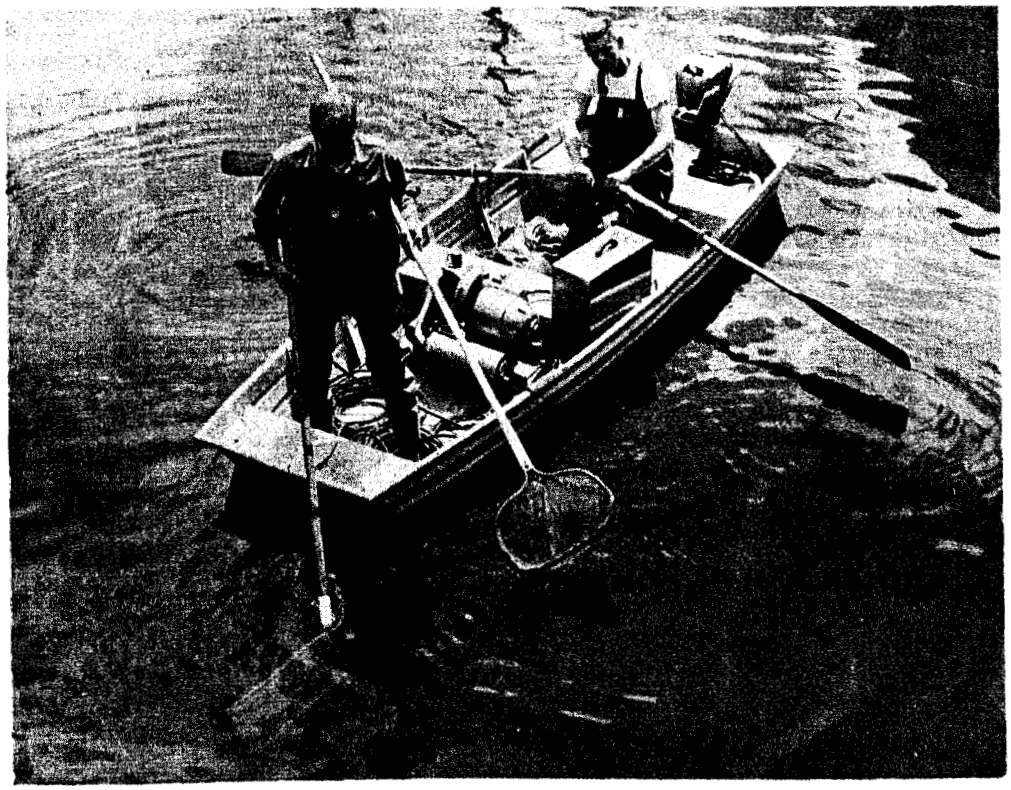
Thousands of migrants are fin clipped at hatcheries above Bonneville Dam. Three Service hatcheries released approximately 4,000,000 fish above Bonneville Dam during the last week of August 1956. In the course of recording fin marks observed on trapped silver salmon, Oncorhynchus kisutch, fingerlings at Bonneville Dam, a close similarity was observed between incidental loss of fins and the results of experimental fin clipping. The loss of fins probably resulted from nipping by other fingerlings during feeding at hatcheries or disease. Fingerlings trapped at Bonneville Dam during 1956 were 31,426 chinooks, 494 bluebacks, 3,049 silvers and 921 steelheads. Reports are being prepared on the age and the size of chinook salmon migrants and the silver salmon migration.

Another program in fisheries research being conducted in the Columbia River Basin deals with the various roles of resident game and non-game (scrap) fishes in respect to the survival and the growth of the important anadromous fishes. The past year has seen the evolution of the program from a preliminary planning stage to one of active and standardized field operations. The Yakima River was chosen as the pilot-study watershed. Aerial photographs were used to locate accurately sampling stations at five river-mile intervals from the mouth of the Yakima River at its confluence with the Columbia River to Easton Dam, 178 miles upstream, the limit of anadromous fish migration.

With the successful development of a portable pulsed direct current electrofishing device, collections were begun in April on a systematic sampling schedule. One complete sampling trip was completed and over 4,000 fishes were collected. The specimens ranged from a 20 mm. red-sided shiner fry to a 12-pound carp. The specimens are being "processed" for length, weight, sex, degree of maturity and identification of stomach contents. Scales were collected from representative samples for age analysis.

These data are being punched on IBM cards for sorting and analyzing. Preliminary results list the following species, listed in decreasing numerical order, as being the most abundant, chiselmouth chub, Acrocheilus aleutaceum; carp, Cyprinus carpio, an introduced species; sculpins, Cottus spp.; suckers, the fine-scaled, Catostomus syncheilus, and the course-scaled, Catostomus macrocheilus; red-sided shiner, Richardsonius balteatus; various species of dace of the genus Rhinichthys; and the squawfish, Ptychocheilus oregonensis, reputedly one of the worst predators on salmon in the river. Less abundant species were the Rocky Mountain whitefish, Prosopium williamsoni, rainbow trout, Salmo gairdneri, small-mouthed black bass, Micropterus dolomieu, and crappie, Pomoxis nigromaculatus, the bass and the crappie coming from the lower reaches of the river. Conspicuous by its small number was the Columbia River trout-perch, Columbia transmontana, of which only two specimens were collected near the city of Yakima.

The data collected under this program will be utilized in life history and ecological studies on the fishes of the Yakima and Columbia Rivers and their relationship to salmon production. Sampling is being conducted on a monthly basis for at least one year to determine the seasonal patterns of distribution and relative abundance of



PORTABLE ELECTRO-FISHING DEVICE USED FOR COLLECTION OF FISHES BY RESIDENT FISH STUDIES PROJECT

the resident fishes. Plans call for expanding the geographical scope of the studies to other salmon-producing waters of the Columbia River Basin.

Stream fluctuation is an important factor in the survival of king salmon, Oncorhynchus tshawytscha, in Mill Creek, a tributary of the Sacramento River in California. Through the progress made in studies of survival, the wide fluctuations in the abundance of Sacramento River king salmon can be understood and corrected.

Silting is the predominant contributing factor in the survival of the king salmon spawn at the Mill Creek Experimental Station. For example, last year heavy silt loads after 67 days of incubation reduced the survival in the channel more seriously than in Mill Creek proper. After 67 days of incubation, survivals dropped from 85 percent in the channel and 87 percent in Mill Creek to 4 percent in the channel and 13.5 percent in Mill Creek at 126 days (fry stage). Filtered water in two gravel filled troughs containing eggs resulted in reduced survivals from 96 percent at 67 days to 73 percent fry when silting overtaxed the capacity of the filters.

Methods have been devised for alleviating silt in the control flow channel where assessment of factors contributing to mortality of salmon spawn is being made.

One method for reducing silt in the channel recently accomplished is enlarging the settling pools. Another attempt at silt control has been the establishment of 250 feet of oxbow in the channel where low velocity flows will absorb silt and sand loads. A third method involves an experimental installation which is in effect an artificial spring. A perforated culvert has been placed under the Mill Creek stream bed which is connected to the culvert leading into the controlled channel. The filtering effect of gravel covering the buried intake will reduce silt introduction. The flushing effect of freshets in Mill Creek may keep the intake of this system self-cleansing.

Laboratory tests are continuing to perfect the measurement of seepage rates

comparable to those in actual salmon redds through use of polyvinyl chloride standpipes in which salt dilution is detected with a conductivity meter. A manuscript covering standpipe description and application with survival comparisons in the field is in progress.

The behavior studies in progress constitute another important phase of research for better understanding the biology of anadromous fishes. A study of the factors affecting the rheotactic response of salmon fingerlings was begun at the Fish Behavior Laboratory in Seattle after exploratory tests in the use of a water jet as a means of collecting fingerlings gave inconsistent results. The experiments thus far show a positive rheotactic response at holding temperatures and a change to a negative response with an increase of temperature. By controlling the level of dissolved gases the threshold of the change from positive to negative can be raised or lowered. The response appears to relate to dissolved O_2 levels rather than to temperature alone.

The importance of spatial relationships to behavior patterns of young salmon was demonstrated in experiments with sockeye smolts that consistently schooled in large water areas but exhibited aggressive territorial behavior in restricted areas.

The reactions of chinook salmon fingerlings to an overfall, an orifice and a siphon were compared at the Fisheries-Engineering Research Facility. Most of the fingerlings that were recovered had entered through the orifice. More passed through the siphon than over the overfall. There was evidence that fingerlings delayed longer before going over the overfall, even when the overfall was the only exit. Echo ranging equipment used during the tests revealed that fingerlings upstream from the collection devices being tested were generally distributed from the surface to an 8-foot depth, a few were scattered between depths of 8 feet and 11 feet and no fingerlings were below 11 feet.

Washington State College, under contract to the Fish and Wildlife Service, is conducting research on the relationships of certain physiological factors to preferences in salmon. The research is directed toward learning the relationship between metabolism and temperature preference, through use of 2-4 dinitrophenol (DNP) to influence metabolism; the response of DNP treated and control groups of fish to 11 light wave bands noting the relation of light and dark adaptation to preferences; and the responses of DNP treated fish and fish treated with other chemicals to differential salinities.

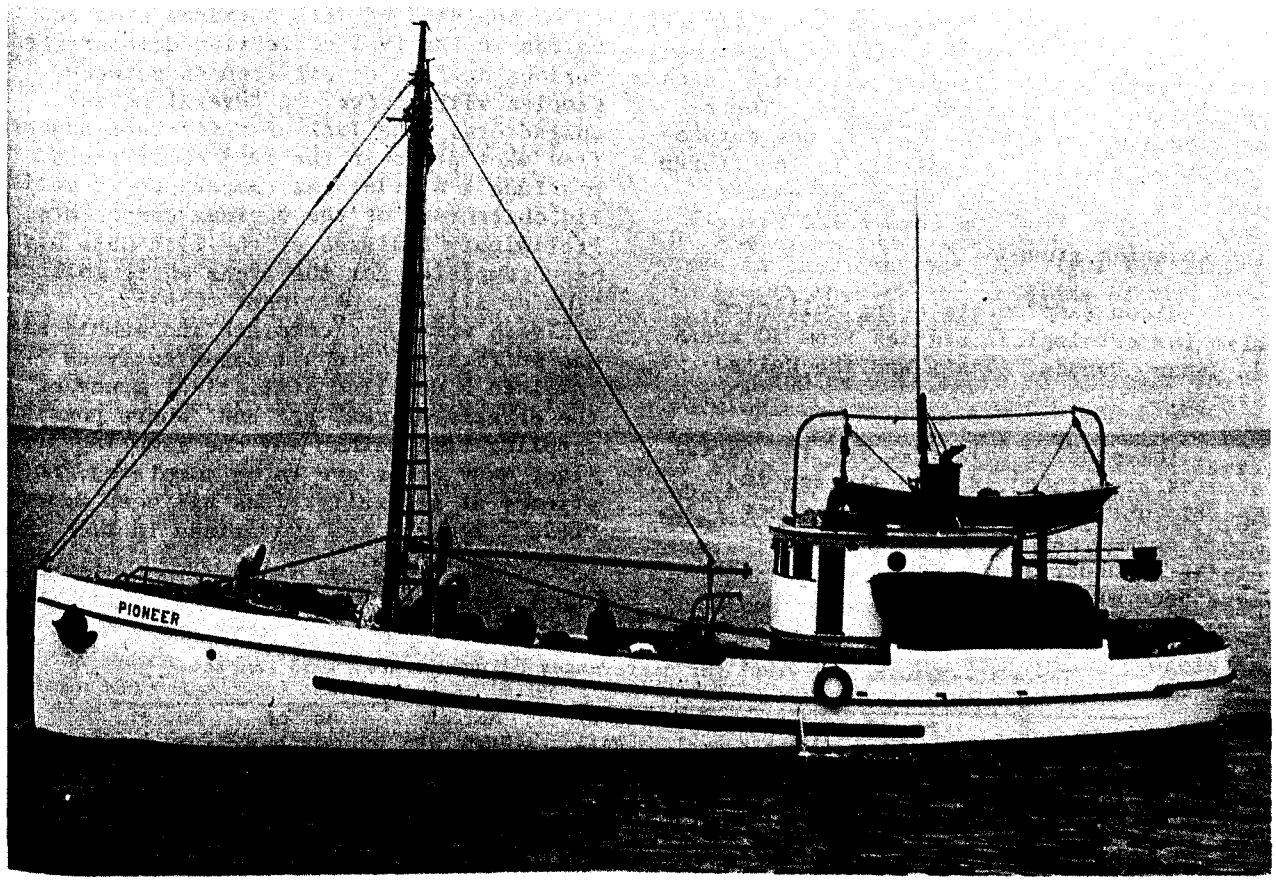
Three hundred and ninety silver salmon were divided into 10 groups, five experimental and five control. The experimental groups were immersed for 45 minutes in .004 percent DNP; the control groups were handled similarly but were immersed in clear water. Four hours after handling the groups were tested in a Y-maze for temperature preference in water of 1, 2, 3, 4 and 5° C. Although the treated fish seemed to prefer slightly cooler water than the control fish, the investigator believed that response to flow might dominate the temperature preference.

Silver salmon fingerlings treated with DNP avoided sodium chloride solution (70 percent strength of sea water) to a slightly greater degree than did untreated fingerlings.

Blueback fingerlings treated with DNP and tested for light preferences moved toward red or neutral lights and away from blue-green light. In recent tests in which blueback and silver fingerlings were used, preferences for light were less apparent, probably resulting from the illumination level provided in the gradients used.

INTERNATIONAL NORTH PACIFIC SALMON RESEARCH

Through the intensive research program outlined by the International North Pacific Fisheries Commission, formed by Japan, Canada and the United States, the location of salmon in the ocean will be known. Progress is being made in determining the patterns of distribution and in distinguishing racial stocks of salmon. The responsibilities of the American Section of the International North Pacific Fisheries Commission are to define the distribution of salmon in the North Pacific Ocean, tracing the seasonal movements and locating the areas of concentration; measure oceanographic conditions related to the distributional pattern; and collect and preserve samples of salmon and



steelhead trout for racial analysis, with the objective of ultimately distinguishing Asiatic and North American stocks.

Four chartered research vessels were operated in the North Pacific and the Bering Sea during the summer and fall of 1956. Each vessel fished 18 shackles of nylon gill net and obtained oceanographic data on a prearranged station pattern extending from the North American coast to Attu in the Aleutians and from 46° N. latitude to 60° N. latitude. The fishing season from mid-May until mid-September include 195 sets and produced 3,522 reds, 3,767 chums, 486 pinks, 115 silvers and 73 kings, totalling 7,963.

The vessels MV Pioneer and MV Attu departed Seattle in May 1957 to continue the distribution studies and the collection of racial samples. To assure adequate sample size, the number of shackles of gear was increased to 24 and on certain primary stations the number of sets increased. Between May 27 and June 24 the vessels had made 23 sets and captured 1,420 reds, 723 chums, 3,055 pinks and 15 kings, totalling 5,203. Compared with the same period of fishing in 1956, reds declined and pinks increased. The MV Paragon will join the Pioneer and Attu in July to augment the sampling effort for the remainder of the season.

Modifications were made in the 1956 program to more closely relate environmental conditions to the distribution and movements of salmon populations. The revised program includes oxygen and phosphate determinations and a more detailed study of the surface layers of the ocean.

The principal objective in a sampling program is to collect adequate, standardized and representative data. To fulfill this objective, sampling of the major red, chum and pink salmon populations, except in territories of the Soviet Union, is being conducted at inshore stations to supplement the charter vessel catch samples. The whole frozen samples requested from Japan, Canada, Alaska and the United States for 1957 will total approximately 25,000 salmon. Each frozen sample will consist of 200 to 235 reds, 135 chums and 135 pinks, except in a

few isolated areas. From each whole sample, 25 salmon of each species will be furnished for parasitological studies and ten of each species for osteological studies. The remaining samples will be used in the morphological studies. In addition to the frozen samples, 50,000 scales and measurements will be taken from the commercial fishery and spawning grounds.

Blood samples are being collected also for serological studies from 30 areas in Japan, Canada, Alaska and the United States.

The samples collected for the racial studies are placed in cold storage in Seattle until needed. Since November 1956, 7,849 salmon sampled from 32 areas in Alaska, Canada, Japan and the high seas have been examined.

Analysis of data obtained from red salmon in the 1955 collection demonstrated various degrees of differences between samples with respect to several meristic characters. The lack of sufficient numbers from many areas in the 1955 collections preclude a statistical comparison of meristic characters of the various components. Preliminary analyses of the 1956 data have been completed for the areas where collection of all data pertinent to racial analysis work were complete and sample size was sufficient. In all cases analyses involved a detailed statistical study of the effects of sex, age and, where possible, sampling time within any one sampling area. Since many areas are to be completed, no attempt at generalizations has been made. Present results are summarized in the following tables:

Table 1.--Results of F-test for differences between sexes, 1956 samples.

Area	No. of scales on lat. line	Pos. of 1st haemal arch	Total gill rakers	No. of branchio-stegal rays	No. of pect. fin rays	No. of anal fin rays
Ugashik	None	None	None	None	None	None
Naknek	"	"	"	"	"	"
Kvichak	"	"	"	"	"	"
Egegik	"	"	"	"	1% level	"
Wood River	"	"	"	"	None	"
Attu	"	"	"	"	"	"
Adak	"	1% level	5% level	"	"	"
Unalaska*	"	None	None	"	"	"
Red River	"	"	"	"	5% level	"
Karluk Weir	"	"	"	"	1% level	"
Fish Creek	"	"	"	5% level	None	"
Chignik	"	"	"	None	1% level	"
Copper River	"	"	"	"	None	"

* Seven sampling localities combined.

Table 2.--Results of F-test for differences among age classes, 1956 samples.

Area	No. of scale on lat. line	Pos. of 1st haemal arch	Total gill rakers	No. of branchio-stegal rays	No. of pect. fin rays	No. of anal fin rays
Ugashik	None	None	None	5% level	None	None
Naknek	"	"	"	None	"	"
Kvichak	"	"	"	"	"	"
Egegik	"	"	"	"	"	"
Wood River	"	"	5% level	5% level	"	"
Attu	"	"	None	None	5% level	"
Adak	"	"	"	"	None	"
Unalaska*	1% level	1% level	1% level	"	"	"
Red River	None	None	None	1% level	"	"
Karluk Weir	"	"	"	"	"	"
Fish Creek	"	5% level	"	None	"	"
Chignik 1/	"	"	"	"	"	"
Copper River	"	None	"	"	"	"

* Seven sampling localities combined.
1/ Not done. Sample of 6_3's only.

Scale studies play a vital part in fisheries research, particularly in determining the racial origins of salmon in the North Pacific Ocean. Scales from the salmon of the 1955 collections taken for meristic studies have been aged and supplemental scale data obtained. Through intensive study of red salmon scales frequencies of various scale characters have been documented for several mainland areas. By means of a systematic evaluation of the intensity of occurrence in various areas of any given scale character from a fish of unknown origin, the most probable area from which the fish came can be determined with a high degree of accuracy.

In a series of tests, fish from the mainland samples were used. The area identification was removed or blocked out. Depending on the test and the setup of the localities, biologists allocated the fish to the correct area in from 60 to 90 percent of the cases. Samples of offshore red salmon were analyzed for racial origins.

These analyses showed for the 1955 season a progressively larger percentage of Asiatic high seas type fish the farther the samples were taken to the westward out to the longitude of Attu. No fish of the typical Asiatic high seas type were found eastward of the longitude of Kodiak Island.

These findings were based entirely on the results of scale analysis studies and while they appear to be definitive they were based only on the data for 1955 which were scanty in certain areas.

Analysis of the more extensive collections of 1956 is under way. Over 5,000 red salmon from the meristic collections have been aged and complete scale data obtained; approximately 1,000 more remain uncompleted. Upon completion, the frequencies of scale characters will be determined and compared with those of the 1955 data. Additional tests will be conducted for the accuracy of the 1956 data for racial determination. Such comparisons as have been made to date through use of the 1956 data show that the scale characters resemble closely the same characters for 1955 for the tested areas.

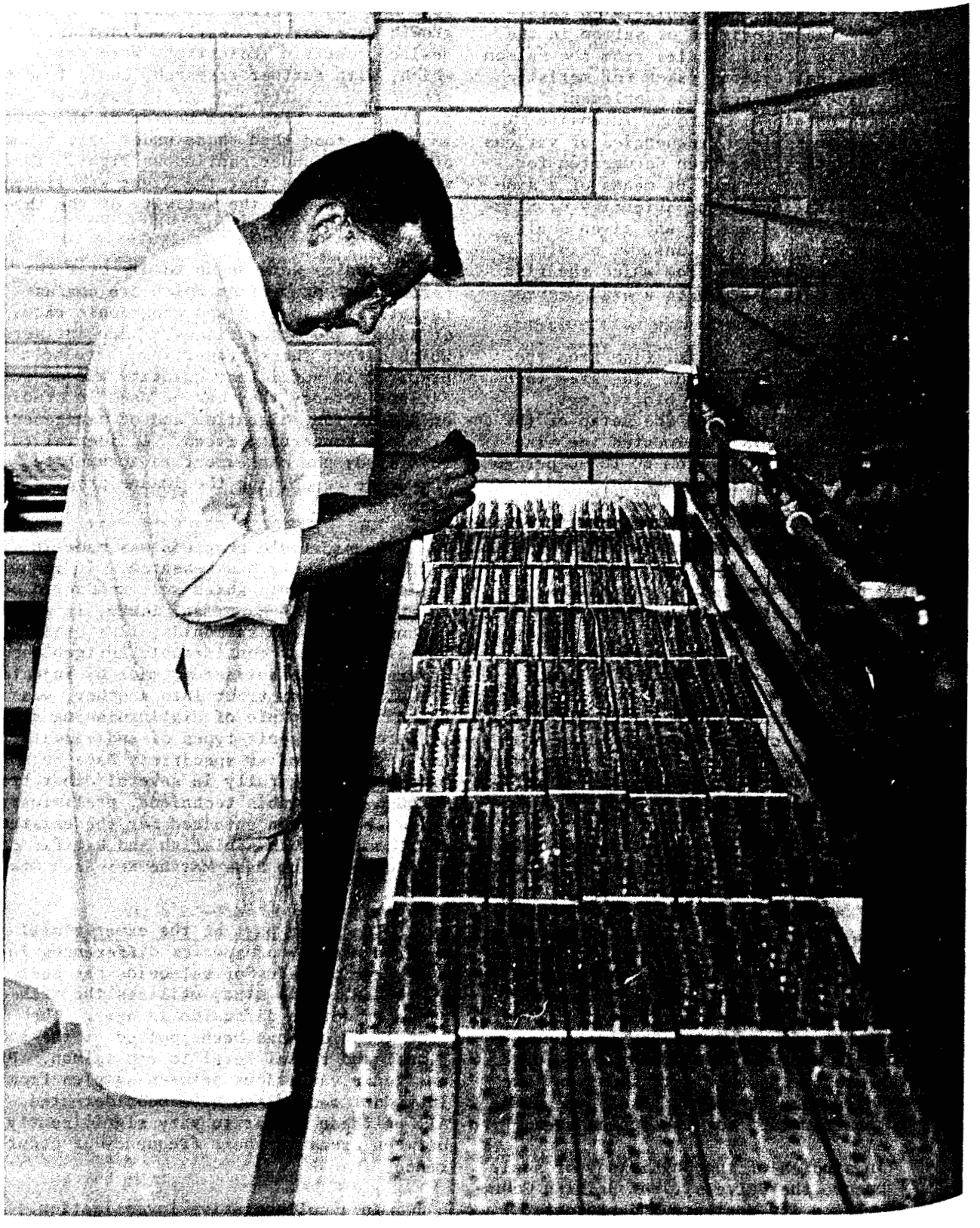
In studies of the physiology of scale development, the University of British Columbia completed its contract and presented a final report to the Pacific Salmon Investigations. While the results of the use of hormones for altering the pattern of scale growth were not as clearly defined as desired, certain indications were found which, with further research, could lead to productive results. Under 16 hours of controlled light fish grew better on the same amount of food than those under only 8 hours of light, or under continuous light. There were indications that the light was linked to growth through the activity of the thyroid or pituitary glands.

Studies were begun to discover the serological properties which are characteristics of species and geographic races of salmon and other fishes. When antisera, which detect these properties, have been prepared in sufficient quantity and of sufficient potency they can be used in studies of speciation, migration and of management problems concerning races. Incidental to this study one can expect to accumulate knowledge concerning the immune process in fish.

Considerable progress was made in various lines of this research. In immunization experiments which were conducted on rainbow trout at Hagerman, Idaho, it was demonstrated that salmonids, like other animals, possess considerable antigenic diversity. One antiserum, made by injecting the blood of one trout into another, was shown to be capable of distinguishing five different antigenic types of individuals. Antisera of similar specificity have been prepared successfully in several other trout. Through use of this technique, preliminary evidence has been obtained for the existence of blood types in sablefish and Pacific cod at the Deception Pass Marine Research Station.

The major part of the experimental work on a study of species differences in the serum proteins of salmonids has been completed. This study utilizes the technique of double diffusion in agar. The same technique has been applied at the individual and racial level to red salmon. Five antigenic variations between samples from idividual red salmon have been detected. All of these appear to vary significantly between areas in their frequency of occurrence.

In a collaborative investigation, significant serological differences were



PREPARATION OF BLOOD SAMPLES FOR TESTING IN SALMON SEROLOGICAL STUDIES.

AN AGAR DIFFUSION DISC USED IN THE SEROLOGICAL STUDIES. THE LINES FORMED AROUND THE CONTAINER IN THE CENTER ARE USED IN DETERMINING THE DIFFERENCES IN RACES OF SALMON. THIS SHOWS THE REACTION OF SPECIFIC ANTISERA IN SAMPLES FROM SEVERAL AREAS

demonstrated between populations of red salmon with a natural antibody found in pig serum. This system has been studied further and used to demonstrate blood types of chum salmon and in Pacific herring.

The use of rainbow trout and sablefish as antibody producers has supplied new evidence concerning the immune process in fishes. The sablefish, while held at temperatures not exceeding 5° C., have produced some of the most potent antisera that the Pacific Salmon Investigations has obtained. This process, while extremely slow, requiring months rather than weeks, indicates that the conventional immune response must be of considerable importance in the survival of such cold water species.

King crabs are another fishery resource of high economic importance to the United States and Japan. The bulk of the Japanese-American fishery occurs in Bristol Bay and the Aleutian Islands. Determination of whether joint Japanese-American conservation measures are needed in the eastern Bering Sea fishery has been approached in several directions. The research on king crab has progressed at an increased rate during the last year.

Continuing the plan of systematically sampling and tagging crabs in the Bering Sea, the Pacific Salmon Investigations chartered a vessel again for 1957. Equipped with otter trawls, beam trawls, oceanographic equipment and live tanks, the vessel Mitkof

departed Seattle, Washington on May 6, 1957 and proceeded to the Bering Sea, where small crabs were caught and sample trawls at predesignated stations are being made. A method of computing the numbers of commercial size male crabs by these sample trawls throughout the area is being refined and shows promise of providing a minimum population estimate.

Crabs caught in the sampling and tagging efforts have been measured to follow the changes in size frequency. This will not only help to better understand the need for conservation measures but may also show rates of growth through the progression of dominant size classes.

During the tagging efforts aboard a chartered vessel in the late summer of 1956, 4,063 male crabs were tagged. This added to 2,458 crabs tagged in previous years made a total of 6,521 male crabs tagged and released by this investigation. The recovery of 422 tags has provided valuable information on migrations, distributions and fishing rates. At least 20 crabs had shown growth. Plans have been made to tag and release 30,000 crabs during the 1957 cruise.

Oceanographic observations have also been recorded on these cruises. There are indications that temperatures may influence the distribution of king crabs in the Bering Sea. Areas with near zero degrees centigrade bottom temperatures contained fewer crabs than adjacent areas where the temperature was slightly higher in the summer of 1956. Information was collected during June 1957 to determine the water movement and may provide indices to the movements of king crab larvae which are believed to be carried by currents.

Observations were made on the moulting and the size increase at moulting of female crabs in the Pavlof Bay area. Crabs in live boxes cast off their old shell by retracting through a break in the membrane adjacent to the first abdominal segment. The carapace, abdominal plates, gills, mouth parts, and parts of the eye, antenna and stomach were cast off intact. The average growth exhibited by the female crabs under live box condition was 4.0 mm. in carapace length. Because meat content is related to moulting, observations were made on the relation of various body parts to the total weight. It was determined that the meat from the merus of the right third walking leg might be used to test the meat content of various size crabs. A report on this study has been prepared.

A bibliography on the king crab is being prepared.

Complete log records of the United States king crab fleet's operations and the Japanese catch and effort data in the Bering Sea from 1953 through 1956 have been assembled. Gross examination shows no decline of fishing success during these years.

SHELLFISH LABORATORIES

I. WOODS HOLE SHELLFISH LABORATORY

Paul S. Galtsoff
Woods Hole, Massachusetts

Manual on Biology and Cultivation of American Oysters

Preparation of the manual on oyster biology proceeded satisfactorily. About half of the part of the manuscript dealing with the structure and the functions of the oyster body was completed, including illustrations and a bibliography. A portion of the section dealing with ecology was prepared during the preceding fiscal year. A chapter on the nerve system and embryology remains to be written.

In connection with the studies of the structure of the oyster shell, a distinct difference was found in the organic matrix of the prismatic and lamellar layers of the shell. Both components consist of conchiolin, but the staining reaction of the two parts is different, indicating differences in chemical composition. Conchiolin of the prismatic layer secreted by the mantle groove is stained red with triple Mallory stain while the conchiolin secreted by the outer surfaces of the mantle is deep blue.

The attachment of muscles to the shell presented another interesting problem. A study of the sections made across the decalcified shells and the muscle showed that the muscle fibers are not anchored in the shell substance but are cemented to it by a thin layer of organic compound about

two microns in thickness. Assuming that collagen secreted by special cells found at the tips of the muscle fibers is involved in gluing the muscles to the shells appeared reasonable. This suggestion was confirmed by experiments in which minute amounts of collagenase, an enzyme digesting collagen, dissolved in a buffer solution of pH 8.2 was injected into the muscles of live oysters or when pieces of shells with the muscles were immersed in this solution. In all cases there was a complete separation of the adductors from the shell. Muscles treated with trypsin remained unaffected.

In contrast to the adductor muscles, the muscles involved in the movements of oyster gills are not cemented to the gill skeleton but form root-like processes which are embedded in the chitinous gill rods. The distribution of these muscles was studied in detail and the mode of their operation was deduced from an histological examination of numerous preparations.

A study of the function of the ciliary apparatus of the gills showed that the lateral cilia which surround the gill openings (ostia) are capable of rejecting particles of relatively large size by throwing them back to the surface of the gill. The prevailing view of oyster biologists has been that this type of sorting is accomplished exclusively by the latero-frontal cilia. Observations on live oysters in which the gills of one shell were exposed to view showed that this is incorrect. The operation of the lateral cilia was recorded by the artist in a series of drawings made from living material.

A system of ciliary currents along the surfaces of the mantles was studied by using phosphorescent powders and colloidal carbon and by tracing the path of the particles inside the shell cavity. Minor corrections were made in the existing descriptions of the currents and of the location of "discharge areas" at which the particles collected by the gills and found unsuitable as food are rejected.

Raft Culture of Oysters

The purpose of this study was to determine the suitability of the raft culture of oysters to the conditions prevailing in Cape Cod. Studies made at Oyster River, Chatham, consisted in recording the rate of growth and the natural mortality of oysters kept above sea bottom and in determining the principal ecological factors affecting them.

The raft was constructed by using two 25-foot painted cedar logs with 5-foot long pieces of galvanized telephone wire attached by staples. Shells with 1956 set attached to them were strung on wires; each shell was separated by a piece of plastic tubing five inches long. The logs, held together by metal crossbars, were moored by two anchors. Two logs were completed by the fall of 1956 and two more are being added this year.

The logs were anchored in the Oyster River until the first threats of river freezing appeared. On December 5, 1956 they were moved into Oyster Pond and remained there until April 1, 1957, when they were returned to their old mooring in the river. An examination of the shells in April found little mortality. Only two strings with shells were lost.

In the spring the shells became heavily fouled. Samples of fouling organisms were periodically preserved, oyster stomachs examined and plankton hauls taken to determine the source of the oysters' food. Fouling film comprised several varieties of algae, Bryozoans, Obelia, tube worms, mussels, barnacles, detritus and many bottom diatoms including Navicula, Lycmophora, Thalassiothrix and Gyrosigma, some of which were found in the stomachs of the oysters.

The temperature at the Oyster River ranged from 23.2° C. on June 17, 1956 to 4.4° C. on December 5. The salinity ranged from 31.06 to 32.68; pH from 7.9 to 8.2 and O_2 from 8.00 to 8.84 p.p.m.

Measurements of small oysters grown on the raft were compared with those of oysters kept in trays at Woods Hole, Massachusetts, and with those left on the bottom in their places of origin. On October 11, 1956 the median length of the Oyster River oysters was 10 mm.; on April 12, 1957 it had not changed; on May 6 it was 12 mm. and on June 27 it was 15 mm. Young oysters taken the Weweantic River and placed in trays at Woods Hole grew from a median length of 3 mm. on September 10, 1956 to 9 mm. by the end of the year; on June 19, 1957 the median length was 9 mm. The Wareham River set, also placed in trays at Woods Hole, grew from a median length of 8.00 on September 19, 1956 to 12 mm. by the end of the year; on

June 28, 1957 the median length was 13 mm.

Oysters remaining in the Weweantic River at the end of 1956 were 2 mm. smaller than oysters from the same set growing at Woods Hole. Since these oysters are killed by winter icing, the measurements cannot be continued.

The median length of Wareham River oysters at the end of 1956 was 11 mm. This is 1 mm. smaller than the same set growing at Woods Hole and 1 mm. larger than the set grown in the Oyster River. Because the Wareham River set was sold early in the fall of 1956 no further measurements could be taken.

Whelk Trapping

On May 15, 1957 many whelks were preying on oysters in the Oyster River. The local oyster growers and the Laboratory attempted to control them by trapping. The traps were constructed of wood 24' x 19' x 8". The sides were perpendicular to the base while the ends were sloped. The trap was covered with chicken wire and an 8-inch diameter hole cut in the top. Four bricks were used for weights. The traps were placed in two rows on the beds.

The best bait was chopped horseshoe crabs which were wired to the bottom of the traps. They were changed every two or three days if the green crabs had eaten much of them.

The traps took 1,122 channel whelks and 4 knobbed whelks. The knobbed whelk is as abundant in the Oyster River as the channel whelk but apparently does not enter the traps. From 5 to 12 traps were used for the month of trapping. The rate of trapping per 24 hours decreased from 11.34 channel whelks per trap at the beginning of the trapping period to an average of 1.60 channel whelks when the trapping was discontinued.

Twenty channel whelks were marked and released on May 31, 1957; two were recaptured on June 5 and 13, about 200 feet down the river from the point of release, and a third whelk was recaptured on June 17 at the place where it was first caught.

To obtain some idea of the destruction of oysters caused by channel whelks, a live car was placed on the Oyster River on June 3, 1957 with 6 whelks, 12 oysters and 6 quahogs. By the end of the month the shells of 8 oysters had been broken and the meat eaten; the 6 quahogs were alive although 1 quahog showed signs of whelk chipping.

Of the 1,122 channel whelks found in traps, 100 were sexed and measured; 43 were males and 57 females. The sizes ranged from 7.3 to 18 cms. The females appeared to be larger than the males; the largest male was 14.9 cm. long and 13 females exceeded that length.

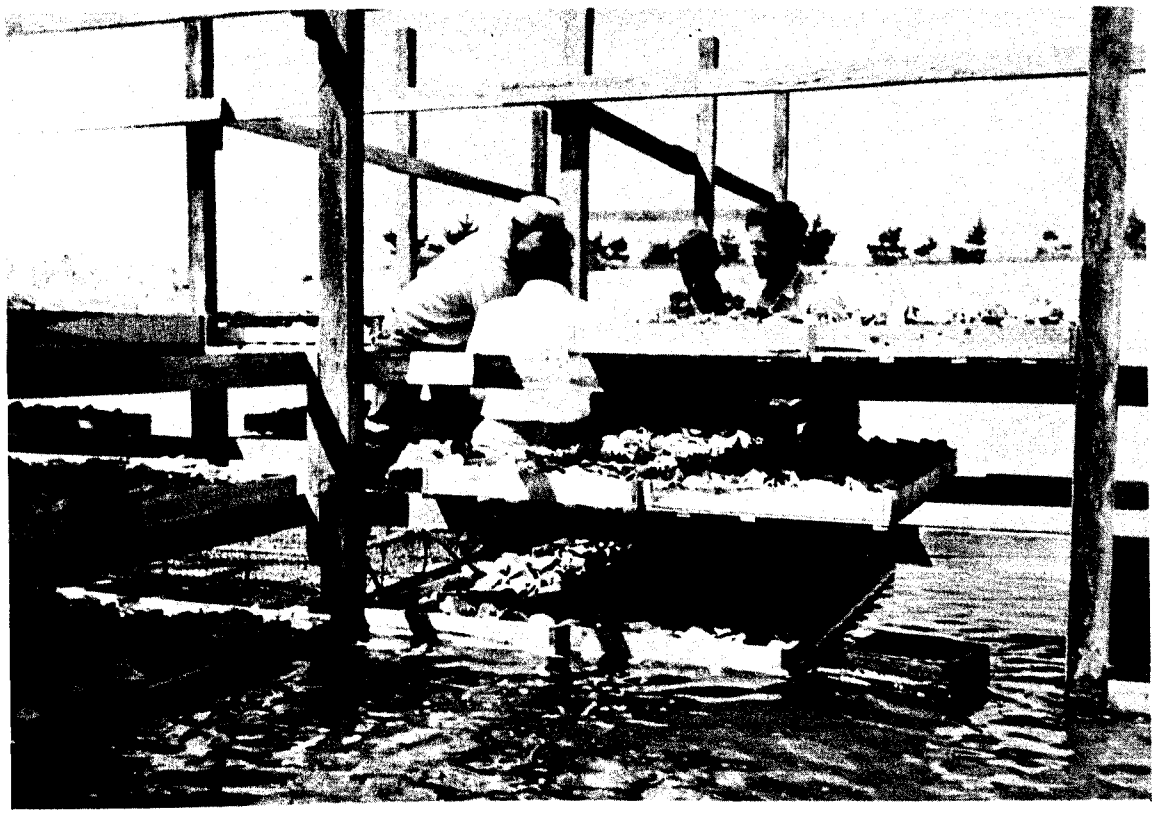
II. MILFORD LABORATORY

Victor L. Loosanoff
Milford, Connecticut

Long Island Sound oyster spawning and setting.--Studies of various aspects of the spawning and setting of oysters in Long Island Sound were continued during the summer of 1956. Setting was the heaviest in the Bridgeport area and relatively good in the Milford area, but the New Haven section suffered another failure. As compared with previous years, since 1936, the setting of 1956 ranked in ninth place. Observations indicated once more that no general prediction of intensity of setting can be made for the entire oyster-producing area of Long Island Sound.

Data on the intensity of setting in different years in the same areas of Long Island Sound were analyzed. The conclusions were based on observations made during the years 1944 through 1956 in ten representative areas of Long Island Sound. The results indicated that none of the stations kept under observation during the 13-year period, and representing a relatively small bottom area, consistently occupied a position among the five best producing stations. However, if larger areas, instead of individual stations, were compared, the Bridgeport area would show a definite tendency to be more productive than the others. There was no evidence that the stations located at different depths, such as 10, 20 or 30 feet, consistently produced better sets of oysters than the stations at other depths.

At the mouths of certain rivers the laboratory and the State of Connecticut Department of Shellfisheries established spawning beds which the laboratory will observe.



PREPARING COLLECTORS FOR OBTAINING OYSTER SET IN ARTIFICIAL SALT WATER PONDS.

The set of European oysters, Ostrea edulis, secured under laboratory conditions, grew well last summer in Milford Harbor and survived a relatively cold winter without appreciable mortality. Practically no mortality was noted among the adult European oysters which are two years old or older.

To continue its studies on hybridization of different species of the genus Crassostrea, the laboratory obtained several hundred C. rhizophora from Puerto Rico. Good spawn has not been obtained from these oysters which, in their behavior under Milford, Connecticut conditions, greatly resemble, C. virginica of the Gulf of Mexico with which experiments have been made at Milford. The laboratory will continue its studies on crossing them with C. rhizophora.

The laboratory cooperated with the Oyster Institute of North America, Annapolis, Maryland in developing methods for utilizing salt-water ponds for shelfish culture. Last summer several ponds on Martha's Vineyard were observed and the behavior of the oysters in these ponds, as well as changes in environment, was studied. Because the salinity in the ponds fell during the summer to approxi-

TESTING PLASTIC COLLECTORS TO SECURE OYSTER SET

CHANGING WATER CONTAINING OYSTER LARVAE IN EXPERIMENTS DEVISED TO DETERMINE THE QUALITATIVE AND QUANTITATIVE REQUIREMENTS OF THESE LARVAE

mately 5.0 p.p.t., practically no set occurred. This occurrence intensified the laboratory's research on the effects of different salinities upon larval and juvenile oysters and other mollusks. This summer the salinity in the Martha's Vineyard ponds has been higher and an excellent set of oysters has been reported there.

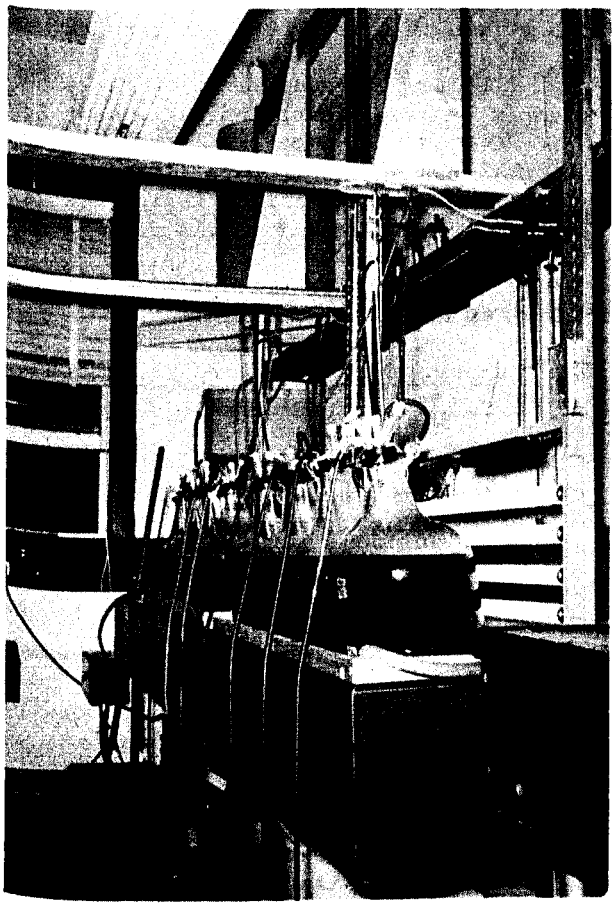
The laboratory has undertaken also a study of the propagation of the European oyster, Ostrea edulis, and the Japanese clams, Tapes semidecussata, in an artificial pond on Long Island. This study promises interesting results which may help in managing salt-water ponds.

Plastic collectors are being tested to collect oyster set. They may have extensive use in pond culture.

Ecological requirements of lamellibranch larvae.--In continuing studies of the factors that affect the survival and growth of larval clams and oysters, many new forms of microorganisms were evaluated as foods. Extensive studies of the effects of reduced salinities on the development of fertilized eggs into straight hinge larvae and the growth of larvae after they reach the straight hinge stage, were also conducted. Among the new foods tried were 4 genera of diatoms, 1 dinoflagellate, 2 chrysophytes, 4 green algae and 1 blue-green alga. None of these was a particularly good food. Several diatoms were fair foods for clam larvae, but not for oyster larvae. They were either poor foods or else the oyster larvae did not utilize them.

During the past year, at times, the laboratory's mass cultures of good forms such as Isochrysis galbana and Monochrysis lutheri became toxic to oyster larvae. Whether the toxin is produced by these chrysomonads or by bacterial contaminants was not determined.

The optimum salinity for development of egg and growth of straight hinge larvae of the hard clam, Venus mercenaria, of Long Sound is about 27.5 p.p.t. If the salinity



A BATTERY OF LARGE GLASS CONTAINERS IN WHICH VARIOUS TYPES OF LARVAL FOOD ARE GROWN

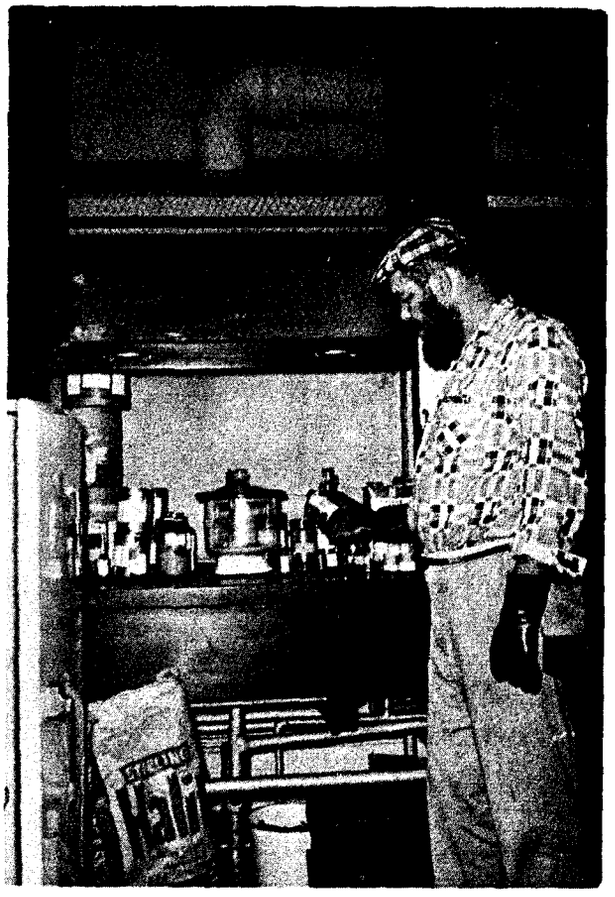
is reduced to 20.0 p.p.t.,usually less than 20 percent of the eggs develops. None of the straight hinge larvae placed in a salinity of 15.0 p.p.t. reached metamorphosis. At 17.5 p.p.t. some grew to that stage but were weak and all died after setting.

The optimum salinity and salinity range for development of straight hinge larvae from eggs of the American oyster, Crassostrea virginica, is governed by the salinity at which the parent oysters develop gonads. The optimum salinity for developing eggs of oysters from Long Island Sound, Peconic Bay and Hodges Bar, Maryland, when parent oysters of these areas are conditioned at 27.0 p.p.t., is between 20.0 and 22.5 p.p.t. When oysters,such as those of Hodges Bar, were conditioned at 8.7 p.p.t. (their natural environment), the optimum salinity for developing their eggs was between 10.0 and 15.0 p.p.t.

RIPE OYSTERS INDIVIDUALLY MARKED AND EACH IN A SEPARATE CONTAINER READY TO BE INDUCED TO SPAWN, TO PROVIDE MATERIAL FOR STUDIES ON PHYSIOLOGICAL AND ECOLOGICAL REQUIREMENTS OF OYSTER LARVAE

The optimum salinity for growth of larvae of Long Island Sound oysters conditioned and spawned in a salinty of 26.0 to 27.0 p.p.t. (normal environment) was near 17.5 p.p.t. Some of the larvae of these oysters developed, however, in salinities as high as 35.0 p.p.t. and as low as 12.5 p.p.t.

Several chemicals used to kill mosquitoes or other undesirable arthropods and which the laboratory successfully used to control crabs which were destroying oysters and clams were tested for their effect on the survival and growth of oyster and clam larvae. The laboratory was interested in the chemicals it found useful for controlling copepods, which are usually great competitors in natural ponds to



BIOLOGIST, WORKING ON DEVELOPMENT OF METHODS FOR CONTROL OF SHELLFISH ENEMIES, IS SELECTING CHEMICALS TO BE USED IN THE NEXT EXPERIMENT

oyster and clam larvae. The laboratory found that it could kill these copepods by using light concentrations of the chemicals and wanted to ascertain what would happen to molluscan larvae exposed to the same concentrations.

Guthion, a potent toxic agent for arthropods, was the least toxic of the group tested on oyster larvae. A concentration of 1:20,000,000 stimulated the growth of larvae instead of harming them. Parathion, another powerful toxin to arthropods, caused no appreciable mortality of oyster larvae even at a concentration of 1:1,000,000, but slowed their growth. Dipterex only slightly retarded the growth of oyster larvae at a concentration of 1:1,000,000, but in lower concentrations caused no apparent ill effects. Lindane caused no appreciable mortality even at 1:1,000,000, the highest concentration tested, but slightly retarded the growth of both oyster and clam larvae.

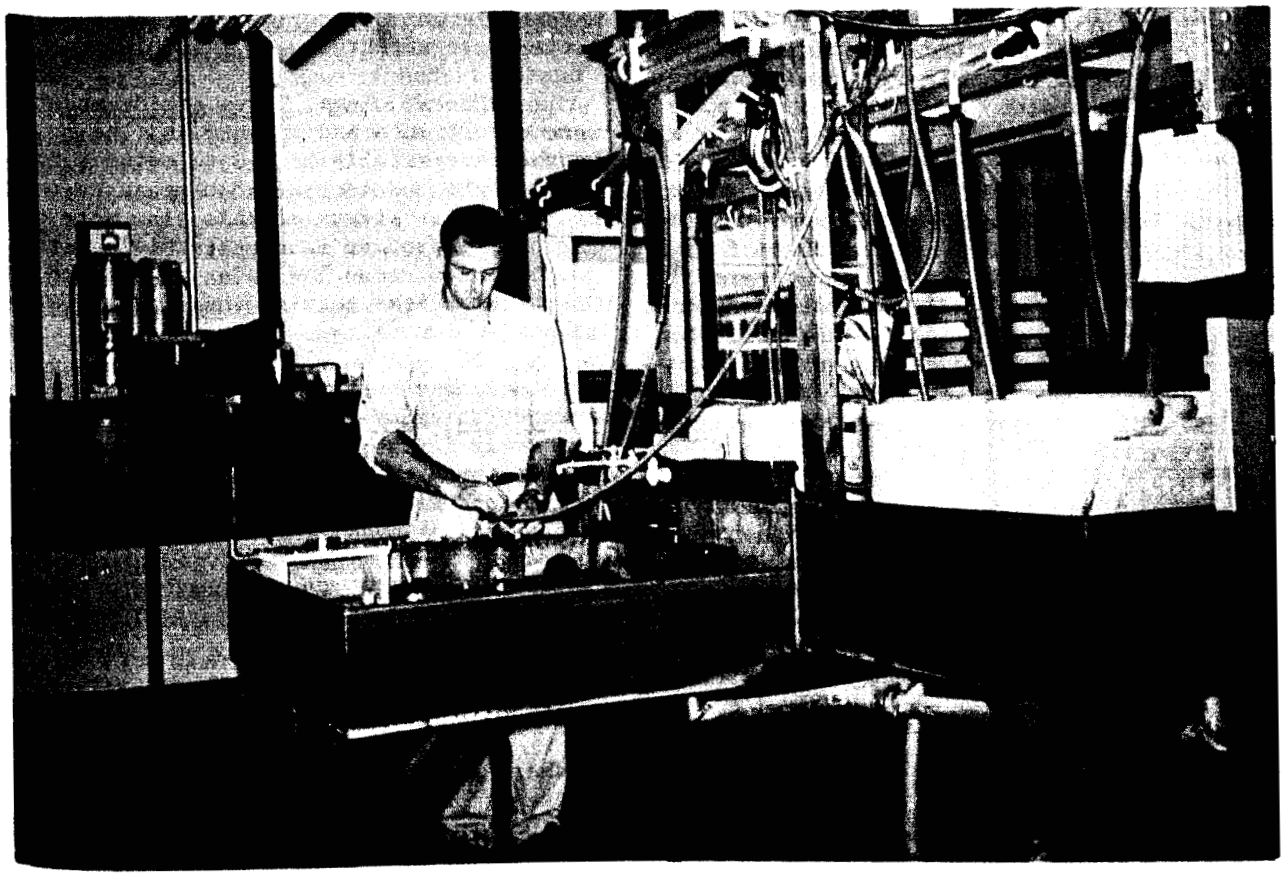
DDT was the most toxic of the substances tested. In concentrations of 1: 1,000,000 it killed oyster larvae within a few days and at a concentration of 1: 40,000,000 it seriously decreased the rate of growth and mortality of larvae. This finding may indicate that spraying with DDT near areas where setting of oysters is taking place is undesirable.

Development of methods for growing juvenile clams and oysters.--Studies were conducted to determine the effect of various ecological factors, including temperature, salinity and foods upon the survival and growth of juvenile clams. This information is needed in connection with planned mass production of hatchery-bred clams and oysters.

Winter mortality of juvenile clams, Venus mercenaria, was investigated. Young clams kept in water of Milford Harbor from October until May survived, regardless of how often they were disturbed or whether they were permitted to dig in. However, the clams that were kept in the laboratory at a water temperature ranging between 15.0° and 20.0° C. and the transferred directly to the cold water of Milford Harbor during the winter were apparently affected by this sharp change and began to die later on, sometimes several months after the change. For example, 36 percent of the clams transferred to cold water in December died in May. All of the clams transferred to water of a temperature about 1.5° C. in mid-winter died in May.

In a recent series of experiments an early set of V. mercenaria was grown at different constant temperatures. The clams kept below 10.0° C. died. At 10.0° C. there was practically no growth. Some growth occurred at 15.0° C., while the clams grew well at 20.0°, 25.0° and 30.0° C. Somewhat larver V. mercenaria were kept at the same condition. Ten point zero degrees C. was again the minimum temperature at which growth occurred, and the clams grew well between 15.0° and 20.0° C.

Juvenile V.mercenaria kept at a temperature of 20.0° C. or higher for nine months grew continuously. Apparently clams can grow continuously if conditions are favorable; this knowledge is important for



BIOLOGIST WORKING IN CLAM HATCHERY

hatchery practice.

Similar expermments were conducted on recently set oysters. They all died when the temperature was below 10.0° C. and at this temperature only 7 percent survived for three months.

Over 20 species of microorganisms, grown in mass cultures, were tried in studying the food requirements of juvenile clams and oysters. Three species of cryptomonads were the best foods for juvenile clams and oysters. In relation to the other microorganisms, however, the requirements of clams and oysters may differ.

Since many salt-water ponds that are available for cultivation of mollusks are often threatened by periods of low salinity, learning more about survival and growth of clam and oyster larvae under different salinity conditions was necessary.

The optimum salinity for the development of eggs of Long Island Sound clams, V. mercenaria, was about 27.5 p.p.t. No normal larvae developed at salinities of 17.5 p.p.t. or lower. The upper salinity limit for development of clam eggs appeared to be 35.0 p.p.t. and only an occasional normal larva developed at this salinity. Straight-hinged clam larvae grew reasonably well at 17.5 p.p.t. and many reached metamorphosis, although the optimum salinity for their growth appears to be at least 27.0 p.p.t. At 15.0 p.p.t. none of the larvae reached metamorphosis, although some lived for ten days or more and showed appreciable growth. At 12.5 p.p.t. straight-hinged clam larvae showed no growth and all were dead by the eighth or tenth day.

The optimum salinity for the development of eggs of the Long Island Sound oyster, Crassostrea virginica, that had developed gonads at salinities of 26.0 - 27.0 p.p.t., was found to be 22.5 p.p.t., although some normal larvae developed in salinities as low as 12.5 p.p.t. and as high as 35.0 p.p.t. The optimum salinity for growth of larvae of all ages, however,

was 17.5 p.p.t., although older oyster larvae grew well and set at salinities ranging from 27.0 to 12.5 p.p.t. Growth evenof older oyster larvae, at 10.0 p.p.t. was considerably slower than at 12.5 p.p.t.

The salinity tolerance of eggs and larvae of Maryland oysters, from low salinity areas, did not differ from that of eggs and larvae of Long Island Sound oysters when both groups of parent oysters developed gonads at 26.0 - 27.0 p.p.t. However, when these Maryland oysters developed gonads in their normal habitat (salinity 8.74 p.p.t. at the time of collection) and were spawned at salinities of 7.5 p.p.t., 10.0 p.p.t. or 15.0 p.p.t., the eggs developed into normal straight-hinged larvae at 10.0 p.p.t. and larvae, normal in shape and only slightly smaller in size, developed at 7.5 p.p.t. Even at 5.0 p.p.t. many of the eggs developed into early shelled stages before they died. The upper salinity limit for development of normal larvae from these low salinity eggs was also appreciably lower than for eggs from comparable oysters that developed gonads at 26.0 - 27.0 p.p.t. None of the low salinity eggs developed into normal larvae at salinities above 22.5 p.p.t.

Whether eggs from Long Island Sound oysters or from oysters in other high salinity areas would behave in the same manner if conditioned and spawned at similarly low salinities is not known. The optimum salinity for subsequent growth of larvae developing to straight-hinged stages at these low salinities needs to be known. Their requirements may not differ appreciably from larvae developing at higher salinities or they may grow so slowly at the low salinities that they will tolerate that they will have little probability of reaching metamorphosis.

Progress was made in developing hatchery practices for cultivating clams and oysters. A method, for example, was found to reduce the mortality of recently set clams which has been high in the past. Ultra-violet-treated water is widely used to prevent diseases. Infection of the laboratory's clam cultures or populations of recently set clams with the fungus Sirolpidium is prevented by raising the water temperature to 33.0° C. for two or three days.

A fungus, believed to be Labyrinthula, was observed in larval cultures of V. mercenaria and O. edulis. Some of the latter were affected with Sirolpidium.

Japanese clams, Tapes semidecussata, were conditioned and spawned and their larvae successfully reared to metamorphosis. Photographs and length-width measurements of the larval stages of this clam were made and distributed to interested biologists. If planted at mean low water in Milford Harbor, these clams survive the winter with almost no mortality.

Clams resulting from the cross of V. mercenaria and V. campechiensis were spawned and their larvae raised to metamorphosis. Several hundred of these F_2 generations are being raised in the laboratory.

III. BEAUFORT LABORATORY (FISHERY RADIOBIOLOGICAL INVESTIGATIONS)

Walter A. Chipman
Beaufort, North Carolina

The studies of the past year at the Fishery Radiobiological Laboratory continued those of previous years on quantitative measurements of accumulated radioactivity from the uptake of fission products by fishery organisms, the nature of the radioactivity accumulated in the various parts of the body, and the levels that could be passed to man through the use of seafoods or marine products. Preparation has been made for including in the investigations studies of the accumulation of radioactivity in those organs and tissues of fishery organisms that are critical to the well-being and the reproduction of these forms and an assessment of the damaging action from radiation from the contained materials. Some studies of the biology of plankton and shellfish through the use of radioisotopes as tracers have been undertaken also. The present studies along this line are concerned with the planktonic food organisms and the feeding mechanisms of molluscan shellfish.

Fission Product Mixtures

The fission product mixture used in the tests during the year was of such an age that the greater part of the total radioactivity resulted from isotopes of the rare earth elements present, particularly to cerium-144 and its radioactive daughter product, praseodymium-144. Other nuclides, including niobium-95, zirconium-95, yttrium-

91, strotium-89, strontium-90, yttrium-90, cesium-137 and barium-137, made significant contributions. Because of hydration and formation of insoluble particles following the addition of the mixture to sea water the greater part of the radioactivity slowly settled out or was adsorbed to surfaces.

Observations on a number of species of marine phytoplankton which were exposed to the fission product mixture and added to the culture medium showed a rapid and great uptake of radioactivity. A great part of this took place within the first 15 minutes, but uptake continued with time. The accumulation of radioactivity by the cells was apparently chiefly related to surface area. From determining the maximum energy of the particles, Ce^{144} was found to be the major contributor to the total radioactivity associated with the planktonic algae, including that of its radioactive daughter, Pr^{144}. A more rapid decay rate of the activity of the cells re: ved soon after adding the mixture indicated a rapid uptake of isotopes of short half life, such as Y^{90}, and a slower uptake of those of long half life.

A rapid uptake of radioactivity from the mixed fission products was likewise observed for marine copepods and other grazers on phytoplankton. However, uptake was less marked than that by phytoplankton cells which were of smaller size. Aside from surface adsorption there seemed to be an uptake from filtration of radioactive particles. This soon leveled off when the losses from excretion equaled the uptake from feeding.

The uptake and the accumulation of radioactivity by marine fishes, croakers (Micropogon undulatus), bluefish (Pomatomus saltatrix) and a dolphin (Coryphaena hippurus), were observed following immersion of the fish in sea water to which had been added the mixture or in tests in which the material was administered orally. Only single doses were given orally while immersion allowed continuous exposure. With continuous exposure the fish increased in radioactivity with time, and there was evidence that the fish would become considerably more radioactive than the water. The uptake of radioactivity by the fish was rapid at first, with large concentrations appearing early in the internal organs on a unit of weight basis. Bone gradually increased in its radioactivity and accounted for the greater part of the radioactivity of the fish minus the internal organs. The muscle tissues slowly took up small amounts of the radioactivity. The internal organs had a major part of their radioactivity resulting from Ce^{144} and Pr^{144} while these were not present in the bone samples in an amount to be apparent in the analyses. There was a great accumulation of Sr^{89} and Sr^{90} by bone. From oral administration only small amounts of the radioactivity given were ever present in the fish tissues. Of the small amount present, 96 percent was accounted for in the muscle, bone and integument, chiefly in the bone and integument. On a unit of weight basis, however, liver showed the greatest accumulation. There was accumulation also in some other internal organs. Muscle tissues were always low in radioactivity. There was a slow rate of decay of the radioisotopes of the liver and almost no change in those of the muscle tissues. This probably resulted from an accumulation of the long lived Cs^{137}. Bone samples, and those of the integument, increased in radioactivity for approximately 20 days or more and then a slow rate of loss occurred. This indicates an accumulation of Sr^{90} in those tissues and a slow formation of its radioactive daughter, Y^{90}. Sr^{89} was present and its decay resulted in a slow loss of radioactivity of the bone following the 23rd day. The accumulation of these specific isotopes by different tissues was confirmed in tests of the aluminum absorption of their particles.

Cerium-144

The greatest percentage of the total radioactivity of fission product mixtures at the age of a year results from rare earth nuclides. Consequently, one of these, Ce^{144}, was obtained and its metabolism by marine fisheries organisms investigated.

Adding cerous nitrate in acid solution to sea water resulted in the formation of particles. The Ce^{144} of fission product origin added to sea water probably exists in the water in the form of particles. This fact has considerable bearing on its uptake by marine organisms.

Adding Ce^{144} to the medium in which phytoplankton was suspended resulted in a rapid initial uptake by the cells. Tests demonstrated that this resulted primarily from adsorption of the Ce^{144} particles to

the cell surface. When the nuclide was present chiefly in an ionic state, uptake by the cells was much less marked. Planktonic algae grown in the presence of Ce^{144} had a high radioactivity. Repeated resuspension of the cells in non-radioactive sea water removed a small percentage of the Ce^{144} each time.

Scallops immersed in sea water to which had been added Ce^{144} immediately became radioactive and continued to become more radioactive during the observation time of 20 days. At that time their shells and bodies, excepting the adductor muscles, were at least 100 times more radioactive per gram than the surrounding sea water. Undoubtedly a great part of the uptake resulted from adsorption to the surfaces of the scallop, but uptake from filtration was probably important.

Blue crabs, Callinectes sapidus, were given Ce^{144} by mouth. Only a small amount of the nuclide passed through the walls of the digestive tract into the blood and the tissues. There was marked accumulation in the hepatopancreas, or liver, and some in other internal organs. No accumulation in the shell was observed.

Zinc-65

Previous reports have described the uptake and the tissue distribution of Zn^{65} accumulated by marine fishes and other marine organisms. This nuclide, although not a fission product, was found in marine fishes following the testing of nuclear weapons in the Pacific Ocean and accounted for a large percentage of the total radioactivity of their tissues.

Further observations on the uptake and the loss of accumulated Zn^{65} by marine fishes demonstrated that high concentrations of orally administered zinc appeared early in the blood with a rapid uptake by the kidney and the spleen. There was considerable accumulation by the liver. A rapid loss took place from the internal organs accompanied by a slow and long-continued accumulation in the bone and the muscle tissues. When fish that had accumulated Zn^{65} from exposure to the nuclide in sea water were returned to flowing sea water, there was initially a marked loss of the Zn^{65}. Only about 20 percent remained after one day. However, 7 to 8 percent of that originally present was retained with almost no decrease in amount throughout the 25 days of observation.

Gill Efficiency of Clams

The efficiency of filtration of phytoplankton cells from sea water by clams was observed and measured in experiments in which two species of planktonic algae were present in the suspension, each labeled with a different radioisotope. It was, thus, possible to measure the removal of each species over a period of time from the same water passed through the filtering mechanisms of the clams.

Although there were a few observations indicating that clams could exercise some selectivity in filtration of different species of phytoplankton cells from the water. in most instances the clams removed the cells of each of the two species in the same ratio as they were present in the suspension. The cells of small species, however, were removed less efficiently than those of a larger species present and seemed to bring about an increased secretion of mucus. Species of dinoflagellates affected the clams and appeared to interfer with their water filtration activities.

IV. PENSACOLA LABORATORY (GULF OYSTER INVESTIGATIONS)

Philip A. Butler
Pensacola, Florida

Oysters

All phases of the oyster's life are studied to aid the commercial oyster fisheries. Research on the biology of local oysters continues to demonstrate that they are more responsive to fluctuations in water temperature than to other measurable hydrographic features (assuming the overall suitability of the environment). The timing of the 1957 reproductive cycle and the setting intensity have duplicated the pattern of 1956 when similar water temperatures occurred, although salinity levels have been decidedly lower this year. Setting started early in March, attaining a peak of $30/cm^2$/ week in mid-May and practically stopped at the end of June when water temperatures reached 85 - 95° F.

During the past year the experimental results, as well as the hydrographic data collected routinely, indicate the importance of water stratification to the biota even in areas where the total water depth is less than three meters. In both open bays, as at Apalachicola, and in constricted sounds, as the laboratory, salinities at the bottom may be five to seven times those at the surface at different tidal stages. On occasion, at a depth of two meters, differences of 13 parts per thousand were found. Differences in water temperatures while not as great may equally indicate environmental differences in the same general area. Such conditions resulted this year in the total mortality of some of the laboratory's experimental clam plantings and trays of scallops while vertical plantings only a few feet away were undamaged. Additional evidence along this line of inquiry appears in the laboratory's analyses of plankton pigments which indicate enormous differences in chlorophyl concentrations from top to bottom and perhaps, therefore, in shellfish food as well. The laboratory's data also indicate the extent to which wind may modify this marine environment.

Oyster Drills

Researchers observed that a majority of young drills first differentiate as males and during their first winter some of these reverse their sex to become females so that a 1:1 sex ratio is established among mature snails. The laboratory sexed 300 mature snails and isolated the males and the females in separate trays. Six months later the snails were examined again and one male was found in the female tray. Seven months later they were re-examined and the male group was still all male whereas there was a second male in the female tray which was also filled with capsules of fertile eggs. Since there were no reversals in the male tray and only two apparent reversals in the female tray, which might have been contaminants from drifting seaweed, sex reversal either does not occur in mature Thais or to such a slight degree that it is insignificant.

Conclusive experiments with the chemical metaldehyde, widely used as a control for terrestial snails, showed that it is selectively toxic to marine snails as well. Such high concentrations of it are required and its insolubility in water make using this chemical impracticable for drill control in oyster producing areas. Final experiments with hermit crabs show that they are of relatively little, if any, importance as natural predators of the drill in this area.

CLAM AND CHESAPEAKE OYSTER INVESTIGATIONS

John B. Glude
Annapolis, Maryland

SOFT CLAMS

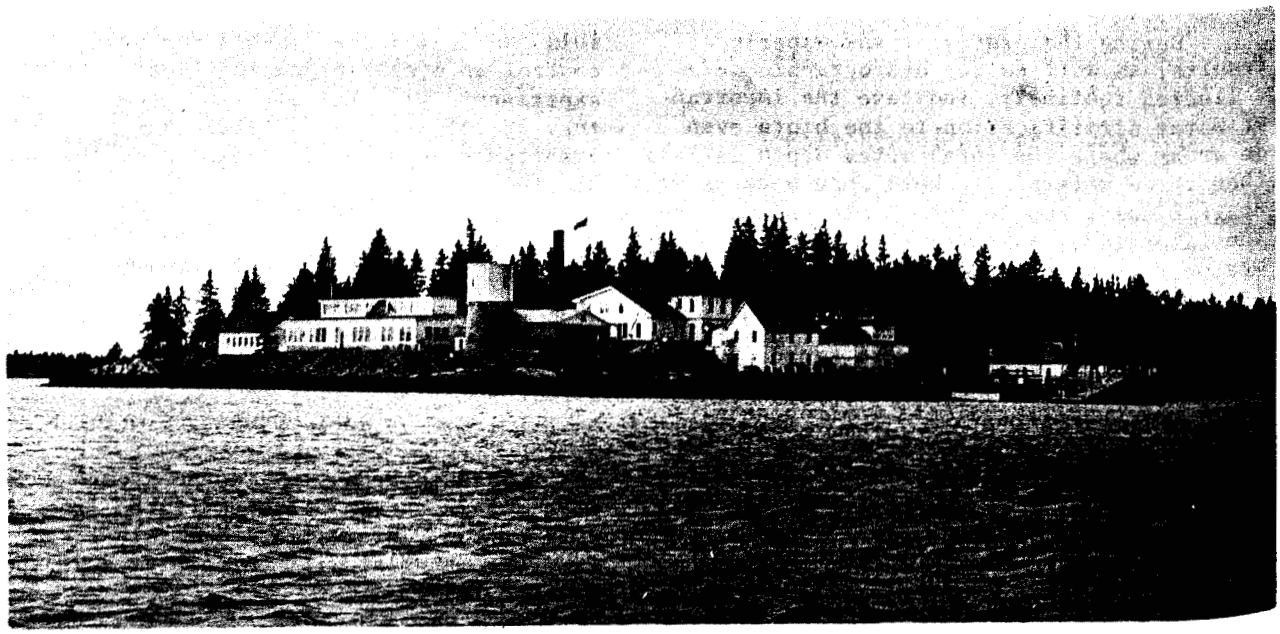
Sagadahoc Bay.--Size and growth data were obtained from all clams taken from the 1956 census. Statistical determinations from the material will be completed in the fall of 1957.

The population is still decreasing; its rate of decline was so low that the census was omitted in 1957 and will be taken biennially in the future until a definite change in the population is indicated, whereupon annual studies will be resumed.

Interviews withdiggers were continued to maintain the records of the volume of clams being removed from the bay. During 1956 the average catch dropped to a half bushel per man per tide. In the spring, however, because of the survival of a set in the outer part of the bay where crab predation is low the catch increased to one bushel per man per tide.

Monthly sediment samples were continued for the purpose of judging the success of setting in the bay. While the 1955 set was almost completely destroyed, a fair 1956 set occurred in the near shore areas. This set survived in numbers up to 60 clams per square foot up to the early spring of 1957. When the clams in this set exceeded the 5 mm. size, green crabs destroyed many of them.

Sam's Cove.--Monthly sampling at five stations within this area, which a low fence protected from crab predation, indicated a good survival of the 1955 year class. An excellent set occurred in 1956 and has survived well. The average concentration for the area in the spring of 1957 was about 100 clams per square foot and the highest concentration sampled was 324. Growth rates slowed down, showing the influence of



FISHERIES RESEARCH LABORATORY, U.S. FISH AND WILDLIFE SERVICE
BOOTHBAY HARBOR, MAINE

PORTION OF CLAM FLATS IN SAM'S COVE, BREMEN, MAINE, ILLUSTRATING EXCELLENT SURVIVAL OF SOFT CLAMS WITHIN THE FENCED AREA (SIPHON HOLES AT LEFT) AND NO SURVIVAL OUTSIDE (RIGHT SIDE)

a greater than optimum concentration of clams. The first of the 1957 set was found during the last week in June 1957. These clams ranged around .5 mm. in size.

Influence of Gemma on Mya set.--In several instances it has been pointed out that where the small bivalve Gemma gemma occurs in numbers, the soft clam will not be found, though the substrate may be suitable for its existence. In the spring of 1957 an experiment was started to test whether this may result from direct competition between the two species.

Several plots of sand were secured from Sagadahoc Bay, an area in which both Gemma and Mya occur, and were placed in Sam's Cove, an area of reliably heavy Mya set. Half of these plots contained Gemma and half only sterile sand.

Throughout the summer of 1957 weekly samples will be taken in these test plots to determine when and in what numbers young soft clams appear and to follow the interaction between the two species.

In addition to the above, a large area of Sagadahoc Bay was sterilized by steaming the flats at low tide with a common weed burner as a portable heat source. The area is probably large enough to prevent new Gemma from being washed into the plot. Since this organism, unlike the soft clam, does not have a planktonic stage, any repopulation will occur only from the migration of young Gemma. If a set of soft clams also appears in this area, then a natural segment of the flats will be available for studying the relationships of the two organisms.

GREEN CRABS

Tagging.--Of 250 crabs, Carcinides maenas, tagged with internal tags and held over winter in a submerged cage at Wickford Harbor, only 62 survived to spring. Up to June 28, 12 of the 62 died without shedding, 6 shed and 4 of these retained their tags. Because of the high winter mortality and the slow rate of shedding no conclusions can be drawn as to whether crabs bearing tags for long periods of time retain internal tags through molting. On May 2, 1957, 59 crabs were tagged and 12 of them shed. Ten of them lived through the molt, 8 retained their tags while 2 did not. Another group of 34 crabs tagged on June 12, 1957 yielded 9 shedders of which 3 retained their tags and 6 did not. Placing each crab in a plastic berry box reduced the numbers of crabs that can be held in the cage. However, the berry boxes eliminate canabalism.

Field studies.--The results of a 2-year study of the stomach contents of green crabs obtained from Plum Island Sound, Massachusetts, was presented at the March staff meeting. Emphasis was placed on the techniques employed in obtaining samples of the crabs. The largest numbers of crabs and the largest numbers having food in their stomachs were found in the early morning collections rather than in the late afternoon collections; this fact indicated that the crabs are primarily nocturnal animals. Data were presented to show that the crabs probably select small foods rather than large ones. Thus, new sets of Mya and Mytilus may be preyed upon heavily, especially since large numbers of small animals, such as Gemma and Hydrobia, appeared so frequently in the crabs' stomachs. A difference because of size or sex could not be demonstrated in the food habits of crabs which were over 30 mm.

Laboratory studies.--During the summer of 1956 approximately 250 green crabs were starved in the laboratory and then selectively fed over given time periods. Data were collected on sex differences in regard to food taken, volume of food material consumed and certain food preferences. Observations were made on rates of shell regurgitation and defecation in an effort to measure digestion rate. Some of the more important conclusions drawn from the study are:

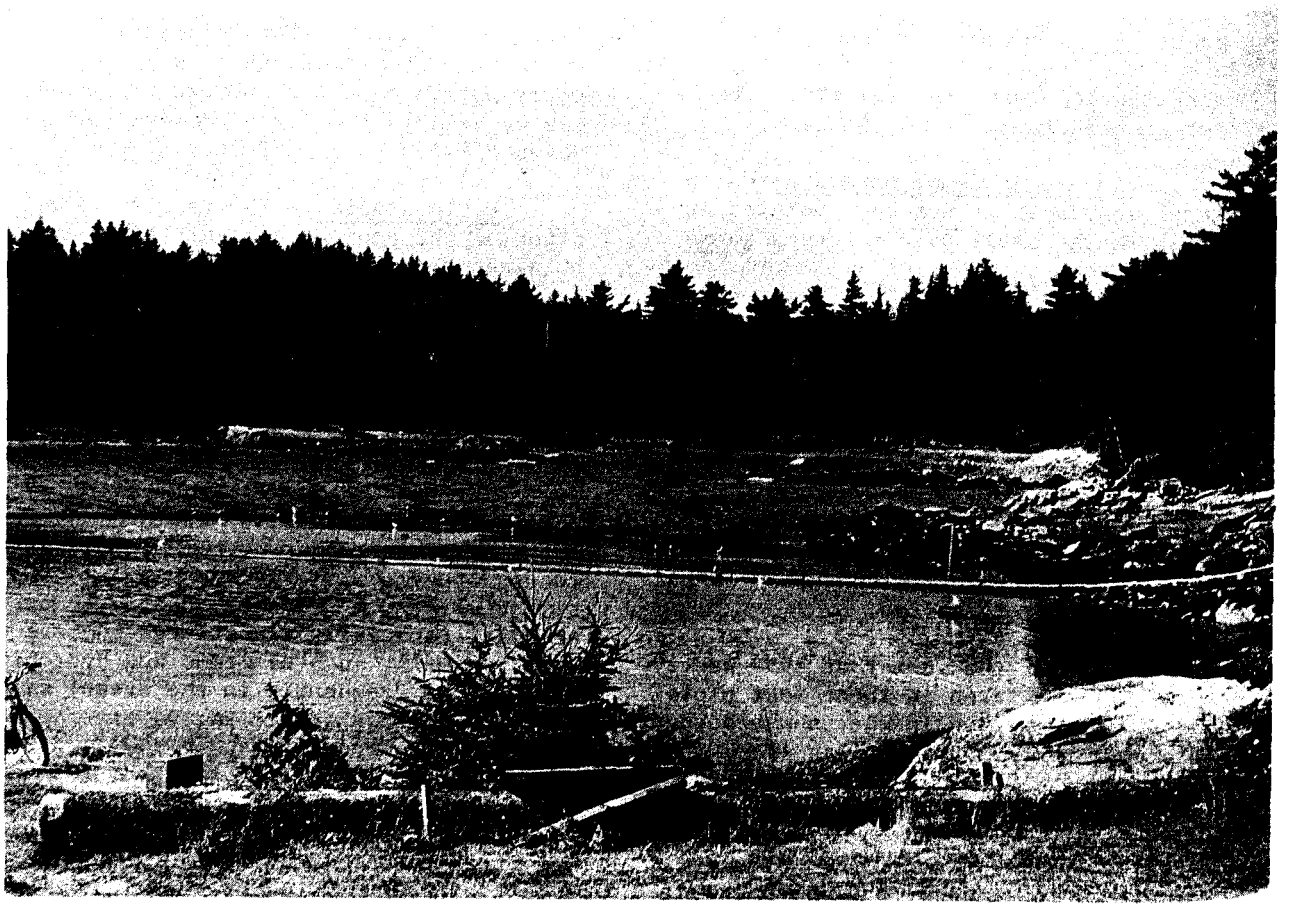
1. No appreciable difference in food habits obtained between sexes of similar size.

2. Shell is both regurgiated and given off with the faeces.

3. Stomach analysis is not a completely accurate quantitative measure of food consumption since in the majority of the cases the umbones of bivalves are not taken in.

4. No cases were noted where a clam over 4 mm. in length was consumed whole.

5. Crabs under 20 mm. can crush softshell clams of a length equal to their



500' FT. GREEN CRAB CONTROL FENCE ENCLOSING ABOUT FOUR ACRES OF CLAM FLATS IN SAM'S COVE, BREMEN, MAINE

carapace width. Crabs over 20 mm. can open clams of increasingly greater length than their carapace width and the largest crabs, around 70 and 80 mm., can handle any large softshell clam.

6. Starved crabs consume the entire soft parts of the clams. Crabs supplied with an excessive number of clams consume only the visceral mass and, after having consumed their limit, break up all remaining clams.

7. Crabs show little preference among small Mya, Mytilus and Macoma; however, when the clams are large, the crabs usually prefer Mya.

Tolerance to low temperatures.-- Under laboratory conditions simulating the exposed intertidal zone green crabs were exposed for various periods of time up to 12 hours to temperatures of approximately 10° F., 0° F. and -10° F. Within this temperature range in nature, the majority of crabs wintering in the intertidal zone would be safe. Since most of these crabs are buried in the sediments near the low water mark, their location is exposed to no more than two or three hours of air temperature. Although a high rate of mortality occurred among crabs exposed for a long period of time at the lower temperatures, good survival occurred among crabs exposed to even the lowest temperature range for periods up to four hours.

During 1956 good evidence was accumulated from ten localities in Maine and two in Massachusetts which indicated either heavy mortalities of green crabs during the winter of 1955-1956 or reduced populations in 1956 or both. In several of the cases of definite winter mortalities the deaths apparently occurred during the extremely cold periods of late December and early

GREEN CRABS DEAD AFTER FEEDING UPON CHOPPED ALEWIVES TREATED WITH LINDANE IN A CRAB CONTROL EXPERIMENT IN UPPER LANDING CREEK, WELLS, MAINE

January. During the winter of 1956-1957, however, numerous field observations in central and eastern Maine during the coldest part of the winter failed to reveal any widespread crab mortalities. A few instances of crab mortalities were reported during a thaw following an extended period of heavy icing. In the spring of 1957 several areas formerly supporting fairly high crab populations had a considerably reduced population. These areas too had extended periods of heavy icing during the winter. These findings, together with the results of the laboratory experiments, indicate that low temperatures alone cannot account for mass crab mortalities. Since oxygen is the only other environmental factor to which the green crab is known to be sensitive, a study will be made of its oxygen requirements to determine whether natural circumstances may arise which lead to oxygen deficiencies.

Control of green crab predation.--The improved model of anti-crab fence erected in 1956 kept the crabs from Sam's Cove throughout the 1956 season. Trap catches of crabs within the fence remained relatively low. A gradual increase in mean size accompanying a gradual increase in catch indicated that the crabs being caught were small ones which were growing within the enclosed area. These limited numbers were soon reduced to a low level, however.

Using the Clam Investigations' basic anti-crab fence design, the Maine Department of Sea and Shore Fisheries, mostly in cooperation with clam-producing towns, in 1956 installed over 7,000 feet of fencing.

In late November, when the crab activity had greatly diminished, the fence was taken down for the winter. The new design, incorporating removable panels of fencing, greatly facilitated the disassembly. The fence was reassembled during April and a trapping program is again being carried out as a check on crab concentrations both inside and outside the fenced areas.

Another method of controlling green crabs is with Lindane (gamma isomer of benzine hexachloride). Expermments reported in fiscal 1956 indicated that Lindane was extremely toxic to green crabs in dilutions as low as one part in 10 million parts of water.

Two large-scale experiments were conducted in the Upper Landing Creek and Popes Creek systems in Wells, Maine during the summer of 1956. Frozen alewives saturated in a 20 percent commercial solution of Lindane were used as bait and distributed along the shoreline. Costs amounted to $21 per mile for materials and $22 per mile for labor. Both experiments resulted in mass mortalities of green crabs which brought about temporary reductions in populations. The trapping program indicated that the catch fell from about 100 crabs per trap

per day before the operation to a maximum of seven crabs per trap per day afterwards. Green crabs remained in low numbers during the remainder of 1956. However, preliminary surveys in the spring of 1957 indicated that the crabs had migrated back into the areas and the population numbers seemed as high as ever.

The temporary reduction occurred at a critical time in the annual cycle of the soft clam population when the crabs are extremely active and when the small clams are reaching a size readily available to the crabs. The reduction was probably responsible for the good survival of a dense 1956 set of clams.

Annual estimate of green crab abundance.--The trapping method consisted of fishing three standard traps in each location for two days during the first part of each month for the period May through October. Fresh herring, a standard bait, was used whenever possible. Trapping in Maine was done with the cooperation of the Maine Department of Sea and Shore Fisheries and in Massachusetts with the Division of Marine Fisheries and Town Shellfish Officers. The following table shows the results of four years of trapping:

Table 1.--Mean catches of green crabs for comparable periods--catch per trap per day.

	1953	1954	1955	1956
Maine:				
Jonesport	300	153	235	332
Trenton	152	155	239	3
Southport	79	113	175	190
Kennebunk River	37	125	47	--
Massachusetts:				
Plum Island Sound	215	129	238	250
Rhode Island:				
Narragansett Marine Lab. Basin	--	--	9	--
Narrow River	--	--	38	78
Potter Pond	--	--	132	135
Connecticut:				
Niantic River	--	--	268	--

Predators of green crabs.--To test the suggestion that populations of green crabs may be checked within their natural range by a heavy predation by fish, the following studies are being conducted:

A beam trawl having a 6-foot mouth and a 12-foot bag was constructed to obtain fish specimens from shallow water areas south of Cape Cod, Rhode Island, inhabited by green crabs. The stomach contents of the fishes will be examined to see if green crabs are being preyed upon. Much of the sampling has been exploratory in nature and the results of stomach analysis have been meager. Samples of fish have been obtained also by trawls from the deep water areas of Narragansett Bay but they have yielded no fishes having green crabs in their stomachs. The beam trawl has been useful in locating green crabs in salt ponds about Narragansett Bay. Large numbers have been caught in Fox Hill Pond on Conanicut Island and others have been dredged from Charlestown Pond.

The collection of fish in waters north of Cape Code, Maine was begun in June. Various types of fishing gear are being employed near shore in areas where green crabs abound.

HARD CLAMS

Productivity in Greenwich Bay, Rhode Island.--Two biologists of the Clam Investigations continued on detail to the Office of River Basin Studies of the Fish and Wildlife Service during most of fiscal 1957 for studies in connection with the proposed hurricane control barriers. As a result of these studies, the hard clam census of Greenwich Bay was expanded to cover all of upper Narragansett Bay. These data which showed the present distribution and density of hard clam stocks can be correlated with the same data after construction of the barriers.

From April to November 1956, 2,482 bottom samples were taken. This number included the annual census of Greenwich Bay. In addition, 305 samples taken in late 1955 and early 1956 in the Providence River and Mount Hope Bay were used also.

The total abundance of hard clams in Greenwich Bay declined to the lowest point in seven years of study. The density for 1956 was about 0.38 per square foot. Although the total population declined, the sublegal population slightly increased from the low point in 1953. This is in contrast to a steady decline in the legal population from the high point in 1953. The geographical distribution of hard clams in Greenwich Bay remained in general the same as in previous years, with the high and low density areas in approximately the same position. The total catch of hard clams in Greenwich

Bay, based on interview data, was the lowest of any year since the study began. The catch, however, in 1956 was made up of nearly equal numbers of "necks" and "large". This is in contrast to all previous years when the catch of "necks" was greater than the catch of "large". This indicates a shift in the fishery to concentrate on the accumulated stock of "large" hard clams.

The other parts of upper Narragansett Bay showed some contrasts with Greenwich Bay. The density of hard clams in the Providence River was much heavier than that of any other locality. The density for 1956 was 1.56 per square foot; this is nearly twice the next most dense area and nearly 20 times the least dense area. It is five times the average density for upper Narragansett Bay. Providence River showed the heaviest densities for "sublegals", "necks" and "large" size categories. The Hope Island area had the lowest hard clam densities. Greenwich Bay ranked close to the average for upper Narragansett Bay in all size categories. A series of distribution diagrams were plotted for total all sizes, "sublegals", "necks" and "large". These charts which show the areas of high and low concentration in upper Narragansett Bay have evoked much interest from the fishermen.

Clams planted in the subtidal area of Greenwich Bay in the fall of 1955 to study growth were redug in the spring of 1957. Of the 550 hard clams planted, 364 were recovered by tonging and SCUBA diving. Growth in the 20 months was 16.7 mm. The mean planted length was 42.8 mm. and the mean recovered length 59.5 mm.

Seasonal abundance of Venus larvae vs. density of set-of-the-year in Wickford Harbor.--Under the right circumstances a relationship would probably exist between the seasonal abundance of Venus larvae in an area and the abundance of set found in the area at a later date. Perhaps the prime prerequisite for this relationship is that the area have an independent or nearly independent water circulation. During fiscal 1957 the data for 1953-1956 from Wickford Harbor were analyzed for this relationship. A summary of these data is presented in table 2. Values are presented as index numbers showing relative abundance between years in each column. Each column uses 1953 as the base value for that column. The table shows that while the relative abundance of both categories of larvae fluctuated within a narrow range during the years under consideration, the relative abundance of set increased markedly each successive year. Apparently there is no connection between larval abundance and set density in Wickford Harbor.

Table 2

	Index numbers		
Year	Early larvae	Mature larvae	Set
1953	1	1	1
1954	2.4	1.4	2.3
1955	2.1	2.1	6.7
1956	4.4	1.3	32.3

Spat trap studies.--Results of previous attempts to collect hard clam seed by using the "tidal spat-trap" showed that the larvae could successfully be retained and would settle out as spat. However, the numbers collected were small and no greater than could be found in the field. The quantity of larvae bearing water filtered by the trap appeared to control the abundance of seed. Consequently, during the 1956 field season two dock traps were operated in addition to the tidal trap. Pumps supplied these spat traps with water. During the spawning season an estimated 5,400 mature Venus larvae were introduced into dock trap #1 and 3,500 into trap #2. Subsequent sampling of the resultant set yielded 24 seed per square foot in trap #1, 808 per square foot in trap #2 and 4 per square foot in the tidal trap. The number of larvae taken into the tidal trap could not be estimated but it was undoubtedly much lower than that in either dock trap. A bronze pump supplied dock trap #1. The toxicity of copper may account for the low initial number of seed in dock trap #1. Subsequent heavy mortality in dock trap #2 reduced the abundance of seed to 4 per square foot. No explanation can be offered for this. The fact remains that an initial set far exceeding any hitherto obtained either in a spat trap or in the field had been caught.

A pumping procedure similar to that used in 1956 was set up for the 1957 season, but two important differences must be mentioned: (1) the pumps were new, all-iron construction, with plastic intake and discharge lines and (2) because of a fortuitous circumstance, many more mature Venus larvae were available. Sampling for the resultant

set will be done in the near future.

Predation studies.--Five experiments were started and four completed during fiscal 1957. Experiment #1 involved three plantings of 900 hard clams each (less than 15 mm. in length). One planting was protected by a covering of 8 x 8 meshes to the inch Saran plastic screen. Another planting was made inside a wooden frame about 3-4" high with a horizontal 3-4" flange directed outward. The third planting was unprotected. The experiment ran from May to the end of October. The results follow: unprotected, 31 percent survival; wooden frame plot, 62 percent survival; and Saran-covered plot, 82 percent survival.

Experiment #2 consisted of five plantings of 1,000 Venus each (3-13 mm. in length). These plantings were made within barriers of the following material and design: (1) straight wood sides, (2) straight wood sides with a strip of copper around the top to discourage entry of oyster drills, (3) aluminum flashing, (4) heavy gauge linoleum and (5) ingot iron sheet metal. These barriers stood off the bottom from 6-10". The plantings were made in mid-August and on October 30 the ingot iron and the aluminum flashing plots were dug up. The results follow: ingot iron, 63 percent recovery, and aluminum, 61 percent recovery. All barriers were left in place to test their durability to winter conditions. Icing was severe in January and the linoleum barrier was crushed almost to the level of the substrate. The remaining barriers were either torn loose or settled until their tops were nearly level with the substrate by spring. Because of the fate of these barriers no attempt was made to redig the plots.

Experiment #3 consisted of a planting of 405 hard clams (12-23 mm.) with no protection against predation. This planting also was made in mid-August and dug up in late October. Recovery was 84 percent. This demonstrates the rapid decline in the predatory efficiency of crabs in Wickford Harbor when the length of the hard clam exceeds about 15 mm.

Experiment #4 consisted of planting 600 Venus (13-24 mm.) with no protection to test the degree of predation on this size range of Venus. The planting was made on November 6, 1956 and a few clams died during the winter. As of June 30, 1957 no evidence of crab or drill predation had been noted. This planting will be dug up in the fall of 1957.

Another experiment was set up in mid-June 1957 and is being maintained. It utilizes a combination of mechanical and chemical control methods. Thirteen plants of 1,000 Venus each (4-11 mm.) have been established. There are nine different treatments and four replicates. The experiment will be examined in the late fall of 1957.

Parasites of the green crab.--A survey of the parasites of the green crab which might be used to effect biological control resulted in identifying two of its principal parasites. The first, a crustacean parasite found in the egg masses, was identified by Professor Martin Johnson of La Jolla, California, as a harpacticoid copepod Choniosphaera cancrorum n.g., n.sp., described by C. J. Connolly in 1929 from eggs of the rock crab, Cancer amoenus, along the North Atlantic coast of America.

Harpacticoid nauplii abundant in the haemocoele of apparently healthy crabs may be a stage of this same species, but this remains to be established.

The other principal parasite is a trematode, Microphallus similis Jägerskiöld (1900), which passes from snails of the genus Littorina to the green crab to gulls. This parasite has caused the death of crabs by heavy infestations produced in the laboratory, but such conditions would probably not occur in nature.

The survey of parasites showed no significant difference in degree of infection of specimens taken north and south of Cape Cod. The most frequent and abundant parasite was the trematode mentioned above. It was found both north and south of the Cape and sometimes abundantly in crabs from Boothbay Harbor, Maine. Crabs are often heavily infected in nature but do not appear to be seriously harmed.

No protozoan parasites have been found that could serve as effective control agents.

In the continuing study of the parasites of Mya arenaria, an effort is being made to work out the life cycle of Cercariae myae and the metacercariae from Sagadahoc Bay soft clams and to determine if they both

may be stages of a single species of Gymnophallus. In the spring of 1957 specimens of adult trematodes were obtained from adult eider ducks from the vicinity of Boothbay Harbor. The eggs from these adult worms were fed to both Hiatella and Mya which will be examined later for the presence of Cercaria. Eider duck eggs were obtained also in the spring of 1957 and the young ducks hatching from them were fed a sterile diet and then infected with metacercariae from Mya. These ducks will be examined for adult worms; if found, they will be compared with those from ducks in nature and from ducks similarly raised and fed metacercariae from Mytilus.

BOTTOM SURVEY

This program, started in 1955, was intended to ascertain the typical common fauna living on and in the level areas of the local sea bottoms. The information gathered in conjunction with cooperative projects in Europe and along the Atlantic and Gulf coasts is expected to lead to the delimitation of world-wide animal communities in relation to marine ecological conditions. A manuscript dealing with the more than 13,000 individual organisms identified from the 1955 samples is nearing completion. In 1956 samples were taken in the Boothbay Harbor area. All organisms have been removed from the samples and sorted.

CLAM INVESTIGATIONS IN THE CHESAPEAKE AREA

Soft clam projects.--Two soft clam experiments were set up at Warehouse Creek on Eastern Bay during June 1957. In one experiment eighteen 1' x 2' x 7" deep trays were dug into the bottom. Six trays were covered with 1/4" asphaltum-painted galvanized mesh screen. Six were uncovered and to six trays a strip of 1/4" mesh screen was attached around the outside edge which extended three inches above the tray surface. The purpose of this strip was to prevent any movement of the clams from the trays and to eliminate displacement of clams by wave action.

Into each tray 100 small clams, averaging about 25 mm. in length, were introduced and all trays protected with screen covers until the clams buried themselves; the covers were then removed from the unprotected trays and the trays with sides. In the fall of 1957 a series of three trays from each group will be removed and the other series of nine trays will be removed in the spring of 1958. The objective is to measure the natural and predator mortality and growth during various periods of the year. The other experiment consists of two 8' x 8' plots, one of which was fenced with 1/2" mesh screen extending above high tide level and the other unfenced. Clams were introduced into each plot at a concentration of 50 to the square foot. Protection was placed around the unfenced plot until the clams buried themselves. Sampling within these two plots will be conducted in the fall of 1957 and in 1958 to measure natural and predator mortality and growth of clams.

Hard clam projects.--Studies on the hard clam are being conducted at Chincoteague Bay. Three experimental plots were established: one plot in mud substrate at Franklin City, one in the subtidal zone (mud substrate) at Watts Bay and another one inshore in the intertidal zone in sand substrate.

At Franklin City three groups of four trays were buried in a random block design. Each tray contains two compartments with an area of 1.5 square feet per compartment. In a manner similar to the plot of trays set out at Warehouse Creek some of the compartments were covered with screen, some uncovered and others with screen sides. Clams used in these plots were hatchery reared at Milford, Connecticut laboratory. Three sizes of clams were planted in order to measure the natural and predator mortality and growth by size groups.

At Watts Bay similar plots were established and, in addition, at each plot two covered trays were set out with 1956 set Rhode Island clams obtained from a natural clam bed. Two covered trays of small and medium size clams were also set up in which a substrate different from that placed in the plot was used. The objective of these experiments is to measure the growth and the natural mortality by substrate and to assess the effect that substrate, tidal zone and size of clams have on predation. The reseachers hope to determine if a singificant difference exists between the natural mortality and the growth of hatchery-reared and naturally reared clams.

OYSTER DRILL CONTROL

Drill trapping in Chincoteague Bay.--Trapping oyster drills with 40 oyster-bait-filled wire bags per acre removed 100,000 of them from 12 acres in two years. The removal of this number of drills was sufficient to permit a survival of approximately 1,200 oyster set per bushel of planted shells in 1956. This is a set of oysters of commercial significance in this area. In 1955, the first summer of these experiments, the planted shells on this plot failed to catch a commercial set of oysters although shells in wire bags held off the bottom caught oyster set at the rate of 500 or more spat per bushel of shells. An adjacent plot from which no drills were removed showed no catch of oysters able to survive the season of 1955 or that of 1956. In fact, a line of oyster baited traps was set out in 1956 to test the rate of destruction of bait and in two weeks the drills killed every oyster on this plot. Nevertheless, drill trapping at the rate described, persistently carried out even in the presence of new oyster set, can remove enough oyster drills to save many seed oysters which would not have survived had no control been exercised.

Another factor of significance developed from the trapping program. That was the importance of the current recruitment on the maintenance of the drill population. Unless the young drills of the year are killed or removed a trapping program is only partly effective. The trapping results of 1955 and 1956 illustrate this. Until August 20, 1955 the catch records on each of the three plots were quite alike but after that time plots #2 and #3 began to show increasing numbers of small Urosalpinx in the catch while plot #1 lacked this size group. Small drills constituted 63 percent of the catch on plot #3, 51 percent on plot #2 and 29 percent on plot #1.

There must be a reason for such a difference in the rates of recruitment on these plots. On plot #1 a definite step to control the recruitment of young drills was made by immersing all traps in a weak copper sulfate bath at the peak of the drill egg case deposition. No such step was taken on plots #2 and #3 in 1955.

All plots in 1955 and 1956 were trapped alike to remove juvenile and adult drills. The copper sulfate method of killing drill embryos used on plot #1 appeared, therefore, to be a significant agent for reducing the number of drills contributed by the current hatching. This method of control was proposed and tested by Engle in 1940 and reported to the oyster industry in 1941 and confirmed by Newcombe in Virginia in 1941-1942 and Lindsay and McMillin in Washington in 1945, 1949 and 1950.

A plot trapped in 1955 yielded 8,000 Urosalpinx of which 3,200 were young of the year caught in September. These young of 1955 were the bulk of the early 1956 season catch of drills. All traps were dipped in a copper sulfate solution when the egg cases appeared during the summer of 1956. At the end of the summer, when the current recruitment of young drills would normally appear in great numbers, only 665 were caught or only 20 percent of the number caught the previous year when the plot was not treated.

Another testing of the effectiveness of the copper sulfate dip to kill drill embryos was performed on another plot in 1956. In 1955 a plot receiving the dip treatment at the proper time yielded only 330 young drills or 7 percent of the total catch. In 1956 this same plot was trapped but not dipped and 1,834 young drills or 33 percent of the total catch was caught. On a plot undipped in 1955 but dipped in 1956 the number of small drills dropped from 41 percent to 5 percent from June to August.

From a plot trapped each year but not dipped in copper sulfate either year the catch of young drills was 1,150 for 1955 an and 1,200 for 1956 or 25.2 and 24.8 percent of the total catch. Trapping at the rate used here appears to be able to hold a population of drills at a certain level but is not effective in reducing the numbers unless the annual recruitment is reduced at the same time. The combination of the trapping and the dipping of traps appears to be effective in controlling drills sufficiently to produce seed oysters. Oyster seed caught on planted shells on these plots will be protected by these methods during 1957 to determine how many can be brought to harvesting size.

Drill trapping in York River, Virginia.--Oyster drills are abundant in lower

Chesapeake Bay and its tributaries whose salinities remain above 15 parts per thousand during most of the year. York River is one of these. Wormly Rock, a natural oyster bar in lower York River, was chosen as a place in which to perform trapping experiments because it had drills and supposedly the stable salinity needed to maintain a drill population. Two areas of three acres each were reserved for the drill control experiments. One area was trapped with 93 oyster-baited traps per acre and the other was untrapped. Clean shell was planted on each area in the spring of 1955.

The results of these protection experiments follow:

1955. On planted shells 75 percent of the total oyster set survived the first season on the trapped area while 53 percent survived on the untrapped area; 5.9 percent of spat were drilled on the untrapped area.

1956. On the planted shell 80 percent of the total oyster set survived on the trapped area while 62 percent survived on the untrapped area; 5.8 percent of the oyster spat were drilled on the trapped area while 19.0 percent of the oyster spat were drilled on the untrapped area.

Drills were much less numerous on these beds than in the Chincoteague Bay beds which account for a moderately good survival of the spatfall even on the untrapped area. The observations on trapping showed that removing oyster drills at the rate possible with 93 traps per acre helped to save 20-25 percent of the oyster set of the two years under observation.

Freshets following a hurricane radically changed conditions in this area and the natural population of drills was reduced by lowered salinity, a most effective control. To continue the study on the value of trapping as a drill control method, the operation in lower York River was terminated on May 1, 1957 and transferred to the Chincoteague Bay to increase the effort there and to consolidate the project where drills and oysters were more abundant.

Future plans.--The excellent set of oysters during 1956 in Chincoteague Bay provided an opportunity to obtain good seed which could be used to evaluate the economic aspects of drill control by trapping. The State of Maryland Department of Research and Education made available 700 bushels of seed caught on planted shells in the vicinity of Ocean City, Maryland, and is cooperating in the following experiment. This experiment includes three methods of drill control either practiced by the industry or advocated by the United States Fish and Wildlife Service and will be continued until the winter of 1959-1960 when the oysters are expected to be of market size. The experiment consists of seven plots, each containing four acres and separated by untouched strips of native oyster land. In the control area, 100 bushels of seed oysters were planted in the center of the 4-acre plot, the planting covering almost a half acre.

In two 4-acre plots the bottom was cleaned by repeatedly dragging a commercial oyster dredge lined with a fine mesh bag over the plot until practically no shells or debris were obtained. The seed oysters (100 bushels in each plot) were planted in the center of each 4-acre plot, the planting covering almost half an acre.

In two additional plots the bottom was cleaned as described above and the oysters were planted in the same way. However, oyster drills will be trapped in these plots by using 40 bags of seed oysters distributed throughout the area in which the seed oysters were planted. These traps will be fished once a week during the warmer months of 1957, 1958 and 1959.

The final two plots were cleaned, planted and will be trapped in the same way as the two plots described above except that the drill traps will be immersed periodically in a copper sulfate solution throughout the spawning season to destroy drill embryos in the egg cases. This treatment will continue for the summers of 1957, 1958 and 1959.

At the end of the experiment the oysters will be harvested by commercial oystermen and production determined. Cost account records will be kept for the entire operation to determine whether these methods of drill control are commercially practicable.

Drill control by copper fencing.--In the first 40 days of an experiment at

Chincoteague Bay, Virginia 539 Urosalpinx entered the control area, which was fenced with a galvanized iron hardward cloth fence four inches high. During the same period only 14 Urosalpinx were found inside the enclosure which was fenced by a brass screen of the same height and two of these were believed to have crawled under the fence through a hole dug by crabs. Only two Urosalpinx were found inside a third experimental area which is surrounded by a plastic screen fence with a 3/4-inch wide copper strip around the outside. Both drills were believed to have crawled under the fence when wave action washed one corner of the fence clear of the bottom.

There was no indication of less setting or greater mortality of oysters which might have been caused by copper in the two experimental plots as compared with the control.

The brass screen fence has remained in place in the intertidal zone for a year but is less effective in repelling drills than it was in the summer of 1956. This experiment will be continued to determine the maximum time which a brass screen fence can be used under the severe conditions of the intertidal zone.

One of the limitations of copper barriers is that the dissolved copper may change the color of the oysters immediately adjacent to a fence to a bluish-green. In the Chincoteague Bay experiment during the summer of 1956, 92 percent of the oysters within 18 inches of the 4-inch brass screen were greenish after four months. Only 8 percent of the oysters within 18 inches of the plastic and copper fence were greenish at the end of this period and none of the oysters in the control plot was green. Later fence designs use smaller quantities of copper which reduces the discoloration of the oysters as well as the cost.

A test was made at the Boothbay Harbor, Maine laboratory of a snail fence which was made of chain, Saran plastic screen and styrofoam floats; a 1-inch strip of copper screen was used as a chemical barrier. This fence resembles a miniature seine with the chain as the lead line and the styrofoam floats holding the screen erect. The copper screen is stapled to the outside of the fence approximately 1/3 of the way down from the top. The height of this fence is approximately 6-1/2 inches. It is hoped that the flexibility, ease of construction and installation of the fence will make its use economical since tests in the laboratory and in a tidal area have indicated that it is effective in design and as a barrier. Six 1/100-acre plots were set up at Watts Bay, Virginia during June 1957 to test the flexible barrier and to compare it with the designs used in 1956.

In line with the work on copper barriers, nine anti-fouling paints were tested at the Boothbay Harbor laboratory for effectiveness as barriers for drills. Six of these paints proved to be effective barriers to oyster drills, Urosalpinx and Eupleura, in laboratory experiments. Field experiments are being set up in Watts Bay to test the effectiveness of these six paints under natural conditions.

Laboratory and field observations of barriers raised the question whether the repelling properties of copper resulted from its electropotential or the chemical release of copper ions. In laboratory experiments at Boothbay Harbor, fences of inert carbon were connected to a 12-volt battery through a variable resistor and given an electropotential of 270 millivolts which is similar to that of metallic copper in sea water (240 millivolts). Drills readily crossed this carbon barrier but were repelled by the copper barrier. The voltage in the carbon fence was then increased to 1,300 millivolts and later to 12,000 millivolts without repelling Eupleura, Urosalpinx and Nassa. The electropotential does not explain the repelling action of copper and, therefore, the release of toxic copper ions probably causes the effect.

Control by suction dredging.--The small-scale model being tested removes drills from the bottom at the rate of 800 per hour when the drill population is 25,000 per acre. The drill dredge at this rate can remove in a 10-hour day about the same number of drills as 93 traps tended weekly can remove in a season. While this speculation is based on limited dredge information, it is encouraging because trapping at this rate can remove enough drills to permit a better survival of oyster spat than was found on an untrapped area.

The drill dredge in tests in 1956 showed a maximum efficiency of 15 percent.

To examine the gear while in operation, Fish and Wildlife Service SCUBA divers observed the action of the dredge on the bottom at different towing speeds for several hours. As the speed increased the dredge was inclined to jump or bounce. When the towing speed was reduced to two knots or less, the cutting blade tended to pile up bottom material in a rolling heap ahead of it, and only a small amount passed over the collecting screen of the dredge.

To maintain a constant movement of bottom material over the collecting screen, a towing rate of three knots was needed. At that rate, however, the dredge did not keep a constant contact with the bottom. Diving blades were designed and attached ahead of the cutting blade to overcome this condition. This addition increased the efficiency of the dredge by 3 percent.

OYSTER SPAT COLLECTORS

Standard cultching practice in the oyster industry consists of broadcasting shells on suitable bottom. The setting potential of the mid-depth water mass is not utilized commercially on the Atlantic coast, although such utilization has proven commercially feasible in Japan and on the Pacific coast of North America.

Various test surfaces, in addition to oyster shells, which are believed to be acceptable to setting oyster larvae were exposed on the bottom and at mid-depths in two different places in Chesapeake Bay having dissimilar hydrographic characteristics. One of these was a protected, shallow depth, slow current, good setting tributary; the other was the opposite of this in environmental factors.

Test surfaces include coated 2" x 2" poles, strings of pierced oyster shells hung on wires and oyster shells in wire bags resting on the bottom. Some poles were coated with fragmented shells known to poultry farmers as "large grits"; others with concrete. While shells on strings were oriented the same on each string, shell bags were filled haphazardly. Some strings were hung with shells with the smooth inner face upward; others with shells with the smooth inner face downward. The coated surfaces of the poles and the shell strings were five feet long installed vertically from the surface to the bottom at mean low water.

Shells on the bottom in wire bags caught an average of four spat per shell at the deep water area and one spat per shell in the shallow water area. Commercial cultch in the shallow water area also obtained an average of one spat per shell. In general, this indicated a low setting rate at each of the testing sites. This also reflected the low setting results reported from other parts of the upper Chesapeake Bay.

Mid-depth studies were made on suspended shell strings and poles coated with concrete and shell grit stuck in the bottom. The low setting rate made conclusive evaluation difficult. Spat setting on poles showed a slight preference for shell grit coatings to concrete coatings. Fouling was about equally abundant on each type of coating. Coated poles did not seem as good a setting medium as shells.

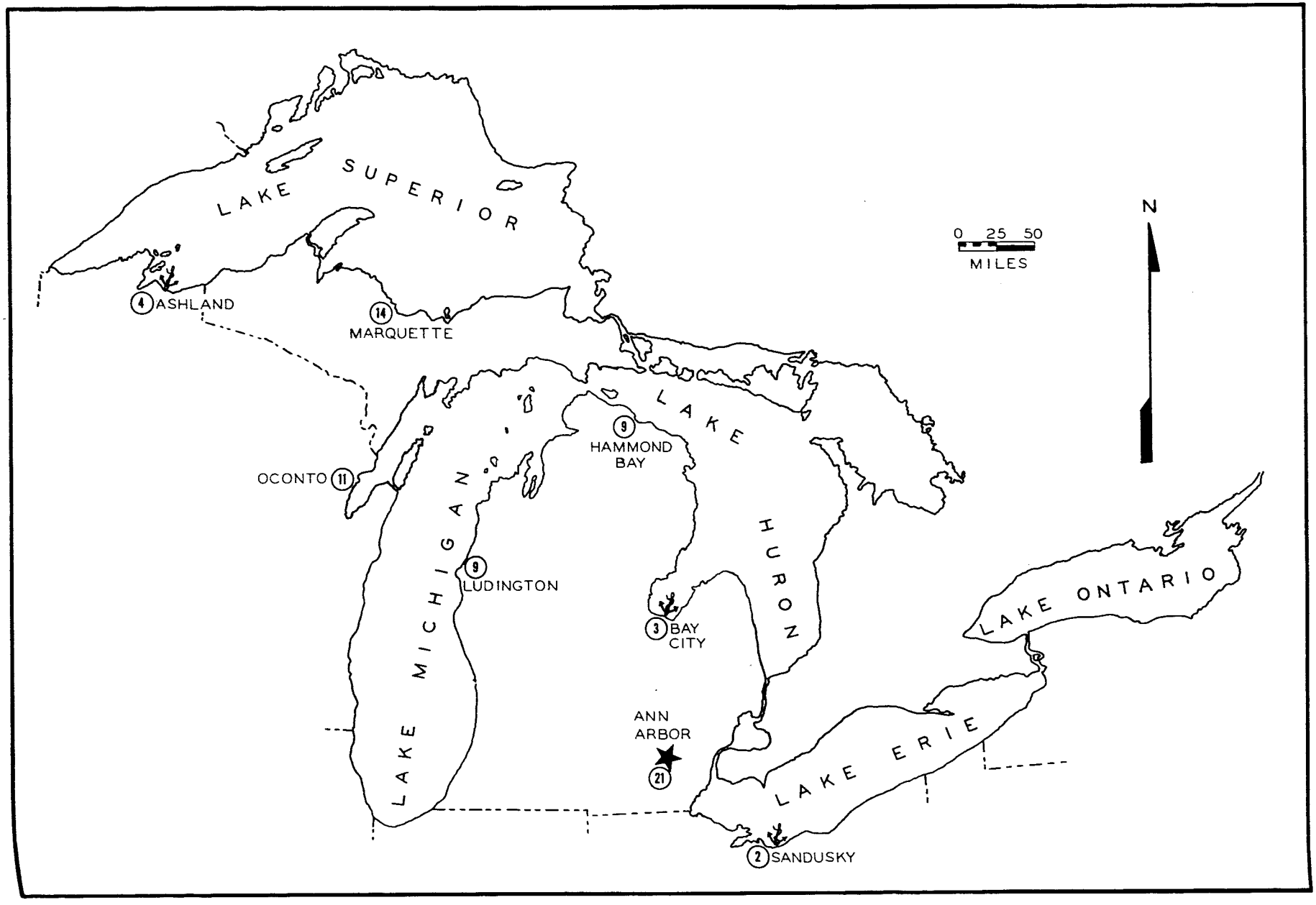
Spat setting was slightly more abundant on lower than on upper portions of poles and shell strings. In the shallow, or 5-foot depth area, spat occurred from the bottom to the 4-foot level and in the deep or 10-foot area spat occurred from the bottom to the 7-foot level.

A spectacular differential setting according to depth zones appeared on suspended shell strings. Measuring up from the bottom better than 50 percent of setting was found within the 1-foot zone and fully 80 percent within the 2-foot zone.

Tests of setting preferences between cleaned and dirty shells were inconclusive. In one instance the spat count on cleaned shells was eight times the count on dirty shells similarly suspended nearby. In another instance, the spat counts on clean and dirty shells exposed together in bags showed no clear preference for original cleanliness.

The physical texture of shell surfaces appeared effective in setting frequency. Despite shell orientation more spat attached to the rough outer surfaces of shells on strings and in bags than to the smooth inner surfaces.

Shell orientation appeared a factor in setting frequency. In spite of surface texture spat were more numerous on the under surfaces of the shells on strings than on the upper surfaces.



FIELD STATIONS (CIRCLES) AND GENERAL HEADQUARTERS (STAR) OF GREAT LAKES FISHERY INVESTIGATIONS AND HOME PORTS OF VESSELS (ANCHORS). THE NUMBERS INDICATE FULL-TIME PERSONNEL AS OF JUNE 30, 1957

Other trends appeared in the spat counts. General setting frequency decreased up the creek with station location. Spat survival decreased also in the same direction. These differences obtained both on test shells and commercial cultch.

The spring and summer program of 1957 under this investigation is a pilot application of the utilization of the mid-depth zone for seed collection on a streamlined commercial basis. The mid-depth collectors will be compared in all phases of effort with the regular broadcast system of distributing cultch.

SECTION OF INLAND FISHERIES

William F. Carbine
Washington, D. C.

Fresh-water fishery research includes studies on the Great Lakes sport and commercial fisheries; fish in federally controlled waters and improvement of fish culture.

The research is designed in part to assist other governmental agencies and stress resource conservation common to many states. Most of the research is designed to provide the facts and principles required by these agencies for the proper management and utilization of their fishery resources. The research in physiology, pathology and nutrition of trout and salmon assist federal, state and private hatcheries in increasing their efficiency, thereby providing better fishing and ensuring the perpetuation of important sport and commercial species.

GREAT LAKES FISHERY INVESTIGATIONS

James W. Moffett
Ann Arbor, Michigan

The Great Lakes are producers of the choicest fresh-water fishes in the United States. The production fluctuates much more than it should and fisheries for certain species collapse or sporadically expand to the ultimate disadvantage of all concerned. These fluctuations and their underlying causes are incompletely understood although specific causes, such as sea lamprey invasions, have received considerable attention. Solution of the problems of sustaining production and development and application of economical methods for control of such known causative factors as sea lamprey predation are the ultimate objectives of these investigations.

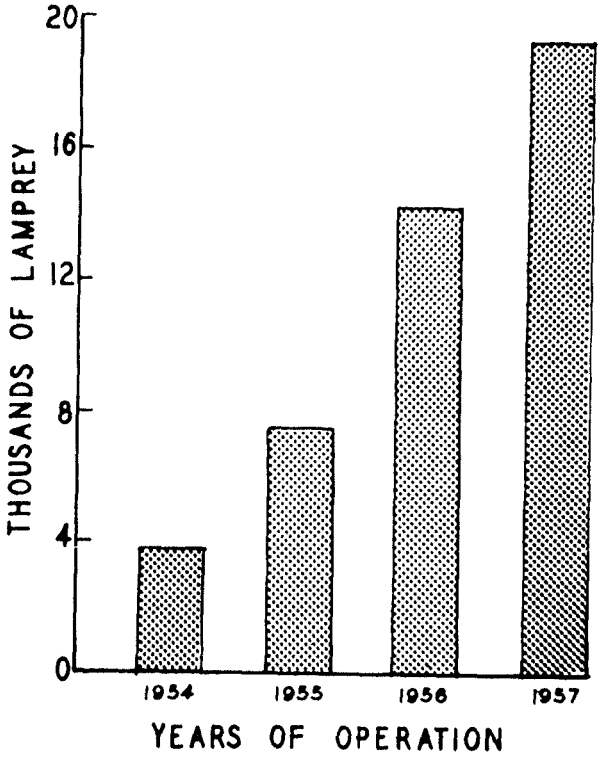
SEA LAMPREYS

Background.--For more than 80 years fishing in the Great Lakes has been a sizeable industry and a popular recreation for fishermen of the United States and Canada. The most prized fish, and the backbone of the fishing industry, has been the lake trout. In good years the trout catch amounted to more than 15 million pounds, worth nearly $8 million. But in 1939 the lake trout in Lake Huron suddenly began to decline in numbers and within 14 years they had all but disappeared from that lake; the catch dropped from more than 5 million pounds a year to 344,000 pounds in 1953. The same fate began to overtake Lake Michigan's trout in 1946, and the catch there fell from more than 5-1/2 million pounds to 402 pounds in 1953. Sea lampreys, not overfishing, weather or disease, caused the disappearance of the lake trout.

The lampreys are old inhabitants of the St. Lawrence River and Lake Ontario. Until 1829 the Niagara Falls blocked their migration into the other Great Lakes. Then the building of the Welland Ship Canal provided passage around the Niagara Falls to Lake Erie. In Lake Erie the lampreys did not flourish because the waters were too warm and spawning conditions poor. By the late 1930s they had penetrated into Lake Huron where because of a favorable environment they multiplied rapidly and made great inroads into the fish of that lake. At the same time they spread through the Straits of Mackinac into Lake Michigan, where they rapidly increased. The locks and dams at the head of Saint Marys River apparently slowed their migration into Lake Superior, but they finally cleared that hurdle and are now well established in that lake.

Because of the lamprey predations commercial fishing for lake trout in Lakes Huron and Michigan ended several years ago. As the lake trout gave out, the lampreys turned more and more to other fish--whitefish, suckers, walleyes and so forth.

To try to save the lake trout and other fish, the United States Fish and Wildlife Service, the Great Lakes states and Canada have been carrying on research and testing measures against the lampreys. On September 10, 1954 the United States and Canada signed a treaty for joint action.



Initial efforts at control of the lampreys focused on the prevention of their spawning. Electromechanical weirs and traps and electrical barriers were developed which successfully block or destroy spawning runs of adult lampreys. When installed in spawning streams, these devices provide an effective method of reducing the numbers of lampreys. Unfortunately, a lamprey control program based on the prevention of spawning will not show results for seven or more years. At least six generations of larvae, spawned before the electrical blockade of the streams, must grow, transform, migrate to the lakes, prey on the fish and enter spawning streams before the blockade is effective. Such delay may prove disastrous in Lake Superior, where there is evidence that lamprey predation will cause the collapse of the lake trout fishery, as has occurred in Lakes Huron and Michigan, before weir control measures can become effective.

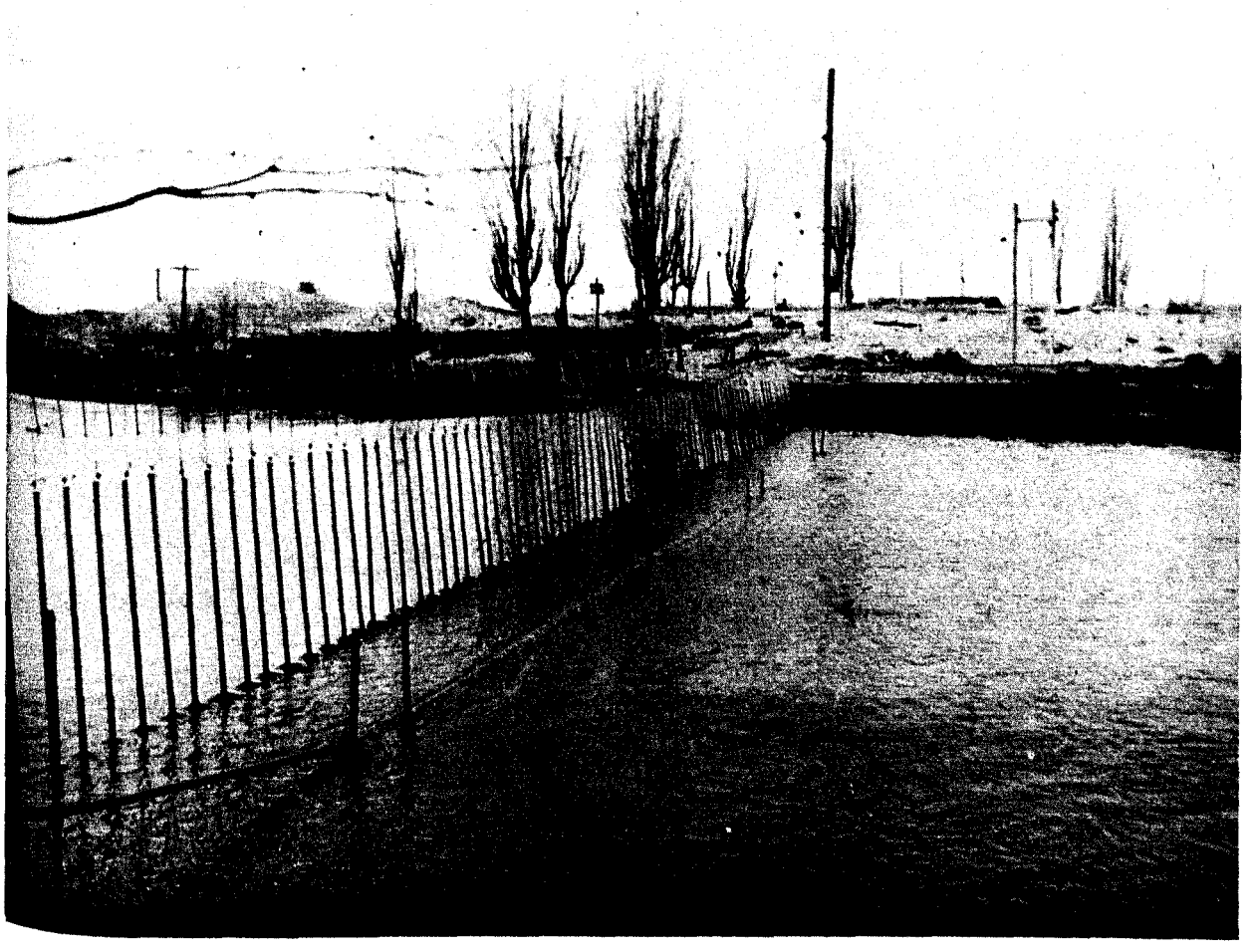
Because of these facts the principal problem became one of developing techniques for attacking the lampreys which might produce more immediate control of the species.

SEA LAMPREY RESEARCH LABORATORY AT HAMMOND BAY NEAR ROGERS CITY, MICHIGAN

If the larvae in the streams could be destroyed, the populations might be reduced substantially in the lakes in less than two years. In an attempt to locate chemicals which would be lethal to larval lampreys but relatively harmless to other fish, more than 4,000 chemicals were tested.

Current research.--The establishment of the Great Lakes Fishery Commission in June 1956 made possible an improvement in operation and in coordination and planning of sea lamprey control and research in the Great Lakes. The Commission contracted with the Fish and Wildlife Service to execute the lamprey program in United States waters and with the Fisheries Research Board of Canada as the agency in Canadian waters.

Lamprey control was confined to Lakes Superior and Michigan with the exception of an experimental barrier on Lake Huron. Discovery of large runs in Wisconsin tributaries of Lake Superior required the installation of five new electrical control devices A sixth new structure was operated on the Little Two Hearted River. By June 28, 1957 the take of lampreys amounted to 53,887 from 39 control devices along the south shore of Lake Superior. The 1957 take exceeded that of preceding years in most major streams. The five new barriers in Wisconsin took 19,555 lampreys.



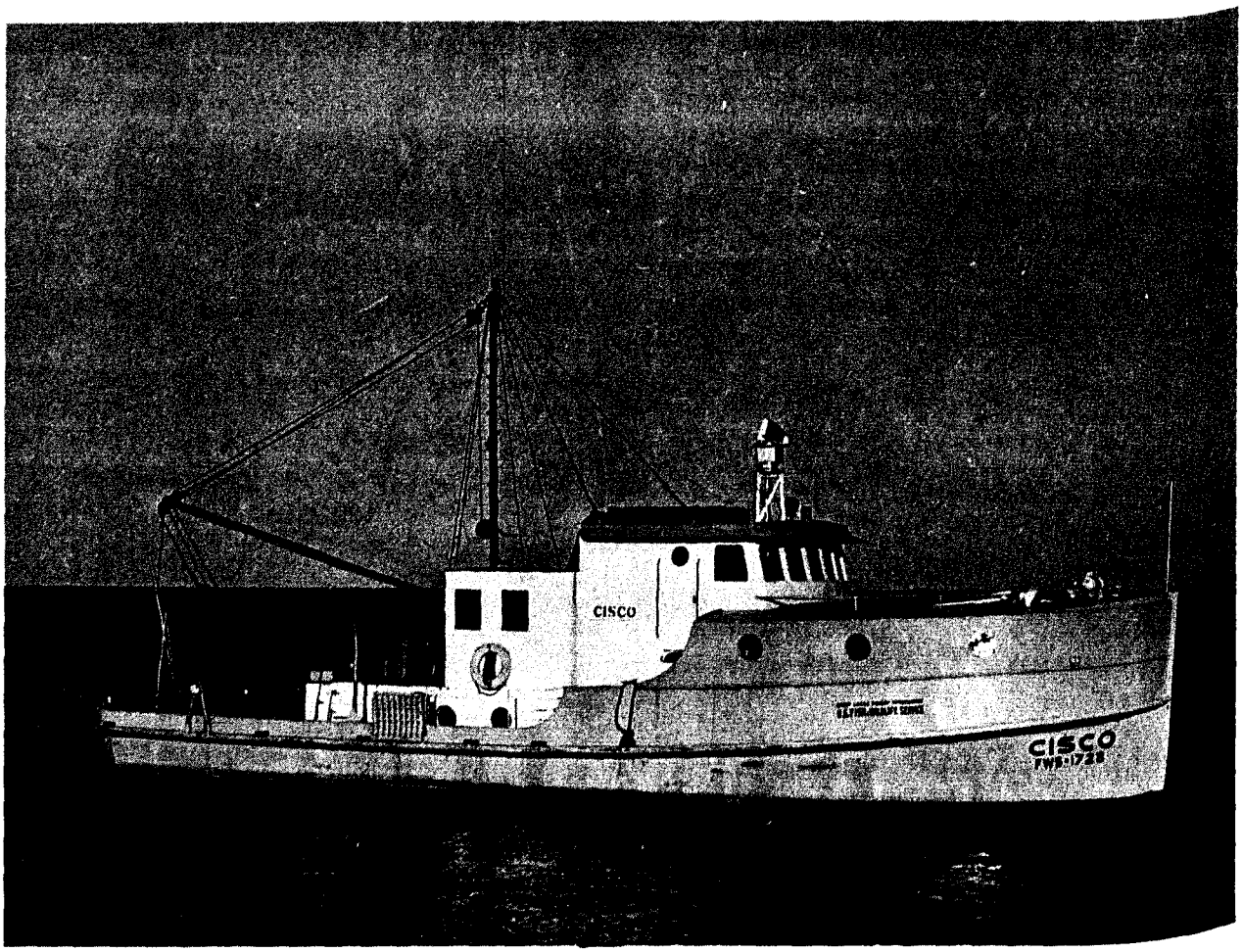
SEA LAMPREY CONTROL BARRIERS ACROSS THE TWO HEARTED RIVER, LUCE COUNTY, MICHIGAN. THE ALTERNATING-CURRENT STRUCTURE IS IN THE LEFT BACKGROUND AND A DIRECT-CURRENT DEVICE IS IN THE FOREGROUND

To support the expansion of the lamprey control program on Lake Michigan, new field stations were established at Oconto, Wisconsin, and Ludington, Michigan. Eighteen electromechanical devices were added to Lake Michigan's control network and construction was well advanced on eight others. By June 30, 1957, 64,102 lampreys were taken from 37 units. The single weir on Lake Huron took 8,163 lampreys. These figures show a continued high abundance in Lakes Michigan and Huron.

Research activities were directed toward testing specific larvicides and experimental operation of direct-current electrical diversion devices. Tests of two larvicides were carried out in raceways designed to stimulate stream conditions. The results of the tests of both a chlorinated and a fluorinated nitrophenol were highly encouraging and indicated that actual "pilot" treatment of streams should be initiated. These two chemicals were selected as the most effective after many experiments with more than 4,000 compounds over the last several years.

Preliminary surveys of 13 streams selected for test treatment were completed and the States of Michigan and Wisconsin have authorized the Great Lakes Fishery Investigations to treat them.

The installation and operation of seven experimental direct-current devices in combination with alternating current control barriers in Lake Superior streams reduced fish mortality from 85 percent to 8.5 percent. A new type of relaxing pulse generator developed under contract for this project produced pulsed direct current through the season. Previous equipment frequently broke down.



FISHERY INVESTIGATIONS

Research vessels.--The vessel Cisco during May-November 1956 made a hydrographic and fishery survey of Saginaw Bay and southern Lake Huron. Experimental trawling revealed that the alewife made up about one-half of the fish population in shallow areas of the Bay (up to 10 fathoms) and smelt a third of the take in both shallow and deep water. Neither of these species is of significant commercial value in the Saginaw Bay fishery. Yellow perch, the only other species taken abundantly in the experimental fishing, made up less than 20 percent of the trawl catches in shallow areas and about 50 percent at depths over 10 fathoms. While the yellow perch is important in the commercial fishery, generally less than 1 percent of the catch of a small mesh trawl was above the minimum legal length of 8-1/2 inches. Inshore areas, where usually shallow-water species such as carp and catfish are found, were not sampled in the Cisco studies.

In deeper areas (25-50 fathoms) of southern Lake Huron, chubs were not nearly as abundant as in Lake Michigan. In Lake Huron, 40 chubs were taken in 500 feet of nylon gill net with equal length of 2-1/2- and 3-inch mesh, while the same experimental unit fished in Lake Michigan at comparable depths and periods in 1954-1955 took 80 chubs in the north portion and 250 chubs in the south. The relatively large size of Lake Huron chubs, however, makes them valuable to the fishery as small fish are unmarketable. Of the fish taken in 500-foot gill nets, 10 chubs (42 percent) in southern Lake Huron were over 10 inches long, but only 9 (12.6 percent) and 8 (6.1 percent) exceeded this length in northern and southern Lake Michigan, respectively. Thus, marketable chubs are slightly more abundant in southern Lake Huron than in Lake Michigan.

The 1956 survey included extensive studies of the physical and chemical characteristics of Saginaw Bay and southern Lake Huron and the collection of numerous samples of planktonic and bottom inhabiting fish-food organisms. Preliminary reports are being made on much of this material. The Michigan Department of Conservation assisted in carrying out a large part of this work.

Starting the last week of April 1957, the Cisco has been surveying Lake Erie to learn the distribution and relative abundance of various species of commercial and non-commercial fish in different areas and times of the year. Their early life history is receiving particular attention.

The vessel Musky participated in special synoptic studies of Saginaw Bay.

Lake Superior investigations.--Prior to the establishment of the station at Ashland, Wisconsin, in May 1957, fishery

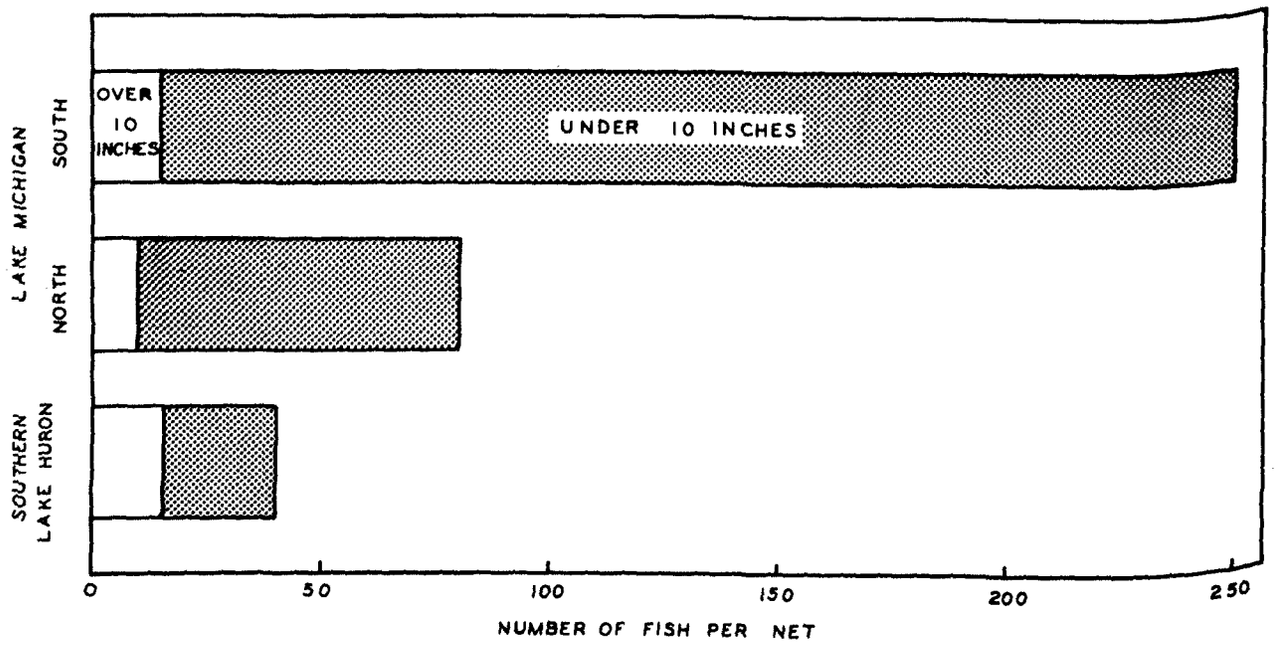
SETTING 1/2-METER TOW NET FROM RESEARCH VESSEL CISCO. THIS CLOSING NET IS USED TO STUDY THE VERTICAL DISTRIBUTION OF LARVAL FISH AND LARGER FOOD ORGANISMS

research on Lake Superior had been on a highly restricted and intermittent basis. The work had been limited chiefly to surveys of the Cisco in 1952 and 1953, to an annual sampling of lake herring spawning runs at selected ports and to observations of lake trout landings at Marquette. The newly organized staff will continue and broaden the work on lake trout and lake herring and undertake a program of study on the whitefish, a species that may be able to withstand greater exploitation and, thus, be valuable to the industry in surviving the anticipated scarcity of lake trout over the next few years.

Lake Erie investigations.--Staff members at the Sandusky station established in mid-June 1957 are acquainting themselves with local fishing methods and problems. Otherwise, the fishery research on Lake Erie was limited to the annual fall sampling of the commercial landings at various ports and a continuation of the inquiry into the age, size and year-class composition of walleye and blue pike.

Green Bay-Saginaw Bay investigations.--A major advance was made in the knowledge of the fisheries of Saginaw Bay with completion of a study of the fluctuation of the yellow perch population based on material collected in 1943-1955. The average age of fish in trap-net samples collected in the spring increased between 1929-1930 (3.8 years) and 1943-1955 (4.3 years) and growth declined sharply. Yellow perch of the 1929-1930 samples reached legal length (8-1/2 inches) in 3 years but those taken in 1943-1955 required more than 5 years to attain the same size. The modal length dropped from 8.5 - 8.9 to 6.5 - 6.9 inches and the percentage of legal-sized fish from 74 to 11. In both periods, the females averaged larger than the males and grew more rapidly.

The growth in length and weight of Saginaw Bay yellow perch in 1943-1955 was the lowest yet reported from any Great Lakes waters. The decrease was believed to have resulted from a more than sevenfold increase in the population density. A "space factor" rather than competition for food may account for the decline in growth rate. Fish of the 1943-1955 samples did not evidence a scarcity of food; on the contrary, they were heavier for their length than fish caught in 1929-1930.



ABUNDANCE OF CHUBS IN LAKE MICHIGAN AND SOUTHERN LAKE HURON SHOWING THE PORTION OF MARKETABLE SIZE (OVER 10 INCHES LONG)

Males were relatively more plentiful in 1943-1955 (62 percent) than in 1929-1930 (25 percent). Both males and females attained sexual maturity at a small size (nearly all males were mature at all lengths of 5 inches and greater; 80 percent of females were mature at 7.0 - 7.4 inches).

The strongest year classes were those of 1939 and 1952 and the weakest were those of 1941 and 1945. Year-class strength was correlated significantly with production 4, 5 and 6 years later, but not with the abundance of legal-sized fish in the year of hatching or with temperature, precipitation, water level and turbidity.

The annual fluctuation of growth in length in the first year and in later years of life was dissimilar. First-year growth was poorest in 1942 but tended strongly to improve in subsequent years. First-year growth was correlated negatively with turbidity in June but was not correlated with year-class strength or other factors investigated. Fluctuations of growth in later years of life were largely without trend. Growth in these years was not correlated with the abundance of legal-sized fish, temperature, precipitation, or turbidity, but varied inversely with the water level for May to October.

The accumulation of material on the yellow perch of Green Bay started in 1948 is nearing the point where an inquiry into factors of change similar to the one made for Saginaw Bay soon may be possible. Certain preliminary analyses have been started and a paper is in press on the question of scale structure and growth.

The routine sampling of other principle species of both Green Bay and Saginaw Bay has been continued.

Deep waters of Lakes Huron and Michigan.--In addition to observations made by the Cisco in southern Lake Huron in 1956, work has continued on the analysis of materials and data on the chubs of Lake Michigan. This study is directed principally at a comparison of 1930-1932 and 1954-1955 with respect to age, growth, distribution and local and regional abundance.

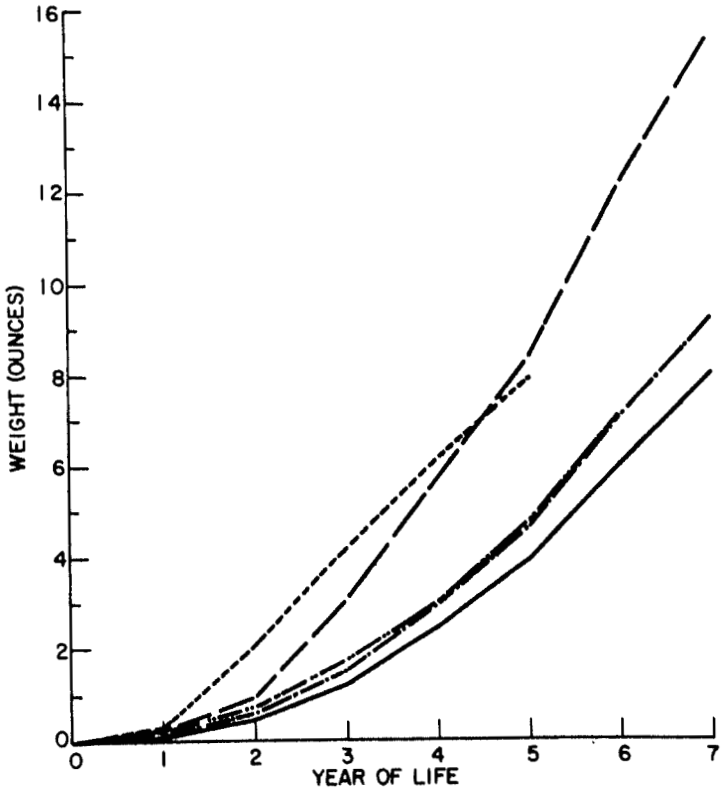
A study of the distribution, migration and life history of the fish-food organism, Mysis relicta, formed the basis of a doctoral dissertation accepted by the University of Michigan.

WESTERN INLAND FISHERY INVESTIGATIONS

I. CALIFORNIA-NEVADA INLAND FISHERY INVESTIGATIONS

Reed S. Nielson
Reno, Nevada

Fishing pressure on high mountain lakes and streams in California and Nevada



AVERAGE CALCULATED WEIGHTS AT THE END OF EACH YEAR OF LIFE FOR YELLOW PERCH FROM DIFFERENT GREAT LAKES WATERS (SEXES COMBINED). LAKE ERIE, SHORT DASHES; GREEN BAY, DOTS AND DASHES; NORTHERN LAKE MICHIGAN, TWO DOTS AND DASHES; SAGINAW BAY, 1929-1930, LONG DASHES; SAGINAW BAY, 1943-1955, SOLID LINE

has more than doubled in recent years. There has been no comparable increase in the fundamental knowledge needed to maintain the fishery resources of these waters in relation to increasing angling pressure. These investigations, through pilot studies, are designed to determine the basic productivity of these lakes and streams, to develop new techniques for assessing the stream and lake productivity, to evaluate the present extensive and expensive practice of stocking hatchery-reared, catchable-size trout in streams, to assess the physical vitality of hatchery-reared trout, and to determine the effects of seasonal climatic conditions on trout and on their stream and lake habitats. This information will be used as a guide in formulating improved management practices and procedures and in developing methods to increase the productive capacities of these waters.

TROUT SURVIVAL

Trout survival in streams.--In July 1956 experiments were begun in a 1-mile, 4-section experimental stream to determine the survival of five groups of catchable-size rainbow trout which had been reared in California hatcheries. Of the two groups of rainbows from Darrah Springs, one group had been fed pellet food and the other a regular meat diet control. The groups from San Joaquin, Fish Springs and Hot Creek had been given the regular diet. A check on November 1 found an average of 90 percent recovery from the stream habitat. This 3-month phase of the experiments demonstrated that 95.1 percent from four of the five groups would have been available to anglers three months after the midseason planting in the stream. The survival of the pellet-fed trout was 73.3 percent.

The trials were continued through April to determine the share of fall survivors from one summer's stocking which would be available at the opening of the next angling season to compare winter vitality of the various lots and to attempt to find sound reasons for any differences in performance. In the November-May period, the mean recovery from all four stream sections was 69 percent for San Joaquin trout (better than expected in consideration of the previous winter experience), 48 percent for Darrah Springs regular-diet trout (about as expected) and an average of 21 percent for the remaining three groups. As in the summer-fall phase, the dry-food group suffered the greatest mortality in the stream sections. The trout of all groups lost 30 to 36 percent in coefficient of condition over the entire nine months, which was comparable to reductions experienced in earlier survival experiments. Although there were some differences in distribution of deaths in the winter-spring period, these could not be linked with differences in initial vitality except in the case of the pellet-fed trout which had demonstrated their weakness in the first three months. Examinations in January and March revealed moderate parasitism and intestinal disorder in all groups, but no serious mortality factors. Winter conditions were about average for the area and the stream sections were bridged with ice and snow for about three weeks. Air temperatures, however, were about six degrees below average in January with many subzero days.

Trout survival in a pond.--Trout from the above-named California hatcheries survived nine months in a 1200-sq. ft. pond, containing some natural food, at rates ranging from 53 to 100 percent. Although no periodic counts of the survivors were made during the test, the pattern of known mortality indicated that most of the deaths occurred in the final two months. Slight gains in length, losses in weight and 25 to 40 percent reductions in condition factor occurred in all groups except that the final mean weight of Fish Springs trout indicated an increase. The increase probably resulted from greater mortality among the smaller trout--these fish were oversize leftovers from the stream-planted lots and could not be graded closely for uniform length. A general comparison between tabulated survivals of stream and pond experiments indicated an advantage in the quiet water situation, despite a 3-month ice cover which for several weeks sagged almost to the bottom of the pond as a result of low water. In this test the San Joaquin and Darrah Springs trout, which had been fed the regular diet, survived best.

Starvation test.--Fifty fish from each of the five groups were held 162 days in food-tight, indoor hatchery troughs. In this stringent test a distinct lack of vitality was observed in the Darrah Springs trout with the history of dry feed. Heavy mortality of this group, apparently caused by malnutrition, began in September and

eliminated 62 percent of the lot after three months. Mortalities in the other groups were rather evenly distributed over the total time and were light among the Hot Creek and Fish Springs trout. Because of the difference in the length of the tests and less exercise by the trout in the starvation troughs, loss of body condition in the starved trout was less than in the stream or the pond. A freezeup of the water supply terminated this experiment on January 10.

Experiments in 1957-1958.--On May 15 experiments, similar to those described above, were begun with two groups of catchable-size rainbow trout from the Moccasin Creek Hatchery of the California Department of Fish and Game. One group was reared on regular hatchery diets while the other was reared on a diet of fortified pellets. Five trout from each group examined at the hatchery prior to transportation were in good condition except for too much visceral fat; this condition was most pronounced among the pellet-fed fish. Epistylis and gyros were moderate to abundant on the body surfaces of all trout examined. The trout arrived in good condition after a 13-hour haul and sustained negligible loss through a 1-week holding period during which fish for the various tests were selected according to uniform total length and marked for identification by amputation of the fins. Selected regular diet fed trout averaged 3.75 per pound, had an average length of 27.6 cm., a weight of 120.8 grams and a condition factor of 1.040 as compared with 4.00 per pound, a length of 22.1 cm., a weight of 103.5 grams and a condition factor of 0.954 for the pellet-fed group. At the end of June 30, losses in the various tests were small but more pronounced among the pellet-fed fish. There were no losses in the pond test; 3 regular diet and 4 pellet-fed trout died in the starvation test and 1 regular diet and 5 pellet-fed trout died in the stream test.

The regular diet trout from the Hot Creek, Fish Springs and San Joaquin hatcheries will be used beginning July 23, 1957 to repeat the 1956-1957 tests. The experiments concluded with trout from these hatcheries disclosed differences in vitality and ability to survive but the reasons for these differences are not clear. Therefore, the next year's program will include the bioassay, histopathological and disease examination of representative specimens of all groups of trout at the beginning, check points and conclusion of each experiment. In addition, the habitat of each experimental stream section will be evaluated to determine the influence of stream quality on trout survival.

Hatchery evaluation.--A chemical analysis of some California hatchery water supplies and some unusually productive natural trout waters has been accomplished as orientation work preliminary to a study of associations among water quality, other hatchery conditions and production and quality of trout. This will embody an evaluation of hatchery waters (physical-chemical-biological characteristics and methods of use) in relation to trout stocks, feeds, growth, losses, vitality and other factors relating to trout produced at the major hatcheries in California, Nevada and elsewhere.

PRODUCTIVITY OF HIGH SIERRA LAKES

Periphyton sampling was conducted on eight of the nine lakes in the upper Convict Creek Basin in August and on Convict Lake in November and April. Constance Lake was not sampled because snow and ice closed it. Quantitative results were similar to but did not (on a ranking basis) duplicate the results of the previous year, although six of the lakes appeared fairly stable with approximately the same amount of material formed at various levels during comparable periods of the two years. Analysis of these samples continues to indicate a general linear relationship between periphyton production and physico-chemical factors, but no specific limiting or controlling factors have yet been identified. Work on the identification, relative abundance and conditions of existence of the periphyton organisms is continuing. Experiments in culturing the organisms under controlled laboratory conditions is proceeding at the Cortland, New York station. A sampling apparatus involving the use of preweighed glass substrates was tested but was impractical for field use.

Partial chemical analyses of water samples from the lakes in Convict Creek Basin, Mammonth and June Lake groups and Lake Crowley were completed.

II. ROCKY MOUNTAIN FISHERY INVESTIGATIONS

Oliver B. Cope
Logan, Utah

Increasing numbers of anglers visit Yellowstone Lake each year. The active hatchery program formerly carried on in these waters took large numbers of cutthroat trout eggs from this drainage each year, and the effects of the program are being assessed. This study is designed to determine the best control procedures to be used in perpetuating this population and this fishery in accordance with the policies of the National Park Service.

Activities this year were devoted chiefly to population work on Yellowstone Lake and its tributaries, to stocking experiments in the Madison River system, to the grayling problems on Grebe Lake and to cooperation on DDT-fish problems with other agencies.

Yellowstone Lake.--The population of the cutthroat trout in Yellowstone Lake must, on the basis of measurements made this year, be considered as being in no immediate danger for overexploitation.

Despite increased fishing pressure in 1956 over that in 1955, fishing success remained high. The spawning runs in the spring of 1957 were high in numbers of fish up to June 30. Pelican Creek spawner counts since 1957 have been

1947 - 19,163	1953 - 12,418
1948 - 9,531	1954 - 10,340
1949 - 32,431	1955 - 12,368
1950 - 15,076	1956 - 7,000
1951 - 7,423	1957 - 16,027
1952 - 6,521	

Indications are that other spawning streams are also supporting sizable spawning runs this year. These trends suggest that the present practice of relying on natural reproduction alone may be entirely appropriate under present fishing pressures. The problem is to predict its adequacy for the predicted increases in the numbers of fishermen as of 1966.

In the spring of 1957 beginnings were made on an intensified program of limnological measurements on Yellowstone Lake. This program will feature smaller numbers of stations and more observations at each station. The aim of the study is to secure

THE BOAT FISHERY IN 600 YARDS OF THE YELLOWSTONE RIVER AND NEAR THE OUTLET OF YELLOWSTONE LAKE TOOK AN ANNUAL AVERAGE OF 54,000 CUTTHROAT FROM 1950 TO 1955

information on the basic productivity in this water. The data collected indicate differences in water quality from place to place in the lake.

Madison River system.--Fishing in the Madison River and the Firehole River in 1956 was below average. This lack of success cannot be associated with the interruption of stocking except in the case of the legal-size rainbows formerly planted in the Madison River. The 1957 program emphasized careful measurements of effort and catch to keep track of trends in these waters. Thus far in 1957 fishing appears to be better than it was in 1956, when high water affected the fishing for several weeks.

Grebe Lake.--The experimental manipulation of grayling planting schedules on Grebe Lake continues. The sizes of egg planting into this water have been reduced from year to year; no planting was done in 1957. The spawning runs of grayling have been sustained at high levels, averaging about 6,000 spawners into Hatchery Creek, and angler catches have been at the same general level. The only major change in fish populations in the past five years has been an apparent reduction in numbers of hybrid trout entering the traps on the spawning streams. A dissertation on the grayling of Grebe Lake is being completed for the University of Michigan.

COUNTING CUTTHROAD TROUT IN THEIR UPSTREAM SPAWNING MIGRATION IN GROUSE CREEK, YELLOWSTONE NATIONAL PARK

DDT-fish studies.--The Rocky Mountain Fishery Investigations, the United States Forest Service and the Montana Fish and Game Department in the summer of 1956 cooperatively observed several Montana streams which were affected by airplane spraying of DDT for the control of the spruce budworm. This study suggested that the spray did not either directly or indirectly affect the fish. Reduction in the numbers of stream bottom organisms resulted, but by the end of the summer these populations were recovering.

Plans have been made for spraying in Yellowstone Park. The Rocky Mountain Fishery Investigations has made pre-spray measurements in seven streams to assess the effects on aquatic animals. This program will continue through the summer of 1957 and probably into 1958.

FRESH-WATER BIOLOGICAL LABORATORIES

I. TROUT NUTRITION LABORATORY

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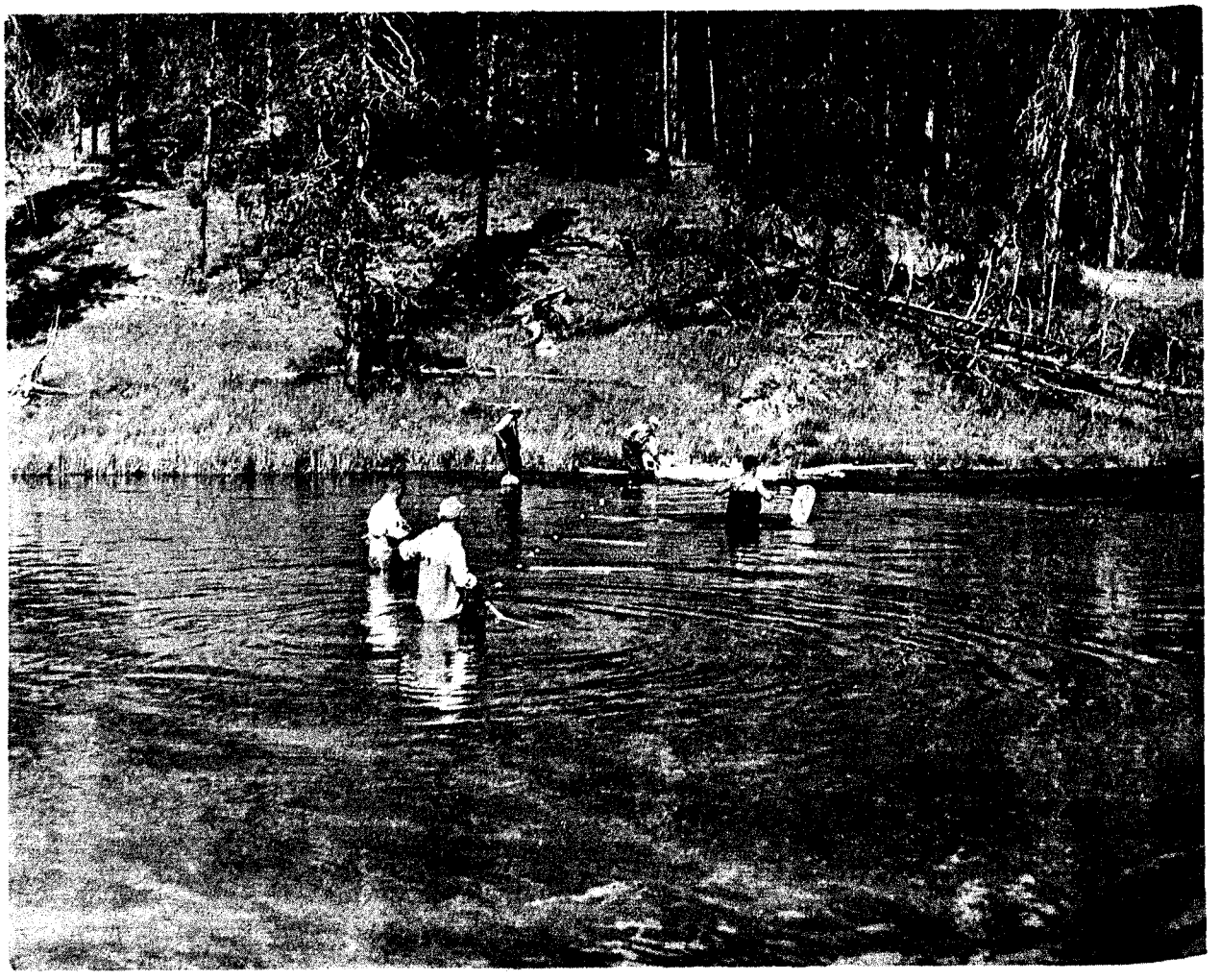
The increasing costs of hatchery foods and the unavailability of many products used in the past have necessitated the study of nutritional requirements of trout to find a better basis for formulating hatchery diets. Studies upon fat, protein, carbohydrates metabolism and vitamin and mineral



USING AN ELECTRIC SEINE TO SAMPLE TROUT POPULATIONS IN THE MADISON RIVER, YELLOWSTONE NATIONAL PARK

requirements of trout provide data that may be applied in preparing their diets which will result in better growth, lower production costs and reduced fish mortalities. An understanding of the nutritional requirements of trout permits the development of new feeding techniques that will reduce the cost of food storage, food preparation and labor of feeding fish. Many of the mortalities of trout in hatcheries are of nutritional origin, and the application of nutritional findings prevents the occurrence of nutritional disorders.

Vitamin requirement of trout.--In tests to determine the vitamin requirement of trout, vitamin omission studies with a synthetic diet established the need of lake trout for riboflavin, pantothenic acid, biotin and pyridoxine. Over a 34-week period no need was shown for five other members of the vitamin B complex. Tests are in progress to further study the vitamin B complex requirement for rainbow trout; however, no conclusions can be reported now.

Absorption of minerals by trout.--Studies were made to determine the ability of trout to absorb minerals. After absorbing dissolved cobalt, brook, brown, lake and rainbow trout revealed their metabolic activity. The brooks, browns and rainbows had a higher rate of metabolism at a water temperature of 51° F. than at 36° F.; the browns had the highest rate of metabolism of these three species. The lake trout had a lower rate of metabolism at 51° F. than at 36° F.

Studies on incubating brown trout eggs to determine their intake of calcium from the water found that they absorbed a greater amount of radioactive calcium as the period of incubation lengthened. The total calcium content of the egg increased also as incubation progressed.

Brook trout made a greater use of dissolved calcium when the waters were enriched with phosphate than when they were not. Fertilization of water with phosphate seems to benefit the fish directly and not solely through the food chain.

Twenty-four hours after feeding food in a gelatin capsule, at a water temperature of 51° F., 60 percent of the food calcium was unabsorbed, 20 percent assimilated and 20 percent excreted. At a water temperature of 36° F., 90 percent of the food calcium was unabsorbed, 7 percent assimilated and 3 percent excreted. The rate of utilization of calcium depended upon the metabolic rate of the fish which in turn depended upon the water temperature.

Through use of the absorption of radioactive cobalt as a measure, the effect of various drugs upon the metabolic rate of trout is under investigation. Data, however, are not sufficient for reporting now.

Feeding trials.--Pellets as food for hatchery trout have resulted in reduced conversions, labor cost of feeding and food preparation. The efficiency of pellets in terms of growth, mortalities and conversions of fish equals that of the standard diets. Tests were made to determine the value of standard hatchery pellets and pellets highly fortified with vitamins as food for hatchery trout. After four months, fish which had been fed a pellet highly fortified with vitamin concentrates became weak and could not be handled without a high mortality. Because the mortality of the fish increased the experiment was discontinued after an 8-month trial. Samples of the fish were preserved for analysis to determine if a hypervitaminosis had developed. The control diet, consisting of the standard hatchery pellet, fed to the fish without supplemental feeding produced different results. After ten months without fresh meat, the fish showed excellent growth rates, normal mortalities and no anemia. These experiments will be continued.

Comparison of hatchery diets and natural food of fish.-- Studies partly confirmed earlier conclusions that natural food is more efficient than hatchery diets in producing fish. Natural food contains about 12 percent of protein and hatchery diets 28 to 35 percent. Natural food gives evidence of producing equal growth rates and conversion factors when fed to fish. Beef liver supplemented with cod liver oil and living brine shrimp for brook trout fry were superior to a control diet of beef liver alone. In terms of protein conversion, brine shrimp was superior to both of these diets.

In terms of calories usable by trout, natural food contains about 70 calories per 100 grams. Hatchery diets vary from 90 calories per 100 grams (all meat diet) to

279 (pelleted types of food). Even hatchery diets producing equal growth and conversion rates will vary widely in their calorie content. In the hope that the calorie content may be the missing key, as it was in chicken nutrition, a series of experiments have been designed to provide a wide variety of calorie and protein contents in diets that more nearly approach natural foods. Since these experiments have been under way only six weeks, the results, while promising, are too inconclusive for reporting.

Composition of trout blood.--For basic studies upon the physiology and pathology of trout, the composition of the blood of the trout must be known. The blood of brown trout was analyzed for nine inorganic compounds and values were established for iron, chloride, sodium, magnesium, potassium, calcium, phosphorus, sulphate and copper. The levels of these elements in the blood of brown trout were similar to those reported for carp and human beings.

Studies are under way to establish the normal level of several of the organic compounds of fish blood. No data are available at this time for reporting.

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The experimental results of this laboratory are described in detail in the annual report of the Cortland Laboratory which the State of New York Conservation Department published. This work is done under a cooperative agreement among the Fish and Wildlife Service, the State of New York Conservation Department and Cornell University.

II. SALMON NUTRITION LABORATORY

John E. Halver
Cook, Washington

The nutritional requirements of salmon in terms of the basic nutrients, amino acids, carbohydrates, fatty acids, vitamins and minerals have not been completely established. A prerequisite for determining which of these nutrients is required and in what amounts must be the establishment of a test diet for each group in which the nutrient to be studied can be experimentally controlled. Application of these test diets then can be used to determine the qualitative and quantitative nutritional requirements, and adequate experimental control of the diet ingredients is possible for extended studies in advanced biology of the animal.

Research in the fields of human medicine, biochemistry and nutriton has emphasized the importance of histological studies. Histology offers one of the best, and in some cases the only, tool for detecting subclinical syndromes, diagnosis of neoplasms, cellular location of biochemical constituents, studies of the etiology of disease and characterization of subtle physiological changes. Similarly, comparative biochemistry, serology, physiology and genetics offer individual and complementary tools for particular problems in advanced biology. Only by understanding the body functions of the animal, the requirements and limits of each chemical and physical reactions and the organization of these functions within the body can the physiological behavior of fish be comprehended.

NUTRITION AND BIOCHEMISTRY

Chinook salmon vitamin requirements.--Through use of the experimental facilities at Hagerman, Idaho, experiments were completed on the quantitative vitamin requirements of chinook salmon. For the first set of experiments large increments of one vitamin at a time were deleted from the complete vitamin test diet and the growth response was measured. At the completion of the 20-week feeding period, the fish were individually weighed and measured and representative 50-fish samples from each trough were eviscerated. The livers were removed from the anesthetized fish while they were still alive, quick frozen in liquid nitrogen and stored at dry ice temperatures in small ampoules until subsequent vitamin analysis, and the carcasses were frozen at dry ice temperatures and similarly held. Blood counts and hemoglobin determinations were run on 20-fish samples from critical lots of vitamin-deficient fish with special emphasis on those lots which previously had indicated an abnormal blood picture. Post-mortem observations were conducted on 10-fish samples from each lot of vitamin-deficient fish. Chemical and histological samples were preserved at each biweekly weigh period and transferred to the laboratory for future analysis. Histological analysis of serially sectioned tissues will be surveyed for deficiency syndromes. Proximate analysis was

completed on each lot of fish at the termination of the experiment. From the information currently available based on growth response and mortality studies, tentative quantitative vitamin levels were determined for thiamine, riboflavin, pyridoxine, pantothenic acid, biotin, folic acid, choline and nicotinic acid. Inconclusive results were obtained, at least in the growth response, for inositol and vitamin B_{12}. When the feeding studies were completed, the frozen livers were assayed for their respective vitamin content. The microbiological assays in general supported the growth results and, with the possible exception of nicotinic acid, tentative safe levels of vitamin content for chinook salmon diets under these experimental conditions were determined. Again, inconclusive results were obtained with vitamin B_{12} and inositol, although the inositol assays indicated an intermediate point of maximum liver storage.

Silver salmon vitamin studies.--A cooperative research program was begun with the State of Washington Department of Fisheries to test the qualitative vitamin requirements of silver salmon. Groups of fish deficient in thiamine, riboflavin, pyridoxine, pantothenic acid and biotin exhibited specific vitamin deficiency syndromes similar to those observed in chinook salmon and have been separated for testing their recovery when the missing vitamin is returned to the ration. A low level incidence of octomitis disease (Hexamitus salmonis) was observed in most lots of fish in the Issaquah Hatchery water supply, but no serious epizootic appeared.

Sockeye salmon vitamin studies.--An experiment to test the qualitative vitamin requirements of sockeye salmon was initiated at the Willard Laboratory. Each of the ten water-soluble vitamins has been deleted one at a time from the vitamin mixture in the complete vitamin test diet; these diets are being fed to individual lots of sockeye salmon in an aquarium. The fish have completed the introductory preparatory feeding program and are being fed the specific vitamin deficient diets. No disease or pathology has been observed and the specific vitamin deficiency syndromes should appear in August 1957.

Salmon protein level studies.--Two sets of experiments were conducted at two different water temperatures to test the protein requirement of chinook salmon when percent gain is plotted against protein content of the diet. From different lots of fish fed a reasonably balanced protein in their diet at different protein levels, a curve was obtained which has an inflection point at the optimum protein intake. The inflection points occurred at approximately 40 percent protein for the spring water temperature (7.7° C.) at the Willard Laboratory and at approximately 50 percent protein in the Hagerman water supply (14.4° C.). These experiments were repeated and confirmed the tentative protein requirements of chinook salmon as approximately 40 percent protein at the Willard Laboratory spring water temperature and at approximately 50 percent protein at the Hagerman temperature. This difference in protein requirement versus water temperature may furnish critical data in interpreting divergent results from different hatcheries feeding the same diet and will become important when various hatchery diets are being formulated. Since the protein component of the diet is the most expensive ingredient and the most critical to keep balanced, testing the optimum protein intake at each water temperature to assure efficient utilization of the diet and production of high quality fish may be necessary.

Amino acid quantitations.--Through use of the facilities at Hagerman and advanced chinook salmon fingerlings a clear-cut separation in growth response was obtained between the .6 percent and .8 percent methionine diet and between the .8 percent and 1.0 percent threonine diet. All diets containing amounts of methionine and threonine diet. All diets containing amounts of methionine and threonine greater than these figures resulted in comparable growth between lots of fish. Calculated on the basis of a 5 percent body weight dietary intake per day, the quantitative requirements for methionine and threonine would be approximately .4 gm/kg/day and .6 gm/kg/day, respectively. These amino acids were quantitated with the protein component in the diets consisting of approximately one-half the casein-gelatin mixture used in the vitamin test diet, and the other half, crystalline amino acids. Using the casein-gelatin mixture for other amino acid quantitations is impossible since even at half-level protein requirement the remaining eight essential amino

acids are present in considerable quantities and may be of sufficient magnitude to satisfy the particular amino acid requirement of one or more of these indispensable amino acids. Therefore, various other proteins are being used to supply the protein component of chinook salmon diets. Corn gluten, which is low in lysine, is being studied. Drackett (soybean protein) is being fed, and various amino acid mixtures containing some inexpensive DL forms are being tested. As the first approximation of the quantitative amino acid requirements of chinook salmon for the other eight essential amino acids, a tissue projection technique is being employed through the use of the levels obtained for methionine and threonine required in the diet. Tissues are being analyzed and from the threonine and methionine content an estimate of the other eight essential amino acids based on tissue completion is being projected. These projected values will be confirmed with feeding studies which may eliminate the need for many increments widely separated to determine the specific amino acid requirement.

Salmon protein metabolism.--At Willard Laboratory the arginine-ornithine-citrulline cycle was investigated by feeding arginine-depleted chinook salmon crystalline ornithine and citrulline to test the possibility of the other two intermediates in the cycle effectively substituting for arginine. Growth responses and general biological observations indicated that citrulline could substitute for arginine in the arginine requirement of chinook salmon, but that ornithine was ineffective. These results substantiate the introconvertibility of citrulline and arginine in both the fish and the chick. Three sets of experiments designed to test the possibility of using only the ten essential amino acids as the protein component of the diet indicated that under the experimental conditions at Willard and Hagerman the animal can maintain body weight but cannot deposit new tissue if the protein component consists of only these indispensable amino acids. This is in contrast to the rat which can grow when the protein component consists of only the essential amino acids. The fish seems capable, however, of utilizing large quantities of arginine as a nitrogen component in the diet. Tests with glutanic acid, diammonium citrate, and glycine urea failed to give any growth response, but the fish seemed capable of utilizing arginine readily.

Digestive enzymes of salmon.--A study of the digestive enzymes of chinook salmon has been initiated. Some specific substrates which will be used to test the activity of protein-digesting anzymes of chinook salmon have been made. To characterize the digestive enzymes of salmon, procedures must be developed for isolating the individual components. Assay methods are needed to follow the activities in various fractions and in the crude extracts of organs. Specific substrates necessary for these assays are being prepared. Specimen organs will be collected from salmon in their natural environment and preserved until used. Various tryptic enzymes will be characterized by physical properties and by specific activities to help fish physiology and to compare with mammalian analogues.

Chinook salmon ovarian sex hormones.--Studies have been completed on isolating and identifying characteristic ovarian sex hormones from chinook salmon. Through use of column chromatography techniques with silicic acid columns, all estrogenic activity from salmon ovarian tissue has been separated into one small fraction. Tests of both mature ovaries and spent ovaries from the spawning operations on the Columbia River found that the greatest estrogenic activity per unit weight was in the spent ovaries of chinook salmon. This material was ground, extracted and separated with the automatic fraction collector using silicic acid columns and various eluents with each set of solvent systems. The technique of collecting all activity in one small fraction offers the possibility of developing a practical collection procedure for these steroids. Rat screening assays for estrogens confirmed these findings and further indicated that the female sex activity of salmon ovarian tissue steroids must act similarly to that of mammalian steroids.

D-amino acid oxidases.--The D-amino acid oxidase study indicated that either low levels of the enzyme were present during the summer feeding period of the salmon or that the isolation technique used was either inactivating the enzyme present or was not efficiently extracting it from the medium. A preparation of hog D-amino acid oxidase is being used as a control for further methods of extraction and identification of this enzyme. As soon as chinook salmon D-amino acid oxidase can be prepared in sufficient quantity the 18 common amino acids fed in

the test diets will be surveyed for rates of oxidation. When critical amino acids are found, such as D-valine or D-isoleucine, they can be eliminated from the diet and reduce considerably the cost of the amino acid test diet feeding studies.

Paper chromatography of free and tissue amino acids in salmon.-- An intensive study of paper chromatography techniques of free and tissue-bound amino acids in various salmon tissues has been conducted. Standardized chromatography techniques have been developed which will separate and detect qualitatively and quantitatively the amino acid content of various eluents and extracts. A number of satisfactory solvent systems have been developed for separating various groups and specific amino acids in tissue extracts. Various physical changes in techniques and methods have been developed for use with fish tissues. A number of sampling techniques have been tested and a rather unique method was devised which seemed most satisfactory for the trying conditions encountered in field sampling. A cylinder of flesh slightly posterior to the dorsal fin and just above the lateral line was removed with a cork borer. This cylinder contained a sufficient sample for investigating free amino acids, lipid, carbohydrate and/or pigment components. The cylinder was removed from the borer, wrapped in aluminum foil and deposited in a rapid freezing area. Liquid nitrogen was the most satisfactory as some autolysis of the tissue was observed even at dry ice temperatures. A control portion of the frozen cylinder was later dissected and the free and tissue acids were extracted. Such critical preservation techniques would not be necessary with tissue amino acids, but histological investigation of those samples obtained for free amino acids indicated considerable autolysis and a corresponding change in the free amino acids extracted. Pressed tissues were also used with varying degrees of success; however, subtle differences in the mixture of components present in the tissue juices crushed on the paper were not detected. Through use of available standardized paper chromatography techniques the specific amino acid content of fish tissues can be readily detected, both qualitatively and quantitatively, by means of the densitometer.

Specific amino acid assays studies.-- A new rapid method for amino acid assays of small amounts of tissue has been initiated. Specific amino acid carboxylases have been obtained and experiments initiated to develop a standardized procedure for rapid amino acid assays with these anzymes. Through use of a small amount of a substrate or hydrolysate in a Warburg flask, together with a buffer and a known amount of the specific amino carboxylase, the amount the specific amono acid metabolized by the enzyme in the Warburg apparatus can be measured. Since the reaction is stoichiometric and rapid, the entire assay can be completed in from 30 minutes to one hour.

Protein and carbohydrate studies with practical diets.--Assays have been completed on dietary ingredients and feeding studies initiated at the Salmon Culture Laboratory at Entiat, Washington, which is using isocaloric diets with a constant carbohydrate-protein ratio. Various levels of protein in the diet have been calculated and diets containing 65, 60, 55, 50 and 45 percent protein and approximately 5, 10, 15, 20 and 25 percent carbohydrate have been prepared which consist of a practical hatchery meat mixture, purified carbohydrate and carbohydrate from a low-cost meal. These experiments are designed to test the optimum protein intake of chinook salmon under practical hatchery feeding conditions where practical hatchery diets are used to furnish the nutrients to the animal . The fish have been on the new diets approximately four weeks.

Inorganic requirements.--To determine if salmon can satisfy all their inorganic requirements from the water in which they live, a feeding trial was conducted on advanced chinook salmon fry in which a diet essentially free of inorganic elements was compared with a complete testdiet in both relatively hard and soft water. Results based on growth rate and mortality during the 14-week feeding period were inconclusive. Analysis to determine the effect of the diet on body composition will be conducted. Feeding trials to determine if the ratio of dietary calcium and phosphorus affects their availability, as with mammals, are being conducted. The dietary calcium-phosphorus ratio is varied in five steps from 10:1 to 1:10 to determine if the calcium content of water affects the dietary requirement. The trials are being conducted simultaneously at Willard with soft water and at Hagerman with hard water.

Survival studies.--Two of the factors involved in survival, stamina and ability to withstand starvation, have been investigated. Various devices for obtaining a reproducible measure of stamina are being investigated. Fish from various completed nutritional studies are being used in the starvation studies. With fish from various quantitation studies, the optimal level found on the feeding trial showed significantly greater survival time. When vitamin-deficient fish were used, a significant variation was noted between different deficiencies.

HISTOLOGY

Normal histology of salmonids.--The collection of normal histology slides of wild and hatchery salmonids compiled during the past several years is available to investigators on a loan basis.

Histology of salmonids under defined nutritional conditions.--A program has been initiated to prepare for histological examination of fish samples taken under defined nutritional conditions. Materials prepared were, first, 14, 28, 42, 56 and 70 percent, and, second, 25, 30, 35 and 40 percent protein, methionine and threonine and the water-soluble vitamin quantitation groups. Examinations were made of all the materials except the vitamin group. The pathological characteristics seen most frequently in the first and second protein samples were fatty infiltration of the liver and fatty degeneration of the pancreatic area. The degree of pathology in the tissues on all levels varied considerably. Further analysis will be made.

In the methionine and threonine material, two levels from each group were examined, .80 and .30 from the former and 1.00 and .40 from the latter. The most prominent histopathology noted in the study was the pronounced hyperplasia of the gills which was most noticeable in the .30 methionine and 1.00 threonine levels. The histology of these gills, with hyperplasia starting from the basal cells of the filaments and in extreme cases resulting in complete fusion of the lamellae, is similar to that observed in pantothenic acid-deficient fish. Fatty liver and fatty degeneration were also observed in all levels of the threonine and methionine material but here again the degree of pathology varied as in the protein quantitation samples. A more detailed survey is planned.

Riboflavin and thiamine groups from the water-soluble vitamin study material have been sectioned and stained and are ready for examination.

Histological comparison of wild and hatchery-reared salmonids.--To investigate the histological changes that may occur after the planting of hatchery-reared fish, the Minter Creek Biological Research Station of the State of Washington Department of Fisheries and the Willard Laboratory conducted a study on a group of hatchery silver salmon by observing these changes at various periods in fish after planting and comparing them with wild fish from the same parent stock. For a follow-up study on the above groups adult silvers returning to spawn after two years at sea were collected and prepared for subsequent analysis.

Histophysiology and histochemistry of salmonids.--The fall chinook salmon in their fifth year in fresh water continue to survive. Between September and December 1956 the majority of the mortality occurred in the mature males. The few females which died during this same period were characterized by underdeveloped ovaries. Beginning in the latter part of January 1957, kidney disease plagued the remaining fish. Since the attempt to check the disease by feeding sulmet was unsuccessful, an experiment was set up to determine the effectiveness of antibiotics. The fish were divided into two groups. One group was inoculated, intermuscularly, with 15,000 units of penicillin per pound of fish; and the other with 10,000 units of combiotic (penicillin plus streptomycin) per pound of fish. All fish from the combiotic-injected group subsequently died while only one mortality occurred in the penicillin group.

A second series of penicillin at 30,000 units per pound of fish was given to the remaining fish when the presence of kidney disease again became apparent. Although it is too early to predict the effectiveness of the antibiotic as a prophylatic against the diplobacillus, the indications are encouraging. Of the 30 deaths since the last mortality of the mature male in December 1956, 25 were immature females and the remaining five immature males.

Neoplasms of salmonids.--Offsprings of the initial group of guppies anesthetized with urethane were given similar anesthetizations. In this second experiment, however, 25 successive treatments over a period of 3-1/2 weeks were given. No gross pathology was observed. Histological examinations of the two groups will be made later.

III. WESTERN FISHERY DISEASE LABORATORY

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Fish diseases are a limiting factor in the numbers of fish produced by hatcheries. Some diseases are of unknown etiology, some are without control measures and some are recognized and have control measures. The goal of this laboratory is to make more fish available to the sport and commercial fishermen. This can be accomplished by understanding the etiologic agent and determining therapeutic and prophylatic measures.

Bacterial and virus-like agents continue to plague the fish populations. The laboratory's etiological study is being expanded by cooperating with fishery groups in Oregon, Idaho and Washington and the International North Pacific Fisheries Commission to determine the sources of infections. About 1,000 kidney smears from salmon in the North Pacific showed the presence of acid-fast bacteria in only three adult sockeye salmon. One of these salmon came from Lake Cories on Attu Island and the other two from about 75 miles west of Juneau, Alaska. The acid-fast bacteria cause fish tuberculosis. This disease is probably contracted mainly through the food at hatcheries and is found in returning adults. On occasion it is associated with high losses among fingerlings but it is generally chronic.

An effort is being made to develop a medium that will give consistent results for isolation and growth of the acid-fast organism. Such a medium will facilitate bacteriological studies, the determination of therapeutic agents and aid in diagnosis. Some drugs used successfully on tubercular human beings have been tested on infected fish, but in no case has a satisfactory control been found.

A tuberculin test for fish tuberbulosis would be advantageous as a diagnostic tool. While no success has been realized, the outcome of present experiments may prove successful.

The possibility of fish tuberculosis being transmitted in the egg is under investigation. Crosses between infected and non-infected female steelhead trout with infected and non-infected males of the same species were made. The fingerlings are being reared for observation.

Corynebacterium sp. cause kidney disease, another serious disease of salmon and trout. Antisera from eastern and western strains were developed. Cross reactions were obtained with the heterologous strains but at a lower titer than with the homologous strains. Kidney disease antisera did not agglutinate diphtheroid organisms of human origin.

To test the theory that the kidney disease organism might be the same as the salmon poisoning rickettsia, comparatively electron microscopic studies of the two organisms were made. They indicated that these organisms are entirely different.

A disease or family of diseases characterized by their ability to pass through a bacteria-proof filter is being studied. Material from chinook salmon fingerlings at the Coleman, California and Willard, Washington stations is being investigated. Similar material from the sockeye salmon fingerlings at the Leavenworth and Carson, Washington stations was maintained in the laboratory but was lost in passage, possibly caused by a loss in virulence. The filtered material normally causes a mortality in healthy fish about six days after inoculation. No therapeutic measures have been found for this type of disease and prevention has been the only control measure.

The survey of parasites of adult chum salmon, a part of the International North Pacific Fisheries Commission research program, shows promise that parasites may indicate the geographical origin of the host fish. Analysis of data from the 1955 and 1956 collections has been completed. The results strongly indicate the practicability of the separation of the continental races of chum salmon based on the differential distribution of three parasite species. A survey of the 1957 collections is in progress.

IV. MICROBIOLOGICAL LABORATORY

Stanislas F. Snieszko
Kearneysville, West Virginia

GENERAL

Fish diseases in hatcheries are a problem of long standing. The federal government has $28 million invested in 98 hatcheries which cost approximately $4 million annually to operate. There are 495 state hatcheries, over 100 private hatcheries, numerous minnow farms and a rapidly expanding farm pond program. Fish culture is a major business in the United States.

As a result of the research done in the United States and in other countries, chiefly in Germany, France, the Soviet Union and Poland, much is known about the nature and control of some of the diseases caused by protozoan and higher animal parasites. In fact, because of improved control measures, worms and other parasites are causing little trouble in trout and salmon hatcheries. In the warm-water fish hatcheries, farm ponds, minnow farms and natural waters, parasitic diseases are still of great importance.

The Fish and Wildlife Service has studied intensively diseases caused by bacteria and fungi only during the past decade. New bacterial and fungal diseases have been identified during this period. Sulfa drug therapy developed by this research permitted the control of furunculosis, one of the bacterial diseases which formerly killed millions of hatchery fish. During the past four years the Service has learned to treat successfully other bacterial diseases with the newer antibiotics. Chemicals have been discovered which successfully treat fungus infections. The diseases for which there is little control still exceed in number those we have learned to treat. These include infections caused by the pathogenic bacteria, many of the fungi and most of the viruses. They are most likely responsible for sudden and "unexplained" epidemics which have frequently destroyed great numbers of fishes in various hatcheries. The role of virus diseases in the propagation of salmon became apparent only recently. Nothing is definitely known about the influence of environmental factors on the incidence and the cause of infectious and parasitic diseases of fishes. Significantly, environmental factors are considered of paramount importance in human and animal medicine and plant pathology.

The Microbiological Laboratory serves the eastern United States as a center for research on the nature, treatment and prevention of infectious fish diseases. It is also a center for information for federal, state and private fish hatcheries on diagnosis, methods of treatment and general control of fish diseases. In addition, courses on fish diseases are conducted for federal, state and privately employed fishery biologists and fish culturists.

RESEARCH

Kidney disease.--Kidney disease is scattered in trout and salmon hatcheries all over the United States and is still spreading. It is a slow progressing disease, but the mortality rate of infected fish is high, as far as it could be established on experimental fish and by losses occurring in hatcheries. Research on kidney disease has shown that Mueller Hinton (MH) medium with 0.1 percent L-cysteine hydrochloride is slightly better than Ordal's blood agar for routine cultivation and isolation of the kidney disease organism. Modified MH medium is used for stock culture and sensitivity testing purposes. Three strains of the kidney disease organism, the drug sensitivity of which had been determined on blood agar, have been similarly tested on MH medium. There were no gross differences between the results obtained on the two media; the results, however, were more easily determined on MH medium. New strains are being sought from different parts of the country.

Kidney disease transmission trials were terminated 101 days after initiation. The results indicated that under the conditions of the experiment the eastern strain was virulent and the western strain nonvirulent for the eastern brook trout used.

Results of attempted disease transmission with an eastern strain of kidney disease bacteria

Treatment	First mortality	Percentage KD mortality
Bacteria in diet	-	-
Bacteria + bile salts in diet	-	-
Bacteria + glass splinters in diet	-	-
Self-abrasion in brick-studded troughs	96 days	4%
Periodic manual abrasion	48 days	65%
Control	-	-

Fish which survived either method of abrasion were held for observation. At the end of six months the residue of these lots was killed and examined.

Treatment	Total mortality due to kidney disease bacteria: Western strain	Eastern strain
Self-abrasion	4%	32%
Hand abrasion	-	68%

The results of this experiment show that kidney disease was not transmitted to fingerling brook trout by feeding. A distinct difference was observed in the relative virulence of the bacterial strains. The eastern strain was the more virulent to the experimental fish; this strain caused the first mortality at 48 days and continued to do so until 288 days after the trials were started. Of the trout used in this experiment 13 which had been challenged with eastern strain bacteria survived and were killed 296 days after the trials were begun; kidney disease bacteria were not found in the kidneys of these fish. Mortalities among the fish challenged with western strain bacteria did not occur until 109 days after the trials were started but continued to do so until the 296th day. Nearly half of the fish challenged with the western strain bacteria survived the 6-month period of observation, and the kidney disease organism was presumptively identified in the kidneys of about 2 percent of them.

The kidney disease was a slow-to-develop infection. It ran an extended course and without treatment continued to cause mortality for months after the period of deliberate attempts at infection.

There is no assurance that the strains of bacteria used in this experiment are representative of the etiological agents of kidney disease in the West or in the East. There is good reason to believe that there are no essential differences in the condition called kidney disease as it occurs in the West and in the East except that in the West it is predominantly a disease of salmon and in the East the species of fish most affected so far is the eastern brook trout.

The successful transmission of kidney disease by methods of abrasion suggests that a similar portal of entry may be involved in hatchery occurrences. The direct agency, however, could be mechanical or biological (parasite).

The results of the in vitro sensitivity testing of various strains of kidney disease bacteria were examined, and the most promising agents selected for in vivo trials. Brook trout were tested for their tolerance of these agents at dosage levels recommended for warm-blooded animals. Similar fish were given a .2 cc. intraperitoneal inoculation of kidney disease bacteria in a suspension standardized turbidimetrically. Within 48 hours bacteria were found in the kidneys of some fish and by the eighth day all fish sampled had bacteria in their kidneys.

Toward the end of the quarter definitive kidney disease therapy trials were initiated. Susceptible brook trout were hand sorted, distributed in aliquots in replicated randomized lots, weighed and inoculated with a .2 cc. of turbidimetrically standardized suspension of kidney disease bacteria. Sampling established that the fish were uniformly affected with kidney disease and treatment was started during the latter part of June.

Many antibiotic and chemotherapeutic substances have been used in the in vitro sensitivity testing of the kidney disease bacteria. Donors have been given the appropriate results. Where agents showed promise samples were requested and received. Price quotations were solicited for those showing most promise in the in vitro work.

Fish furunculosis.--Research was carried out on two projects: (a) a rapid and reliable method of determining the drug sensitivity or drug resistance of Aeromonas salmonicida and (b) differences in pathogenicity and in other characteristics between the sulfonamide sensitive and resistant strains of this bacterium. The results of the first project are in press. As the result of this research, the resistance or sensitivity of A. salmonicida to sulfonamides and antibiotics can be determined in vitro within 24 to 48 hours. During the experiments on the first project sulfonamide resistant strains of A. salmonicida were less virulent to fingerling eastern brook trout than the drug sensitive strains. This finding shows that sulfa therapy may reduce losses even when the disease-causing strain of A. salmonicida becomes sulfonamide

resistant. A report on this experiment is in preparation.

Blue-sac disease.--In a joint project the State of Pennsylvania and the Microbiological Laboratory investigated the hereditary aspects of the blue-sac disease. The following table shows the results:

Type of incubation		Parent species: Rainbow x Rainbow	Rainbow x Eastern brook	Eastern brook x Eastern brook
Normal	Percentage hatched	100%	25.5%	96%
	Percentage blue-sac fry	18%	61%	62.5%
Closed-system	Percentage hatched	66%	2%	28%
	Percentage blue-sac fry	100%	100%	100%

These results indicate the following:

1. The closed-system type of incubation uniformly resulted in blue-sac disease among all three replicated lots.

2. Under the normal type of incubation in the experimental trials not all hybrids of eastern brook trout and rainbow trout developed the blue-sac disease. Chi-square (X^2) = .064; degrees of freedom = 1 P = 80%, therefore, the percentage of hybrid fry having the blue-sac disease is not significantly greater than the percentage of disease that occurred in the eastern brook trout half-siblings.

Various fish pathogenic and saprophytic bacteria.--There are at the Microbiological Laboratory more than 100 cultures of bacteria isolated from fish with miscellaneous pathological conditions. Some cultures were received from foreign countries. There are also on hand several well-described type-strains of Aeromonas liquefaciens (synonyms: Pseudomonas punctata or Proteus hydrophilus). In past years all characteristics of these strains were determined. This work was recently completed by determining the sensitivity of these cultures to many antibiotics and sulfonamides. The results will be evaluated later. They may give a tool for rapid typing of bacteria which are causing low-grade or sometimes explosive mortalities in trout and warm-water fish hatcheries.

Pancreatic necrosis.--Preparations are in progress for an all-out effort to determine the nature of this disease. The tissue culture technique will play a predominant role in this research. In preliminary work, eastern brook trout fry which had symptoms of infectious pancreatic necrosis were ground and extracted with saline. The resulting fluid was clarified by centrifugation, Seitz-filtered and inoculated into growing cultures of eastern brook trout swim bladder at 1/40 of the volume of the fluid phase present in the culture flask. In three separate trials the replicated inoculated cultures displayed degeneration of epithelial-like cell sheets. This change became evident at about four days at 19° C. The uninoculated controls did not evidence this change. A transfer of pooled fluid from cultures displaying degeneration into new cultures of brook trout swim bladder resulted in similar degeneration. This inoculum was calculated to contain 1/1600th of the original inoculum. These results are cautiously interpreted as supporting the hypothesis of a virus etiology.

Diagnostic service.--An employee of the Microbiological Laboratory visited periodically the federal hatcheries in Regions 3, 4 and 5 of the Fish and Wildlife Service to routinely diagnose diseases and to recommend routine treatments. Much of the work was directed toward accumulating data on the distribution of kidney disease. As a result of this information, experiments will be performed at the Berlin, New Hampshire station and possibly at one of the trout hatcheries in Region 4 to determine the conditions favoring outbreaks of this disease and to test various control methods.

V. SALMON-CULTURAL LABORATORY

Roger E. Burrows
Entiat, Washington

The objective of this laboratory is to increase the survival rate of artificially propagated salmon in the hatchery and after release in the stream. To achieve this objective, the laboratory is developing economical, practical diets for salmon, exploring factors influencing artificial

propagation and developing techniques and equipment for more efficient fish-cultural operations than the present ones.

Feeding trials.--The feeding trials for 1956 were made to evaluate the effect of various types of binding agents on diet utilization. The results indicated that no commercial binding agent was superior to salt for increasing diet utilization but that, with one exception, all of the binding agents increased the food utilization by 100 percent when compared to fish fed an unbound control diet. A report on this experiment has been prepared.

The feeding trials for 1957 are being conducted in cooperation with the Fish and Wildlife Service's Salmon Nutrition Laboratory, Cook, Washington, and are designed to determine the optimum protein level for chinook salmon.

Acceleration of sexual maturation of adult salmon.--Studies show that a reduced light exposure will accelerate the maturation of sockeye salmon. Sockeyes subjected to 9-1/2 hours of light, normal sunlight for October 1, spawned 19 days ahead of the control fish after 36 days of the shortened light exposure. The light exposure this season will be shortened to one hour per day and the acceleration measured.

Pituitary glands were collected from chum salmon, frozen and forwarded to the University of California Medical School for lyophilization. The lyophilized glands were then sent to the University of Buffalo for fractionation. The attempt to isolate ACTH-free gonadotrophins from a portion of these glands has failed as indicated by the lack of gonadotrophic activity in gonadectomized trout. Other fractions will be prepared but field trials will be delayed until 1958.

The acceleration experiments are being conducted to find a practical method for reducing the holding period required for long-run fish trapped on their upstream migration. A reduction in the length of the holding period should result in a reduction in the adult mortality.

Diversion and retention of adult salmon.--Testing of the electrical diversion weir is complete. Results indicate that for efficient operation the weir should have a barrier strength of 0.5 volt per inch with an effective field length of 10 feet in which the voltage gradient may vary from 0.3 to 0.7 volt per inch. The minimum water velocity at the weir site should be three feet per second. This type of weir has proved practicable for the diversion of adult salmon and a report on it has been prepared.

An experiment to determine a more efficient method for trapping impounded salmon as they approach ripeness is in progress. The late run adult salmon which spawn in late October and early November do not readily enter an upstream trap. These large fish have a predominantly downstream movement on their spawning migration. Downstream adult traps have been constructed to determine if these fish may be trapped effectively in this manner.

Evaluation of rearing pond design.--The rectangular recirculating rearing pond, developed as a result of these investigations, was tested under actual operating conditions during 1956. These preliminary tests indicate the superiority of this pond over other pond types. A more detailed evaluation to determine the carrying capacity of the pond and the environmental conditions in it is in progress. The full-scale prototype and the 8-1/4 scale models will be evaluated in the second half of 1957.

An intensive investigation of the environmental conditions in various pond types and the response of salmon to these conditions is being made. Studies show that extreme differences in environmental conditions develop in a raceway pond stocked to near capacity with chinook salmon fingerlings. Oxygen, carbon dioxide and ammonia determinations were made at 10-foot intervals, surface and bottom, in a Spring Creek Station raceway pond 115 feet long by 10 feet wide carrying 1.52 pounds of fish per cubic foot of water or 14.2 pounds per gallon of inflow. Under these conditions a highly favorable environment existed in the first 25 feet of the pond, good conditions in the next 50 feet, and near lethal conditions in the last 40 feet. At these intervals abrupt changes in environment occurred as indicated by drops in the oxygen content of the water from 10.3 p.p.m. at the head of the pond to 4.8 p.p.m. at the foot and increases in the ammonia up to 0.57 p.p.m.

In a 30-foot circular pool operating under similar conditions carrying 1.51 pounds of fish per cubic foot of water and 20.2 pounds per gallon of inflow, no abrupt oxygen gradient existed but near lethal conditions were evidenced by an oxygen content of 5.1 p.p.m. at the periphery and 3.1 p.p.m. at the center outlet.

Both pond types were stocked beyond their optimum carrying capacities as indicated by the fact that the fish were not consuming their normal amount of feed. The circular pond was carrying 42 percent more fish per gallon of water inflow than the raceway pond. In the circular pond, oxygen was the limiting factor. An increase in the amount of water introduced or in the oxygen content of the pond water by other means could have alleviated this condition. As the water supply was being fully utilized the only alternative would be to increase the oxygen content by other means. In an incidental experiment the oxygen content was increased 13 percent in 73 percent saturated water by means of an aspirator installed in the inflow pipe of a circular tank. The installation of similar aspirators at the Spring Creek Station would probably increase the oxygen content of the circular ponds in excess of 13 percent.

Conditions which limit the capacity in the various pond types will continue to be explored.

Development of an effective algicide.--Tests of potential algicides are continuing. Lignasan X, a 6.25 percent concentration of ethyl mercury phosphate, is the most satisfactory algicide tested to date for controlling green algae in rearing ponds. A 1:1,000,000 concentration for a 1-hour exposure at weekly intervals has proved effective for experimentally controlling algae. Tests are being conducted on a production basis.

Thresholds of normal development of salmon eggs.--Previous experiments demonstrated that chinook salmon eggs subjected to constant water temperatures below 42.5° F. or subject to increasing mortalities until at 35° F. experience a loss in excess of 95 percent. The experiment this season was designed to determine at what stage in development chinook eggs could tolerate temperatures of 35° F. with impunity. The egg mortalities indicate that when development has progressed to the forepart of the blastula stage, 6 days at 42.5° F., eggs can tolerate temperatures of 35° F. for the remainder of the incubation period without abnormal mortalities. The experiment is not concluded and significant differences in fry mortalities may develop in the lots which were subjected to 35° F. temperatures in the blastula stage, 6 days at 42.5° F. and the forepart of the gastrula stage, 9 days at 42.5° F. These lots of fish are showing evidence of coagulated yolk and an abnormally high mortality is anticipated.

SPECIAL INVESTIGATIONS

I. BIOLOGY OF GREAT LAKES FISHES

John Van Oosten
Ann Arbor, Michigan

Since 1921 materials have been collected on the Great Lakes fishes and fisheries but these data have remained largely unworked. Now that the Great Lakes investigations have been greatly expanded, this valuable, older material is being analyzed so that it may form a basis for comparison with current data. A preliminary report on the fishes taken in experimental and commercial gill nets in Lake Erie in 1927-1932 has been prepared, and studies were begun on the trap-net experiments on the same period.

The expanded biological program has created a demand for complete references on the biological researches on the Great Lakes. To meet that demand a bibliography of the Great Lakes fauna and flora and their environment, which lists approximately 3,040 papers, has been completed.

II. EASTERN FEDERAL WATERS

Robert E. Lennon
Kearneysville (Leetown),
West Virginia

The federal lands in the southeastern United States include the Great Smoky Mountains National Park in North Carolina and Tennessee and the Shenandoah National Park in Virginia. The numerous streams in these parks drain some of the highest and more remote slopes of the southern Appalachian Mountains. The courses of these streams

are generally short, steep and rough and the waters are among the softest in North America.

The most important fishery resources of these areas are the eastern brook trout and the rainbow trout. Many factors have contributed to their depletion. Fishing pressures became great and are increasing and severe droughts and floods have affected the productive capacities of the waters. Liberal fishing regulations and haphazard stocking procedures in the past altered the status of the fishery resources and the fishing pressures.

To remedy the depleted fishery resources, a program was established in 1953. Its objectives are to define measures to arrest the decline of wild trout populations in the face of increased fishing pressures, restore or reestablish trout, especially brook trout, in streams where populations have been reduced or destroyed by severe floods or droughts, determine factors governing fish production, formulate fishing regulations based on the potentialities of the fishery resources and develop methods and equipment for surveying streams and collecting fish in the mineral-deficient waters.

SHENANDOAH NATIONAL PARK

Precipitous declines in fish populations occurred in the Shenandoah streams in 1952 and 1953 and the lowest levels of abundance occurred in 1954. Because of severe drought many of the more important trout streams were largely dry for most of the 3-year period. Extensive surveys showed that 0-year and 1-year age groups were almost entirely missing, the 2-year and older trout were in poor condition and disappearing and the production of food organisms in the streams had beenbadly damaged. The National Park Service, acting on recommendations of the Fish and Wildlife Service, prohibited fishing in the Park in 1954 and 1955.

Water conditions improved in 1955 and trout populations rapidly improved through early 1957. Small numbers of adult survivors produced strong year classes in 1955 and 1956. A good distribution of trout occurs throughout the courses of the streams, stretches of which were previously barren. The improved condition of the trout reflects the great increases of food organisms. Semi-annual surveys on representative streams indicate, however, that recovery has been much more rapid in some streams than in others, as shown below:

Stream	Estimated number of brook trout per acre		
	1954	1955	1956
Big Run	15	529	363
Jeremys Run	13	624	1216
Moorman River, North Fork	8	48	76
Piney Run	91	245	943
Rapidan River	94	292	426

The National Park Service opened all streams of the Park to fishing in 1956 and 1957 and extended the seasons to conform to the State of Virginia's seasons on trout. Restrictions specified the use of artificial lures and a minimum legal size of nine inches to permit continued recovery of the fishery.

The Moorman River is important because of its proximity to Charlottesville and Waynesboro, Virginia. On surveys last fall and this spring of the North Fork of this river young-of-the-year brook trout and rainbow trout were collected. No 0-young fish were taken there in 1954 and 1955. Since this river is more marginal for trout than other major waters of the Park, the recovery of the trout fishery will probably be slow. The collection of the small rainbows was the only instance in which exotic trout were found in the Park. No doubt Virginia-stocked rainbow trout have become established in Charlottesville Reservoir and will spawn in the North Fork when water conditions permit. Anglers on Moorman River took adult fish up to 20 inches long in the spring of 1956 and 1957. The overwinter survival of young-of-the-year rainbows was good and their growth for the period exceeded that of brook trout in other streams; specimens average 3.49 inches long on November 29 and 5.49 inches on April 12.

GREAT SMOKY MOUNTAINS NATIONAL PARK

Brook trout.--Marked fingerling brook trout of native Appalachian strain have been stocked in several barren or near-barren streams since 1954. Trout stocked as 3-inch fingerlings in Alum Cave Prong in 1954 and 1955 survived well and now range up to 10 inches long while those stocked in West Prong Little Pigeon River in the same years range up to 10.2 inches long. There are some

natural reproduction by these fish in 1956. Measures of fishing success for brook trout seven inches or more in length were made in June and catches ranged from 2.8 to 11.4 fish per hour of effort. Both streams, however, are restrocted to sport fishing only and no possession of fish is permitted.

The 3-inch fingerling brook trout stocked in Ramsey Prong in July 1956 made excellent growth. The Greenbrier creel-checking station found that specimens seven inches or longer are entering the legal catch. Porters Creek showed similar results.

Racial studies on native brook trout collected in remote headwaters have been continued. Data on meristic characters and condition factors are complete and observations on egg production, age and growth are being continued. The frequent occurrence of diseased ovaries in adult females may be related to the fewness of small trout and to a sex ration two to one in favor of males.

Hazzard-plan streams.--The improved populations of brook trout and rainbow trout have resulted from protection afforded by the Hazzard plan. Contacts with anglers on West Prong Little Pigeon River and Bradley Fork indicate that use of these sport-fishing-only streams has increased in 1956 and 1957. An estimated 610 anglers were on the West Prong and 1,319 on the Bradley Fork in 1956. Surveys on the West Prong, the poorer of the two streams, showed 8.0 pounds of brook trout and 10.6 pounds of rainbow trout per acre in 1955 in contrast to 12.9 pounds of brook trout and 23.6 pounds of rainbow trout per acre in 1956.

The increasing numbers of visitors in the spring and fall seasons will have opportunities for good sport fishing. Under the Hazzard plan the West Prong and Bradley Fork, beginning September 1, 1957 will be open to fishing the year round. Up to June 30, 1957 they had been open to fishing only during the regular season. In addition, long and easily accessible sections of Little River and Oconaluftee River also will be open to year-round fishing beginning in the summer of 1957. The Hazzard-plan restrictions will apply from September 1 through May 15, but general regulations which permit possession of five fish per day will apply from May 16 through August 31.

Electrofishing.--Alternate-polarity electrode systems built of No. 8 welding cable have proven more durable and less subject to breakdowns than systems built with braided shielding and will replace them.

During winter resistivities in streams which ranged from 100,000 to more than 200,000 ohms per cubic centimeter greatly reduced the efficiency of electrofishing. Extensive tests with 50-pound blocks of cattle salt showed that these resistivities could be lowered by as much as 82 percent in the immediate vicinity of survey sites. Spring and fall trials made to test the value of the salt blocks found that the effectiveness of the shocker is greater in salted water than in salt-free water. In salted water the shocker stuns the fish more completely, making them easier to collect than in salt-free water. A greater proportion of available fish, thus, can be removed on single passes through test areas. The chief advantage of the salt, however, is making efficient electrofishing possible in winter when extremely high resistivities prevail. A block lasts about four hours in a stream, making its cost about 20 cents per hour.

Creel census.--Creel census stations were operated on Little Pigeon River and Big Creek in 1956 and are in operation on the Little Pigeon and Little Rivers this season. In addition, the mobile checks begun on four streams last year are again being made. Station records show that in 1956 there were 11 percent more fishermen on Little Pigeon River and 54 percent more on Big Creek than in 1955. Increases in fishermen of the magnitude recorded on Big Creek reflect partly improvements in access to streams. Non-residents from 8 states and Canada were recorded on Big Creek last year, from 17 states on Little Pigeon River and from 22 states and the District of Columbia on Little River.

Catchable-size rainbow trout which were stocked in creel census streams in May, June and July 1956 received distinctive fin clips. Returns from fish stocked in June exceeded those stocked in May and July. Of 6,000 rainbow trout stocked in Oconaluftee River in 1956, anglers took an

estimated 4,010. Records of the first two weeks of the 1957 season indicate that a substantial number of carry-over fish may be taken this year.

Reclamation of streams.--Indian Creek, a tributary of Deep Creek, was selected for an experiment in reclaiming a mountain stream. Rotenone (PRO-NOXFISH, Formula 56 for Cold Water) was applied at selected streamns between April 22 and May 1 to eradicate rainbow trout and longnose dace from the lower six and a half miles of main stream and one mile of Georges Branch. Results were successful and no escapement was observed. Five hundred and ninety-two rainbow trout, 0.9 to 13.7 inches long, and 85 longnose dace were collected for measurements. A potassium permanganate solution was added to Indian Creek Falls near the mouth to reduce the toxicity of the rotenone.

Methods for determining stream velocities, flow volumes, concentrations of toxicants needed at various flow rates, frequency and concentrations of strengthening doses and the spreadout and dilution of a toxicant moving downstream were developed through repeated trials with blocks of cattle salt used in conjunction with an electric conductivity meter. The results obtained with salt were confirmed by tests with malachite green dye and comparator tubes. Tests were also made with rotenone in streamside troughs on rainbow trout and longnose dace to define minimum toxic concentrations and required durations of exposure to kill fish.

Indian Creek and Georges Branch were restocked with 12,000 fingerling brook trout, Appalachian strain, in late June. Both streams appear to offer an excellent opportunity for reestablishing the native species. The growth and survival of the fish will be closely observed.

The near completion of the Chilhowee Dam at Chilhowee, Tennessee, under construction by the Aluminum Corporation of America, has prompted the largest reclamation job yet attempted in the Southeast. The new 17,000-acre impoundment on the Little Tennessee River will be managed for rainbow trout. The lake will inundate the lowermost two to two and a half miles of Abrams Creek in the park and nine miles of the Little Tennessee upstream to Calderwood Dam. Since both Abrams Creek and the river contained abundant trash fish, an agreement was made in May 1957 among the Tennessee Game and Fish Commission, Tennessee Valley Authority, Aluminum Corporation of America, National Park Service and the Fish and Wildlife Service to reclaim the waters before the lake is created. The date for the work was originally set for July 1957 but was suddenly advanced to early June.

Abrams Creek is a large stream with an average discharge of about 90 cfs. Surveys showed that carp and other trash fish occurred throughout the entire 17-mile lower section between Abrams Falls and the mouth; short cascades and long deep pools characterize this section. The terrain is so rough that the area is one of the most inaccessible areas in the park. Round-the-clock tests were made with salt blocks and a conductivity meter to determine the velocity of the stream over long distances, its discharges at various levels and the factors of spreadout and dilution. High turbid water precluded confirmatory tests with dye. Tests were made with rotenone in streamside troughs to determine their toxic concentrations and effective durations of exposure. Some carp, for example, survived a 3-hour exposure to rotenone at 1 p.p.m. while others died only after exposures up to six hours at 0.1 p.p.m.

For the poisoning job to be successful the Fish and Wildlife Service's bolt of rotenone in Abrams Creek had to meet the State of Virginia's bolt in the Little Tennessee River at the confluence exactly at noon on June 9. Therefore, rotenone was introduced continuously from 12:20 to 6:20 P.M. on June 8 at Abrams Falls. Strengthening doses were applied in the main stream and in the tributaries as the bolt moved downstream. Eight hundred and eighty-eight pounds of rotenone were used, and the bolt arrived at the mouth of Abrams Creek on time.

Counts and measurements were obtained on 3,233 fish picked up during the toxicity tests and reclamation operations. These included larval and adult lampreys, gizzard shad, 448 rainbow trout, several species of suckers, 45 carp, blue and channel catfish, sauger, smallmouth bass, rock bass, bluegill and other sunfishes and drum. The non-appearance of small carp indicates that carp cannot spawn successfully in Abrams Creek.

Fingerling rainbow trout will be stocked in Abrams Creek. The main stream and tributaries below the Falls are too warm for brook trout.

National Park Service personnel gave excellent assistance during the operations on Indian and Abrams Creeks. They contributed greatly to the successful program on Abrams Creek by establishing a work camp, clearing trails, packing in supplies, furnishing vehicles and participating in the poisoning job.

Water quality in streams.--A program was begun in December to collect all-season data on water chemistry, temperatures, levels and discharge rates, and electrical resistivities at selected sites in three of the major watersheds in the park.

SECTION OF MARINE FISHERIES

Howard H. Eckles and Harvey L. Moore
Washington, D. C.

The Marine Section is studying the causes of the great fluctuations in abundance, both natural and man made, which occur in the major ocean fisheries in order to recommend such conservation measures as will effectively maintain continuing production without unduly hampering fishing operations and to predict changes in abundance sufficiently in advance to minimize their effects on dependent industries. Increasing yields from existing fisheries are being sought by such means, for instance, as establishing the appropriate age and the time of capture. Efforts are being made to define through oceanographic surveys the area variations in fertility within the oceans for the purpose of making more effective the search for new fishery resources and the solution to such specific problems as the cause of the destructive "red tides". The areas under study encompass the waters of the Atlantic Ocean from the Grand Banks to Florida, the entire Gulf of Mexico, and the western and central Pacific.

NORTH ATLANTIC FISHERY INVESTIGATIONS

Herbert W. Graham
Woods Hole, Massachusetts

The New England fishery is one of the most valuable in the world and is being fished with an ever-increasing intensity. The purpose of this investigation is to obtain the information necessary for sound management of this important resource.

After a period of years some of the important questions concerning the dynamics of the haddock population are nearing solution. Now, the program must be re-oriented to study the ecology of the banks in order to understand the effect of the various species on one another and the role of the physical factors in causing fluctuations in abundance.

The management of the offshore fisheries in the North Atlantic is the concern of the International Commission for the Northwest Atlantic Fisheries. Accordingly, the research of the North Atlantic Fishery Investigations is directed in large part toward supplying the Commission with information necessary for the international control of fishing in this area.

As in past years, research planning has been conducted in close collaboration with the Atlantic States Marine Fisheries Commission and the International Commission for the Northwest Atlantic Fisheries.

INTERNATIONAL COMMISSION FOR THE NORTHWEST ATLANTIC FISHERIES

An active program of research continued in Subarea 5 (Georges Bank and the Gulf of Maine), Subarea 4 (Nova Scotian Banks and the Gulf of St. Lawrence) and Subarea 3 (Grand Banks). These studies were directed toward the cod, haddock, redfish and halibut.

The recommendations for a long-range program to be conducted in the Convention Area, made by the Committee on Research and Statistics at Biarritz, France, in 1956 were reviewed at a Joint Scientific Meeting of the Commission, the Food and Agriculture Organization of the United Nations and the International Council for the Exploration of the Sea which followed the 1957 annual meeting of the International Commission. Remarkable progress in furthering the Biarritz recommendations was noted for all Commission countries.

Progress of especial interest to the United States was the publication by the Commission of the current statistics of the

total catch by species and value of fish taken from the Convention Area by the European countries. At least one of the European countries conducting extensive fishing in Nova Scotia, Newfoundland and Greenland waters is attempting to obtain from its fishing companies the complete statistics of catch over the past ten years. This information is valuable in assessing the condition of the fishery resources on this side of the Atlantic.

The United States contributed substantially to progress in futhering the recommendations made at Biarritz, France. Among these steps were standardization of methods of measuring fish, studies of the effect on fish abundance of the drift of eggs and larvae, successful tagging of redfish, measuring the natural mortality rate of haddock, standardization of methods of measuring net meshes and the development of a new mesh gauge.

INTERNATIONAL PASSAMAQUODDY FISHERIES BOARD

The International Joint Commission appointed the International Passamaquoddy Fisheries Board to conduct a 3-year study for determining the possible effects on the fishery of the construction of a tidal power project in the Passamaquoddy area of the Bay of Fundy. The Board set up a research committee composed of biologists and oceanographers from the Biological Station at St. Andrews, N. B., Canada, and from the laboratories at Woods Hole, Massachusetts, and Boothbay Harbor, Maine.

Since herring is the principal commercial species in the area, the research on this project is closely integrated with the Atlantic Herring Investigations centered at Boothbay Harbor.

ATLANTIC STATES MARINE FISHERIES COMMISSION

At the fifteenth annual meeting of the Atlantic States Marine Fisheries Commission at Atlantic City, New Jersey, in September 1956 progress on the investigations conducted within the jurisdictional area of the Commission (the 3-mile limit) was reported. The reports included the haddock mesh regulation, redfish studies, the yellowtail flounder fishery, the whiting or silver hake fishery, the industrial fishery and the Maine herring fishery. Summaries of the activities in these fields will be found elsewhere in this report.

VESSEL OPERATIONS

Albatross III.--The 18 scientific cruises included several haddock and cod tagging trips, measurement of fish escapement, studies of the distribution of several species, bottom sampling, plankton work, gear testing and underwater television experiments.

Two of the cruises were of international interest. The first cruise was a joint operation with the Canadian research vessel J. J. Cowie. The second was for the purpose of comparing C.P.S. Emitron and Image Orthicon underwater TV equipment. Representatives of the Scottish Marine Biological Laboratory operated the British equipment. A joint cruise, "Pair Tows Two", involved the Albatross III and the Delaware to determine the comparative fishing powers of the 41 "Balloon" and the 41 "Standard" trawls and to make simultaneous tows with different mesh sizes.

The staff members of the Woods Hole Oceanographic Institution collaborated in several cruises throughout the year.

T-79.--The activities of the T-79 were largely confined to investigating the flounder and the industrial fisheries off the southeastern coast of New England. This investigation included hydrographic work, trawling, underwater photography and tagging.

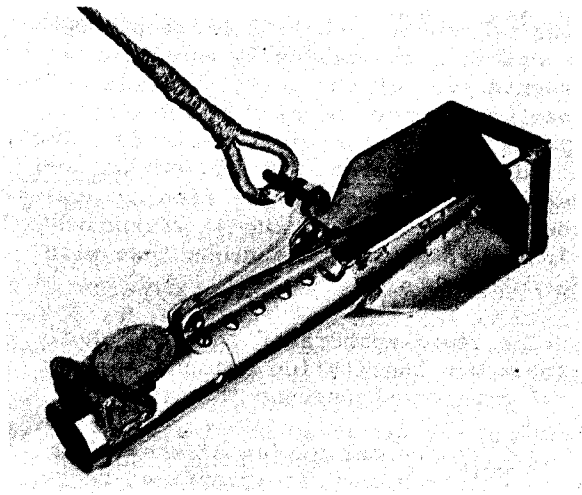
BOTTOM ECOLOGY

The survival, growth, migrations and distribution of the commercially important groundfish depend substantially upon the kinds and the quantities of food available to them. The food organisms, in turn, flourish or fail according to the suitability of their environment. The groundfish feed predominantly on the bottom-dwelling organisms. Many of these organisms are intimately associated with the sea bed, and their geographical distribution and abundance depend to a greater or lesser extent upon the type of substrate. Thus, the relationships of food organisms to the physical and the chemical composition of the substrates are a significant phase of the groundfish

production cycle. One aspect of the bottom ecology work is being investigated by a survey of the substrates on Georges Bank and vicinity.

Particle size composition.--Particle size analyses were made from 99 stations on Georges Bank and in adjacent waters. The Scoopfish bottom sampler and other dredging gearwere used to obtain the samples.

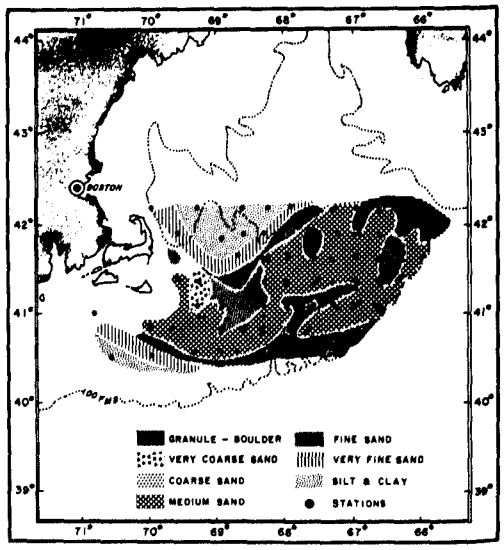
The substrate samples were sifted through a graded series of screens and the quantity of each size-fraction was measured.



SCOOPFISH BOTTOM SAMPLER

A large portion of central Georges Bank is composed primarily of medium sand (particle diameters between 0.50 and 0.25 mm.). A rather wide band along the southern edge of the Bank consists mainly of fine sands (0.25 to 0.62 mm.). Granules, pebbles, cobbles and boulders with admixtures of medium to coarse sand cover the bottom on the northern edge and parts of the northeast peak of Georges Bank. Silt-clay deposits (0.062 mm.) are located south of Nantucket Shoals and in the deep water in the northern portion of Great South Channel.

Chemical composition.--Fifteen substrate



GEOGRAPHICAL DISTRIBUTION OF ORGANIC MATTER IN THE SUBSTRATES ON GEORGES BANK AND VICINITY.

Five substrate types

Substrate type	Particle size[1/]	Organic matter (percent)	Ca	P	NO_3 N	Mg	K	Mn	Fe	Al	Number of samples
			(Extractable quantity in parts per million)								
Silt-clay	0.03	3.6	2115	30	6	1225	700	48	3	6	2
Very fine sand	0.09	2.6	2750	19	6	658	338	16	4	1	3
Fine sand	0.19	0.8	1000	11	2	303	92	11	2	1	3
Medium sand	0.38	0.2	1662	4	2	179	170	18	1	1	4
Coarse sand	0.75	0.3	337	5	2	187	70	16	3	1	3

1/ Mid-point of the predominant size category.

samples from the Georges Bank area were analyzed for organic matter and extractable calcium, phosphorus, nitrate nitrogen, magnesium, potassium, manganese, iron and aluminum. In general, these elements and the organic matter are inversely related to the particle size composition of the substrates.

The geographical distribution of the organic matter in the substrates expressed as percent weight on and adjacent to Georges Bank is illustrated below. The chemical constituents tested had distributional patterns similar to t hose for organic matter.

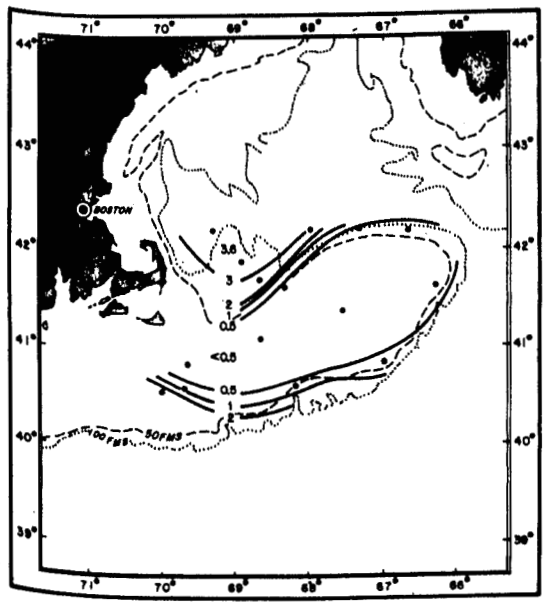
Off the northwest side of Georges Bank, where the substrate is a silt clay, the organic matter and the elements tested for were abundant. Along the southern periphery of Georges Bank, where the substrate is primarily a fine sand, the organic matter and the elements were present in moderate quantities. On the central and the northeast portions of Georges Bank, where the predominant substrate is a medium sand, the organic matter and the elements were present in small quantities.

COD

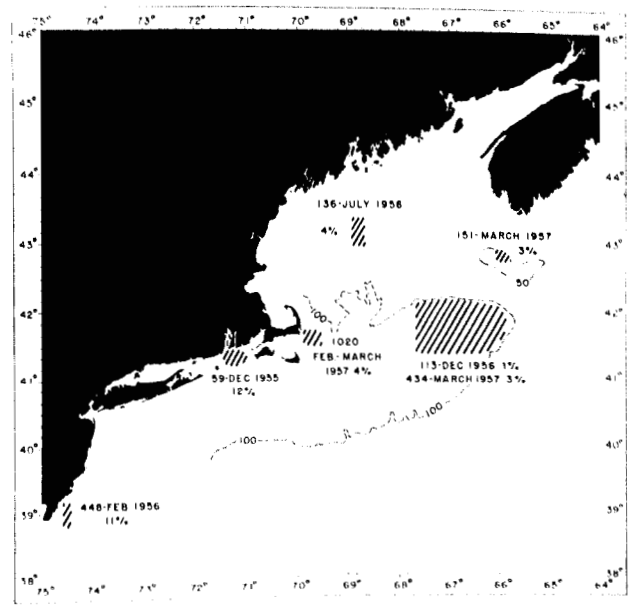
The major effort during the past year was devoted to identifying stocks in the New England area. Tagging was used because of its simplicity and the "fringe benefits" that may be obtained, such as information about population size, mortality and growth rates. The figure below shows the numbers of fish and the locations of all tagging to June 30, with approximate percentages of returns from each operation.

Observations on the incidence of Lernaeocera, a copepod parasite, were started and will continue through the summer. In other areas this parasite has proved useful as a biological tag in identifying races of cod.

At this time tag returns combined with the results of the United States Bureau of Fisheries' marking experiments from 1890 to 1930 allow the formation of the working idea that there are four major stocks in the New England region. There are two relatively stationary groups, one group on the offshore part of Georges Bank and the other in the Gulf of Maine. A third group, fish which winter in inshore Cape Cod waters, apparently moves to the Great South Channel in the summer, where they are joined by a migratory stock that



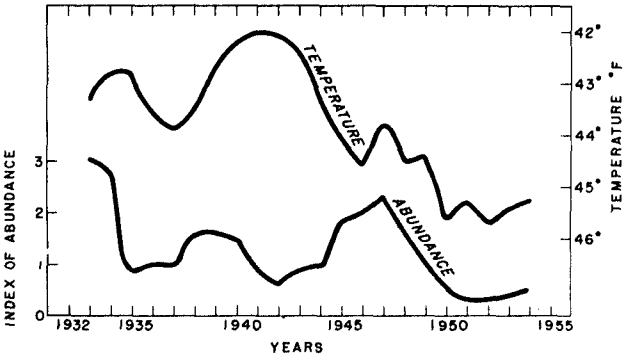
GEOGRAPHICAL DISTRIBUTION OF ORGANIC MATTER IN THE SUBSTRATES ON GEORGES BANK AND VICINITY. VALUES ARE EXPRESSED IN PERCENT WEIGHT.



AREAS, DATES AND NUMBERS OF COD TAGGED, WITH APPROXIMATE RETURN PERCENTAGES TO JUNE 30, 1957

spawns and spends most of the year in Long Island and New Jersey coastal waters.

A preliminary analysis of records of large otter trawlers fishing primarily for haddock on Georges Bank indicates that the local changes in abundance of cod may be related to the long-term hydrographic conditions. In recent years there has been a change in the relative abundance on Central and Western Georges Bank and a similar change may be demonstrated for the shallow and the deep zone of the Eastern area for the same period. This has been a period in which the winters were considerably milder than they usually are.



ANNUAL MEAN WATER TEMPERATURE AT EASTPORT, MAINE AND INDEX OF ABUNDANCE FOR LARGE COD IN DEPTHS OF 0-30 FATHOMS ON EASTERN GEORGES BANK, 1932-1955 (ALL DATA WERE SMOOTHED BY MOVING AVERAGE OF THREE)

A further examination of these data shows that the differences in the abundance are related to the size of the fish, as evidenced by the market categories caught. Large cod seem more affected than small cod; this finding supports the concept that this is a temperature-associated phenomenon. The similar abundance and the temperature curves, particularly since 1946, suggest more than a casual relationship.

An attempt, made in conjunction with the Woods Hole Oceanographic Institution scientists, to find a relation between the abundance of inshore cod and the amount of fresh-water runoff was unsuccessful.

Work continued on a bibliography of cod biology with emphasis on the Northwest Atlantic. Over 500 papers have been abstracted to punch cards which may be sorted mechanically for authors, subjects, dates and geographical areas.

A synoptic collection of all published cod growth rates, plotted on transparent paper at a uniform scale, is being made from bibliographic sources.

Efforts are being made to improve the collection of landing statistics on cod. The collection of length-frequency samples was adequate this year for the first time to report to the International Commission on the size distribution of cod in the United States otter trawl landings.

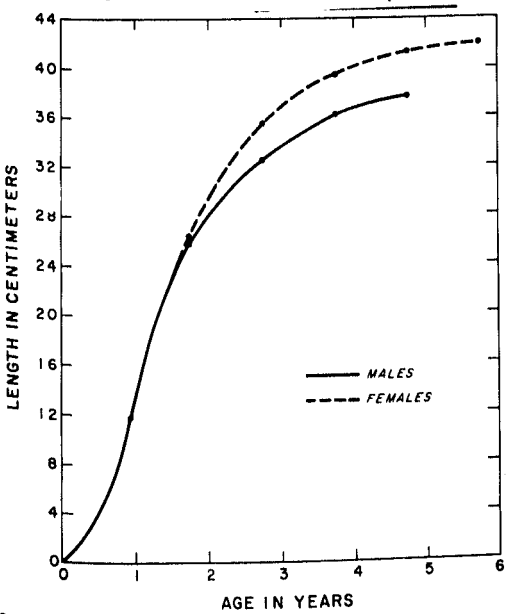
FLOUNDERS

State of the fisheries.--The landings of the principal flounder species, yellowtail, blackback and fluke, at southern New England ports in 1956 did not differ significantly from the 1955 figures. The slight increases in the Rhode Island yellowtail and blackback landings appear to have been caused by the high abundance of small fish in the catches from the Rhode Island waters. There is evidence that strong year classes of both species are moving into the fishery which may increase the 1957 catch.

Research.--The growth studies have been concentrated on the yellowtail during the past year, but some fluke and blackback data have been collected also for future work. When possible, yellowtail otoliths were obtained at monthly intervals during 1956 to provide evidence of the validity of their use for age determination and to show the seasonal sequence in annual ring formation in otoliths. Only one complete ring, consisting of an opaque band and a hyaline band, is laid down each year, although the beginning of the second annulus is found before the fish have reached the end of their first full year of life.

There is good correspondence between the size of the fish and the age determined from otoliths, indicating that otolith rings are laid down in a regular manner. Modes in the length-frequency distributions of 1- and 2-year old fish coincides with the model lengths of age groups based on otolith readings. These modes corresponded closely during the course of a year and the average

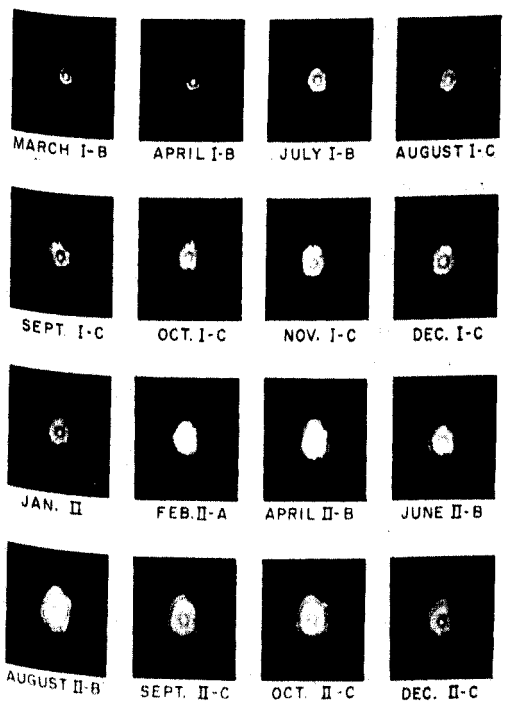
sizes within the young age groups increased regularly through the growing season. This information furnishes evidence that only one annulus is laid down each year.



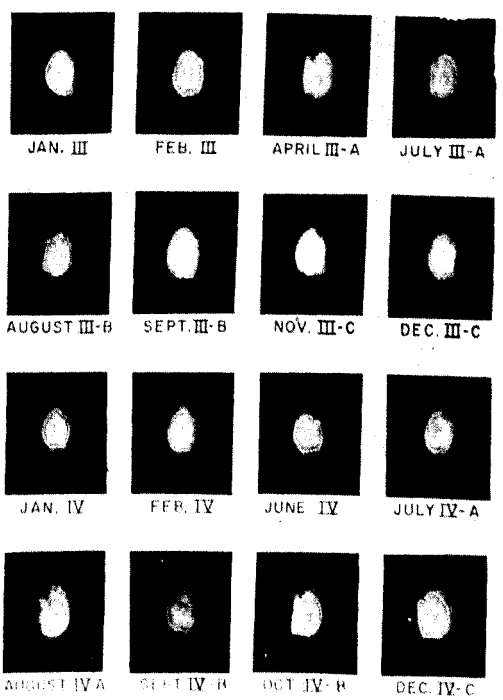
GROWTH CURVE FOR YELLOWTAIL FLOUNDER, BASED ON OTOLITH AGE DETERMINATIONS FROM THE FOURTH QUARTER OF 1956 CATCHES FROM SOUTHERN NEW ENGLAND GROUNDS

A growth curve for male and female yellowtails from the fourth quarter of the 1956 catches is shown. The growth in length is rapid during the first two years of life and the weight increases at a rapid rate for another year. Following the second year the females grow at a significantly greater rate than the males. The current work indicates that growth is faster at present than it was during the 1940s. The length-frequency samples of the commercial catches show a smaller proportion of old fish in the present catches than in the former catches. The work is planned to determine whether a real change in the growth rate and the age structure of the southern New England stocks has taken place.

In addition to counting the number of complete annual rings in the otoliths examined, the extent of the development of the ring being laid down on the otolith edge at the time of the collection was recorded for the purpose of tracing the ring development. The amount of edge growth was designated by letters: A, where the beginnings of a new opaque band could be distinguished; B, where an opaque band of considerable width was present; and C, where the peripheral opaque band was complete and the development of



OTOLITHS FROM 1- AND 2-YEAR-OLD YELLOWTAIL FLOUNDER, CAPTURED AT DIFFERENT TIMES OF THE YEAR, SHOWING DIFFERENTIAL GROWTH ON THE EDGES



OTOLITHS FROM 3- AND 4-YEAR-OLD YELLOWTAIL FLOUNDER, CAPTURED AT DIFFERENT TIMES OF THE YEAR, SHOWING DIFFERENTIAL GROWTH ON THE EDGES

they hyaline band of the annual ring was in evidence. The annulus formation was considered complete after January 1 and no letter designation was assigned to otoliths between January 1 and the time of the beginning of a new band.

The photographs of the otoliths from 1-, 2-, 3- and 4-year-old fish, showing the various stages of band development (no edge growth, A, B or C condition) are shown. The otoliths for the photographs were chosen to represent the stage of the development shown by the greatest proportion of otoliths examined from a given age group in a particular month. January 1 was taken as the birthday here in order to keep the age and the number of annuli the same.

The band laid down d uring the second year is the broadest in all of the otoliths. This corresponds with the period of most rapid growth in the fish length.

The first otolith of age group I, collected in March, has one complete annulus (center white opaque kernel plus the surrounding hyaline band), and in addition it shows development of a substantial part of the second opaque zone. It was, therefore, classed as age group I-B. The fourth otolith of age group I shows a completed second opaque band and the beginning of the second hyaline band. It was assigned to age group I-C. The first otolith of age group II shows no evidence of the beginning of the third opaque zone and it was classed as age II with no letter designation. The stage of the edge development was determined for the other otoliths in the same manner. Since the stages used to classify the edge growth are somewhat subjective, they allow no ironclad classification of the ring growth. They do serve to describe what is reasonably apparent when the otoliths are examined.

The young fish evidently begin to lay down the bands for the succeeding annual ring earlier in the season than do the older fish. The otoliths from the fish of age group I show stage B in late winter. In age group II stage B appears in mid-spring and in age groups III and IV it does not appear until August and September, respectively. Stage C also makes its appearance earlier in the otoliths of the young fish than in the older fish. It was evident in age group I fish in late summer but was not apparent in the otoliths from age group IV until the fall and the early winter.

Since the annual bands on the otoliths in later years are narrow compared with those of the first two years, detecting the beginning of a new band on the otoliths from the older fish is more difficult than from the young fish. This offers a partial explanation for the apparent time difference in the beginning of the otolith growth between the young and the old fish. It does not, however, seem sufficient to account completely for it. The possibility that young fish resume fast growth earlier in the season than old fish appears reasonable. If this is the case, it could account for part of the more rapid growth during the early years of life.

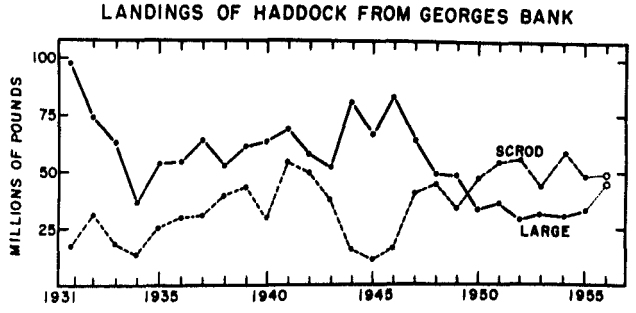
The opaque and hyaline zones of the annual ring of otoliths have sometimes been referred to as the summer and the winter bands, respectively. The foregoing information suggests that for the yellowtails they might be more accurately termed the spring and the summer band and the fall band.

As a part of the yellowtail study, over 1,000 fish were tagged from commercial draggers on southern New England grounds in early 1957. These tagging experiments were designed to help delimit the separate yellowtail stocks, if such exist, for individual consideration in future study. In addition, the growth of recaptured fish should contribute substantially to the validation of the otolith age and the growth studies.

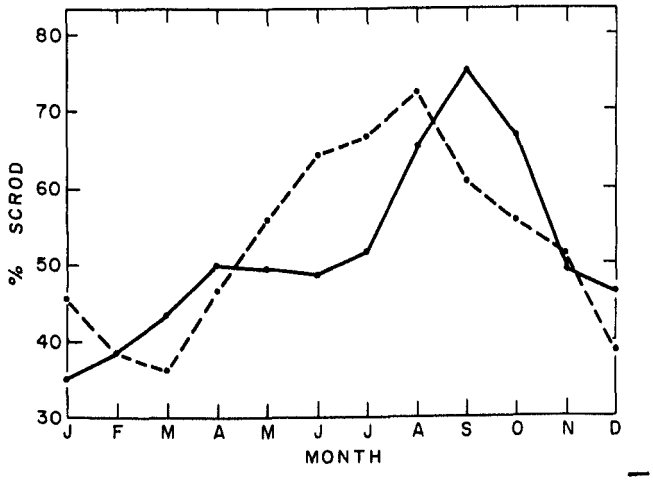
HADDOCK

The haddock landings from Georges Bank in 1956 were the largest since 1948. They resulted from an increase in the amount of fishing and a considerable increase in the catch of large haddock.

The large haddock landings, higher than in any year since 1950, failed to surpass the scrod haddock landings. The late arrival of the scrod on Georges Bank presented increases in their landings comparable to those for the large haddock. For the past nine years scrod dominated the landings from May to November. In 1956, the scrod were dominant from July to November.



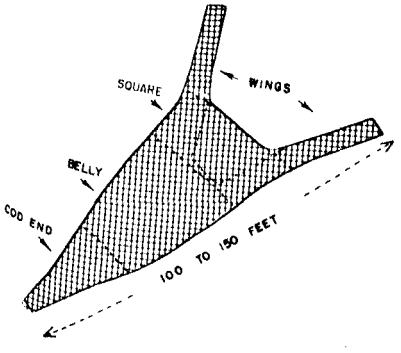
The regulation 4-1/2" mesh has a conservation value. It releases most of the unmarketable haddock which weigh less than a pound, retains the most marketable fish weighing over 1-1/2 pounds and catches slightly more fish weighing over three pounds than does the preregulation 2-7/8" mesh. These findings resulted from a comparison between four to eight large Boston trawlers which used the 2-7/8" mesh and other large Boston trawlers which used the 4-1/2" mesh.

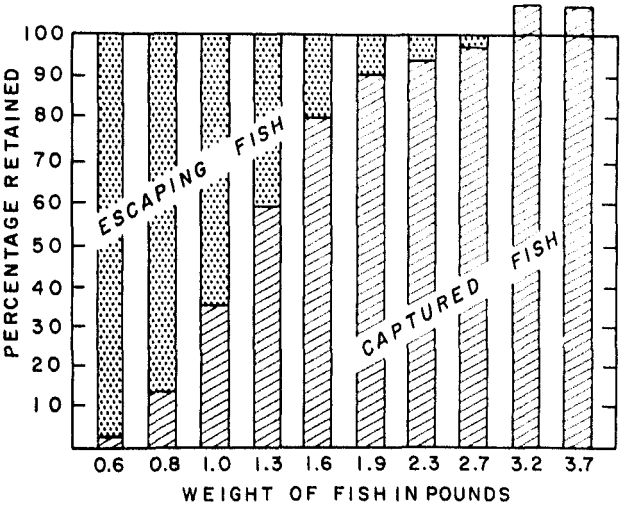


Underwater television increased our knowledge of the capture, the behavior and the escapement of fish through the trawl meshes. The camera unit, housed in a waterproof case, is rigged inside the cod end of a standard otter trawl. Shock-aborbing springs protect the camera from jarring when it is towed over uneven bottom.

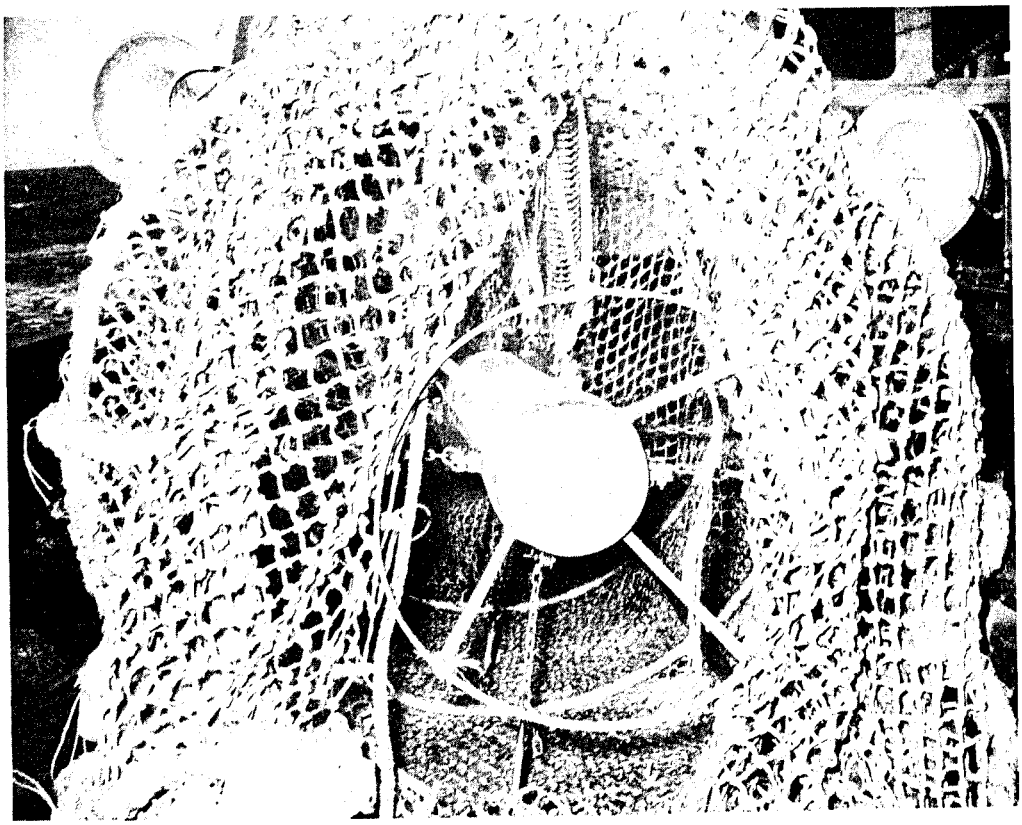
The net, with the camera in the cod end, was set out and towed on the fishing grounds.

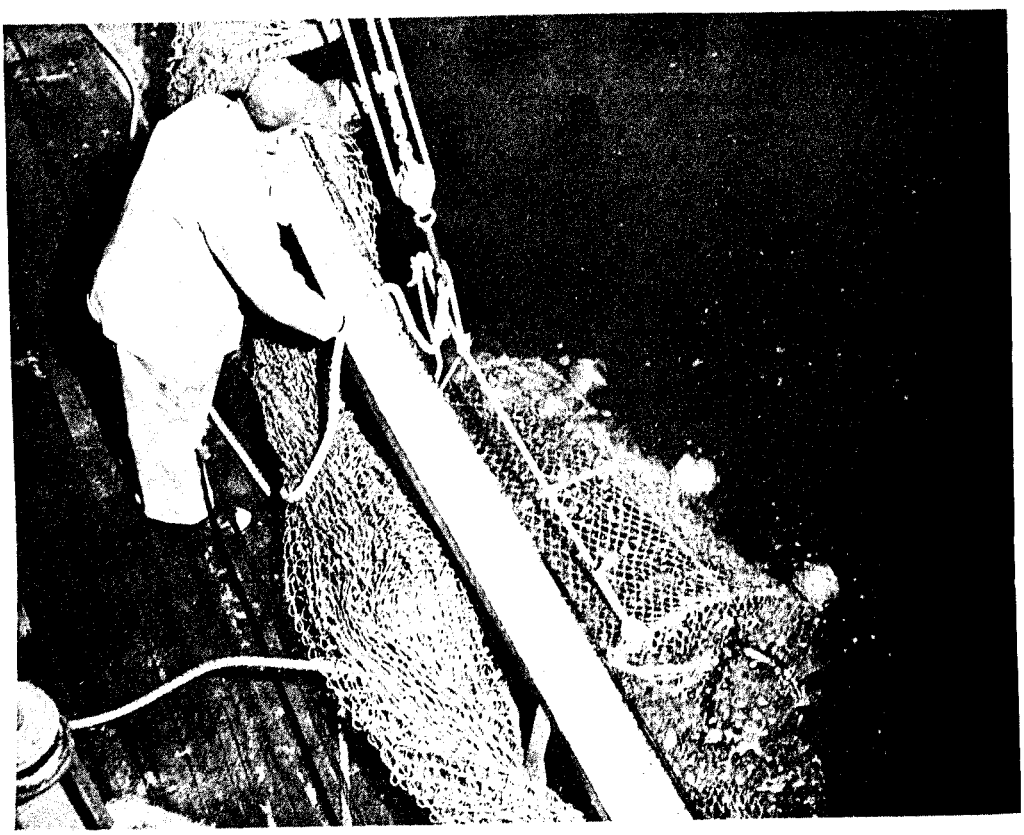
The TV camera, mounted vertically in a mesh-covered cage, gave a clear picture of the behavior of trawl-caught haddock. Lowered to

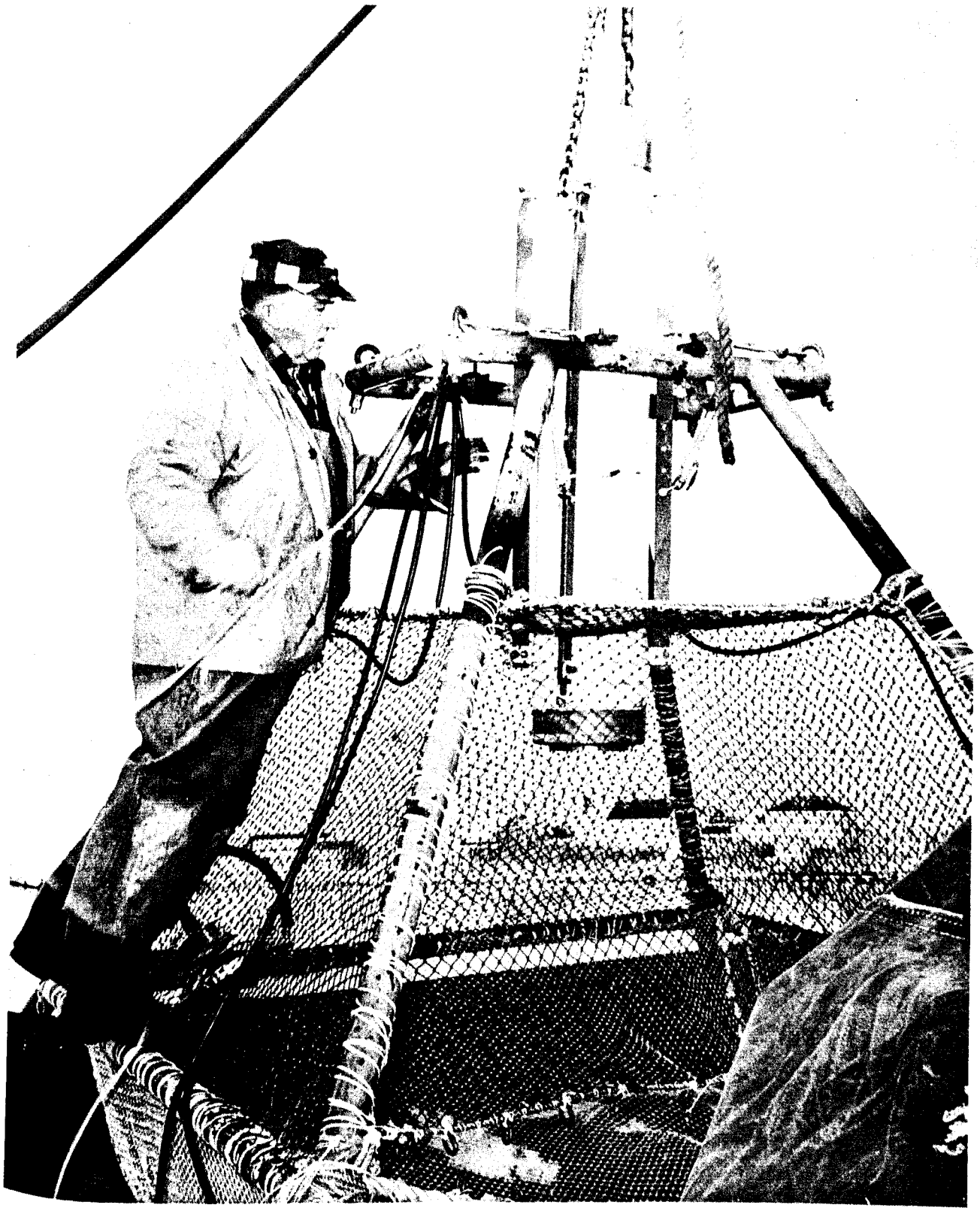


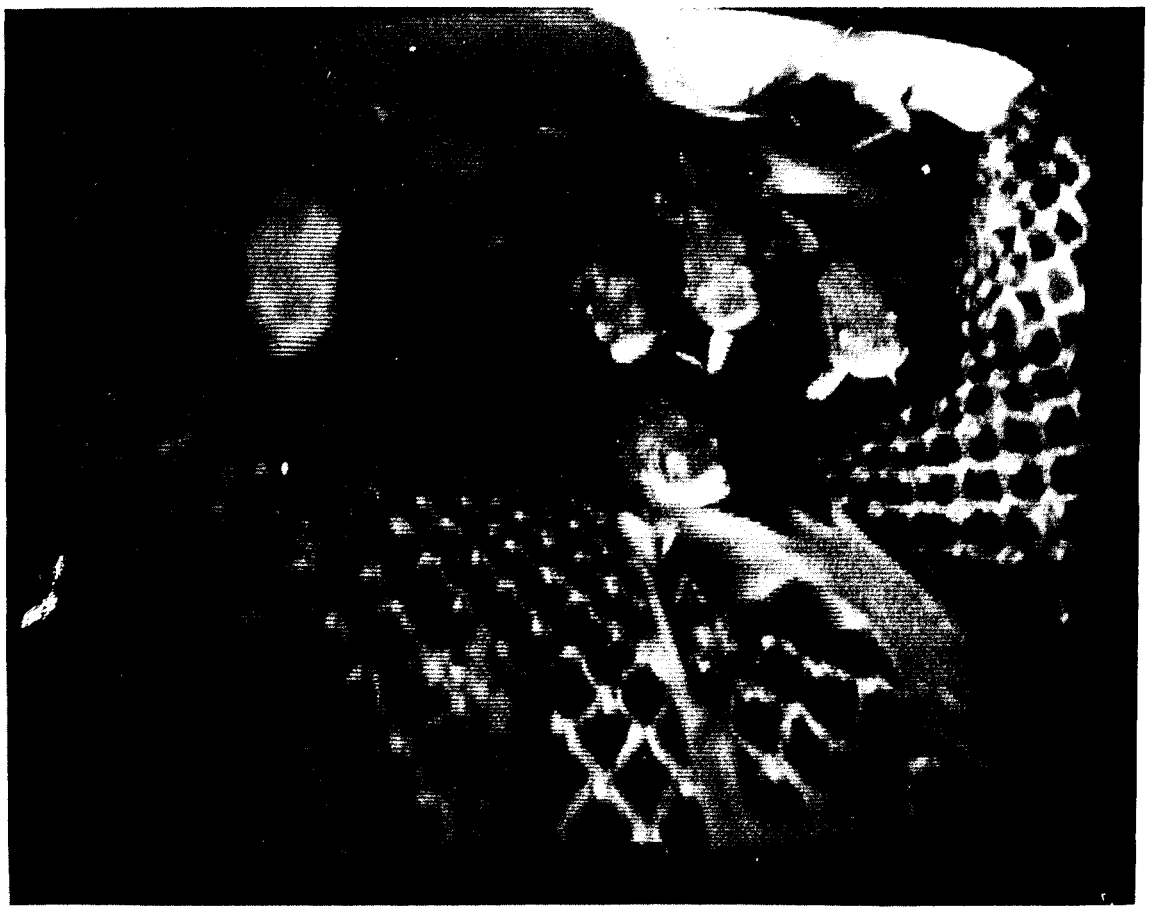


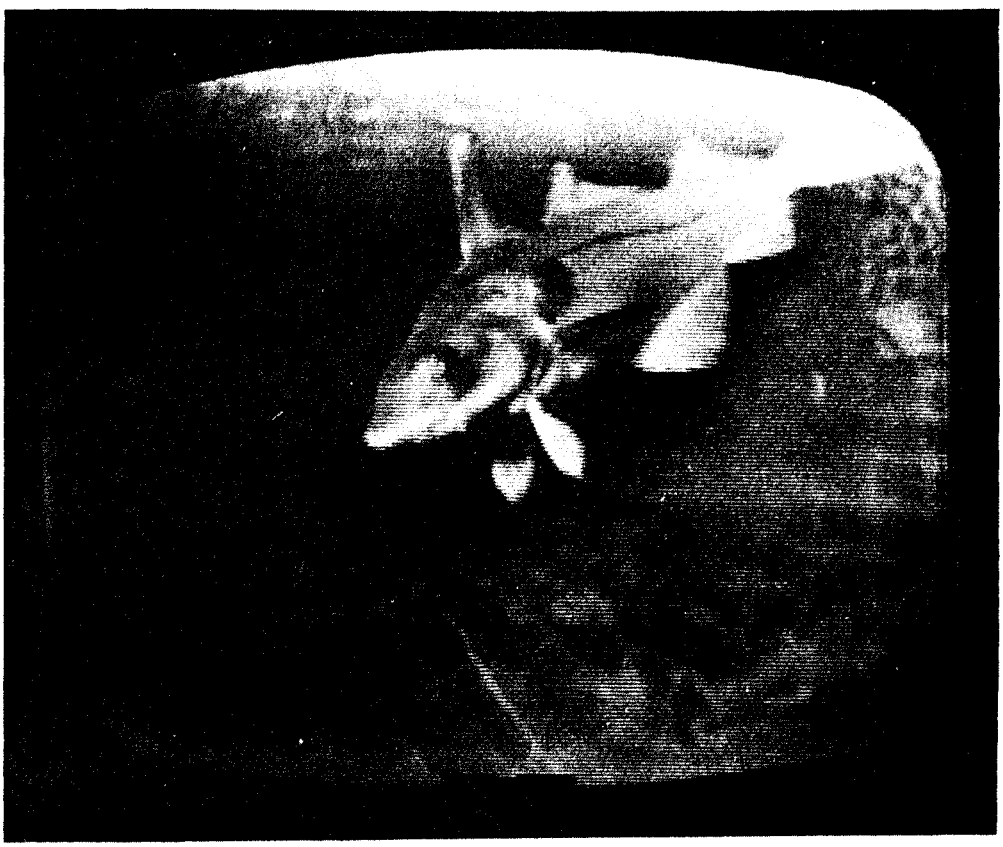
Otter trawl

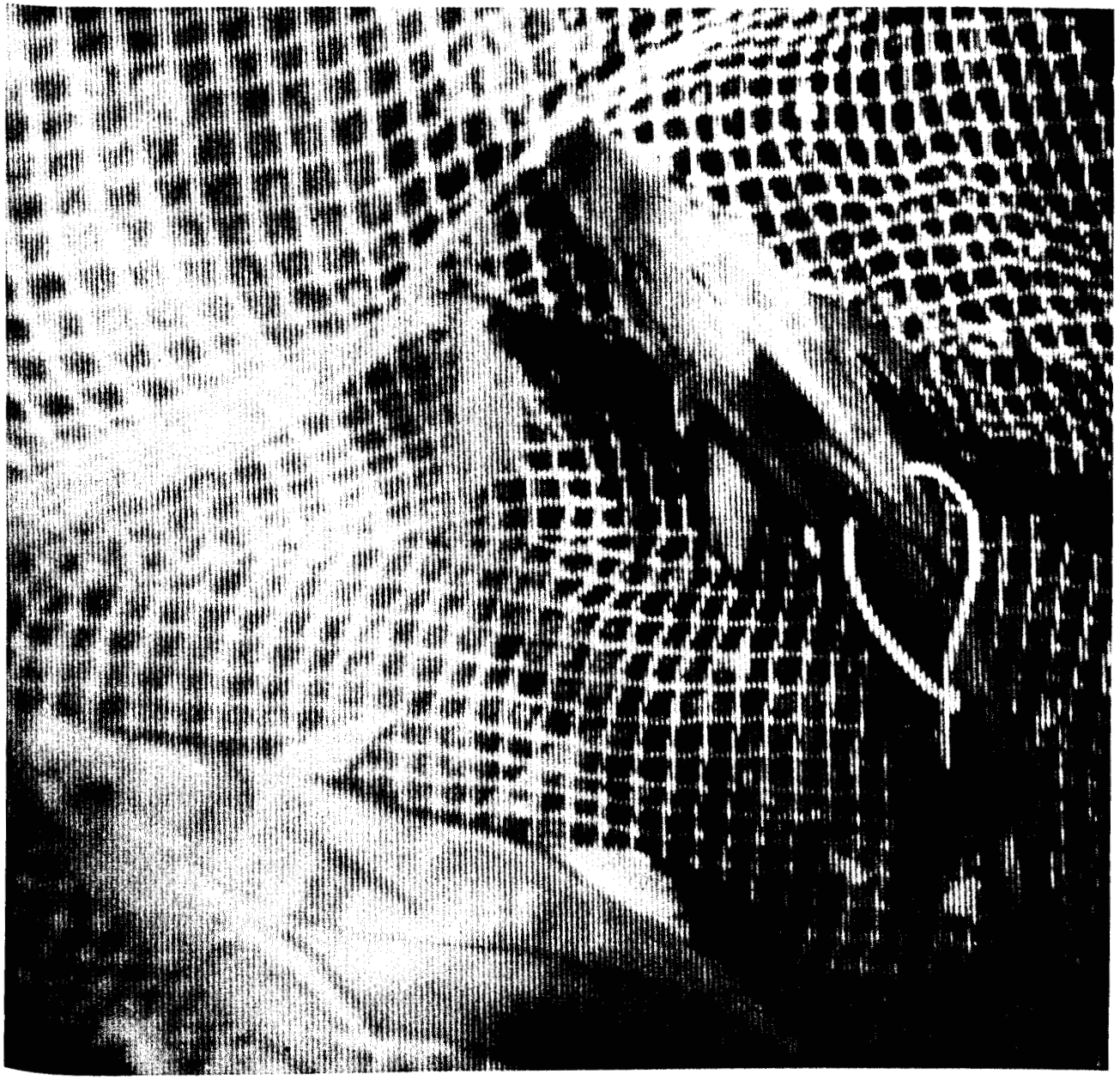












various depths, including the bottom at 40 fathoms, the TV camera recorded the activities of the tagged fish in the cage.

Through use of the camera in the cod-end, the fish can be identified and counted as they enter the net. In addition, many small fish, including scrod haddock, are seen escaping through the meshes of the trawl. Movies and still photographs of the image are taken for permanent records.

The picture of the haddock (bottom, page 84) shows how easily fish can be seen and identified on the television screen.

Tagged haddock (above), observed with the TV camera, recovered when they were quickly returned to the water. Thus, with the help of underwater TV, direct appraisal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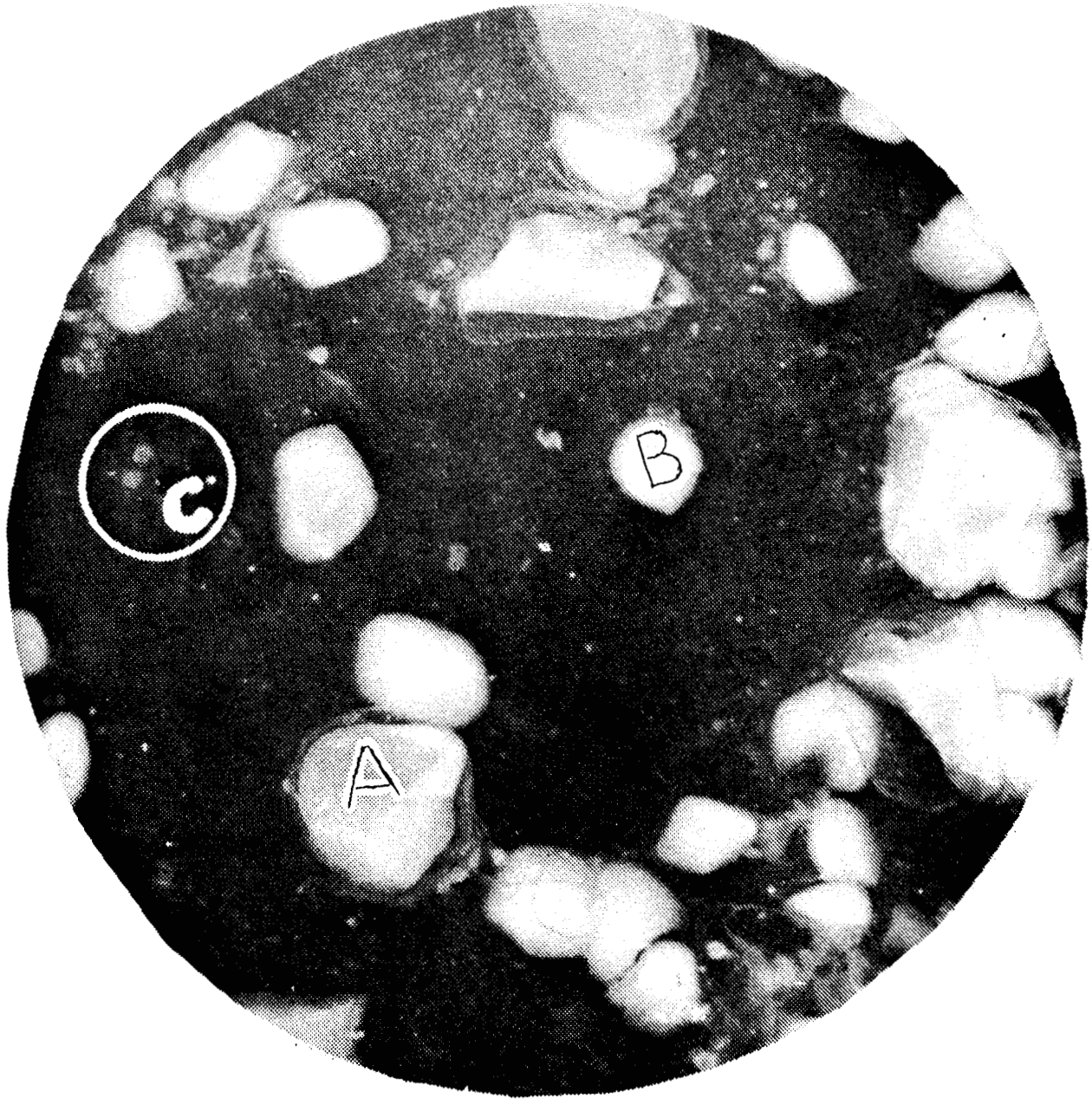
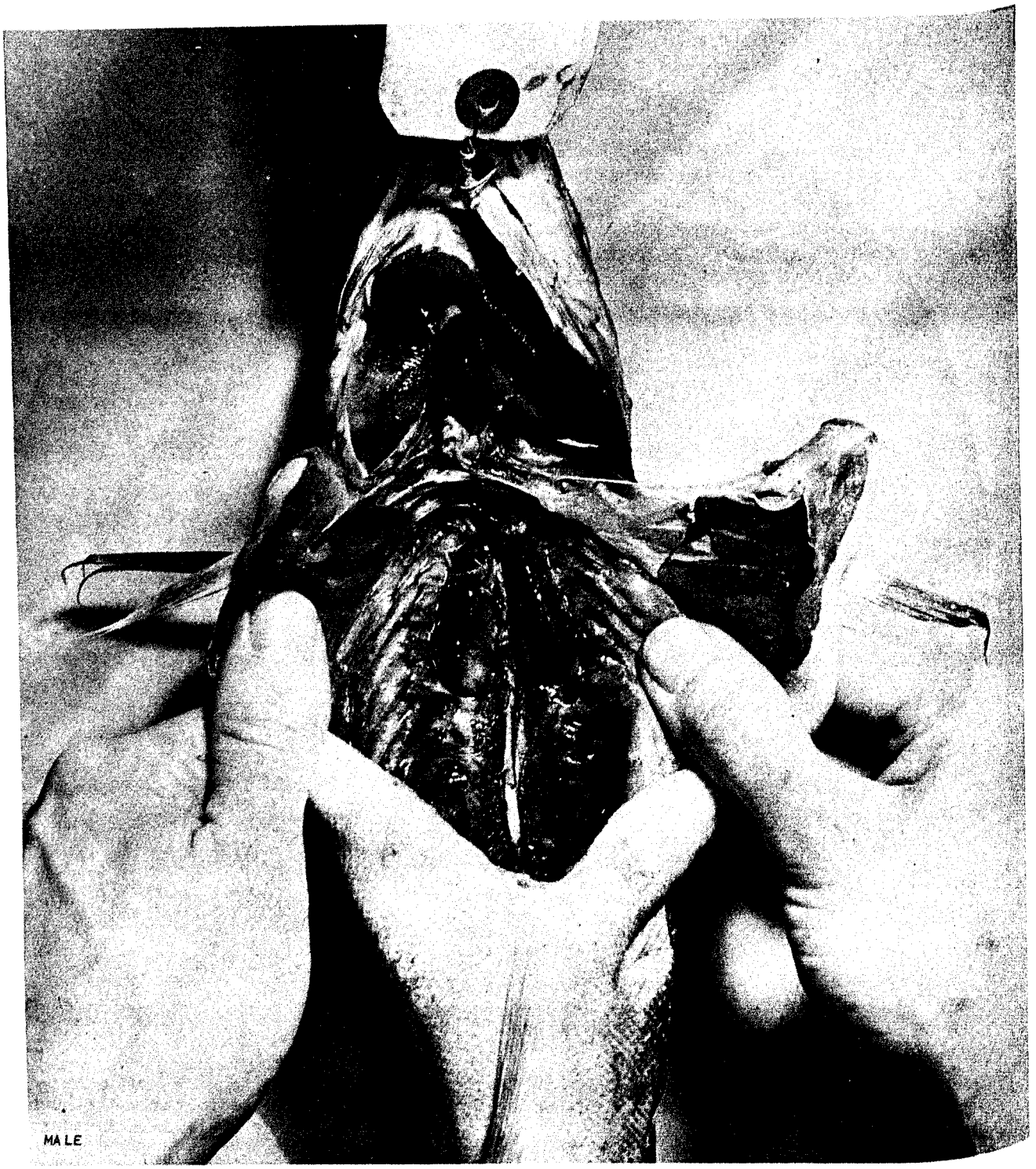


of the effects of trawling and tagging of haddock has been possible.

Eggs.--Counting the eggs in the ovaries of the haddock gives an index to the number of eggs spawned by each female. For example: A 2-1/2 pound fish contains about 170,000 eggs; a 5 pound fish contains about 635,000 eggs; a 9-1/2 pound haddock nearly 2 million eggs. This information is used with other data to help predict the future abundance of haddock on the banks. The eggs to be studied and counted are removed from the ovaries. A hand counter is used to tally the number of eggs while they are examined under a microscope (see opposite page).

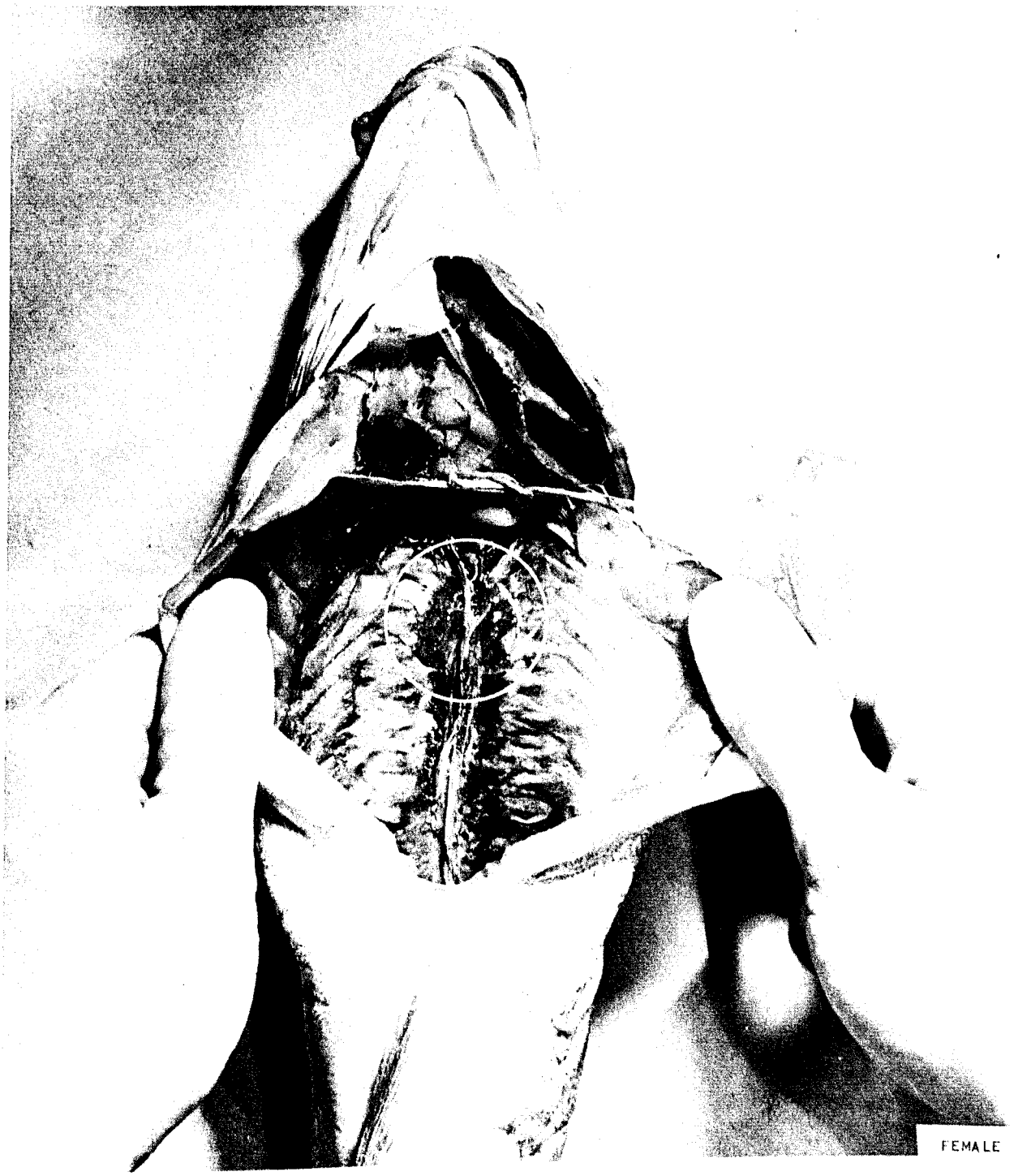
When greatly magnified (above), the mass of tiny eggs may be seen to contain three different kinds. Each kind is a different size. The large whitish eggs (A), to be spawned first, are about 1/16 inch in diameter. The eggs (B), to be spawned later in the season, are yellow and about 3/64 inch in diameter. Eggs (C), less than 1/64 inch in diameter, are clear and



colorless. They will probably be spawned the next year.

Sex determination.--The swim bladder muscle, located in the body cavity of mature haddock, is examined as a means of separating the male haddock from the female haddock after the fish have been gutted. Separating the sexes of gutted haddock had been impossible in the past because the sex organs were removed with the other viscera and discarded at sea.

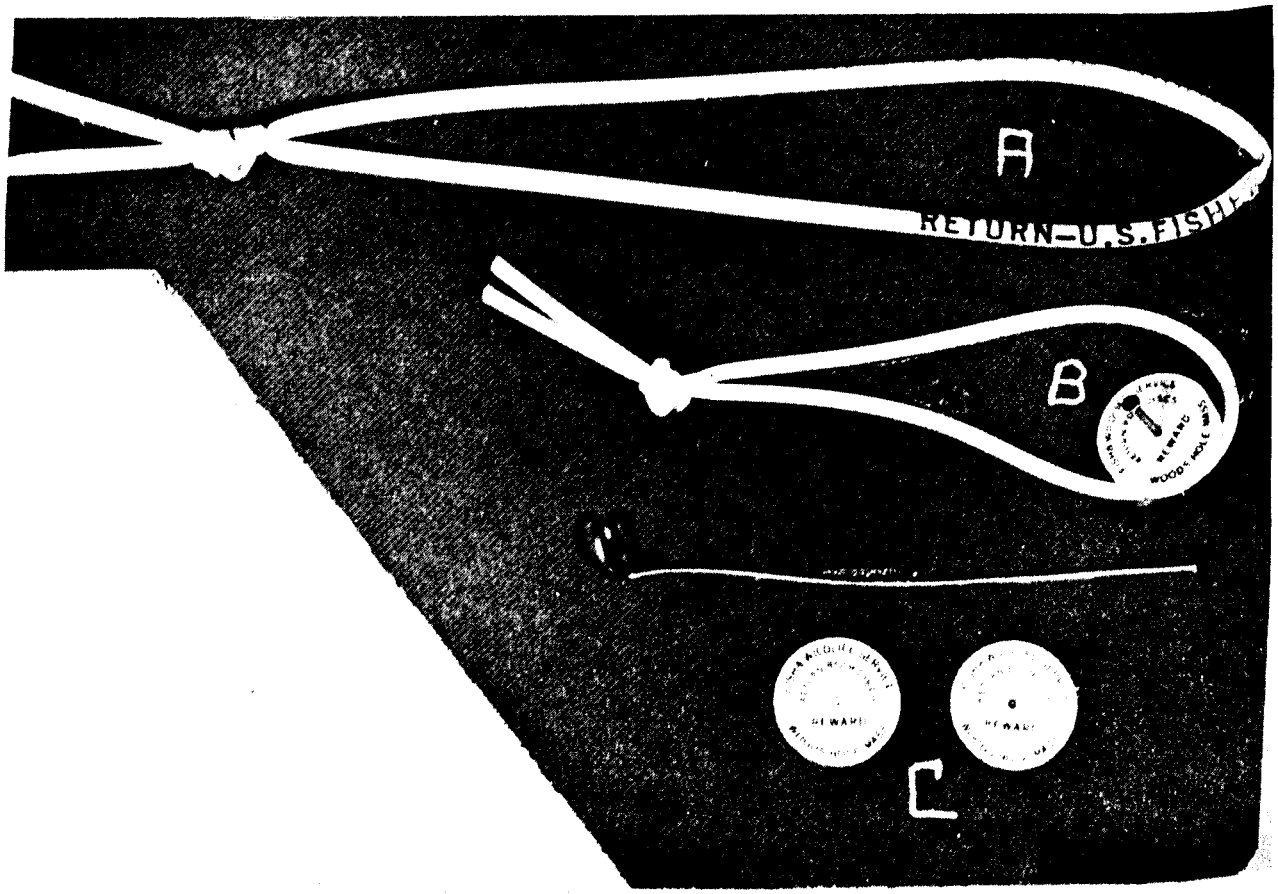
The color and the size of the swim



bladder muscle are different for the two sexes. In the males it is dark, almost black, and larger than that of the females which is light to dark gray.

Since this organ is easily seen during the spawning season, it may be related to the spawning activities. Its function is not completely understood.

Tagging.--Three new tag types were tested on haddock in 1957 aboard the Albatross III to see which tag would give the most returns. Tag A (see next page), made

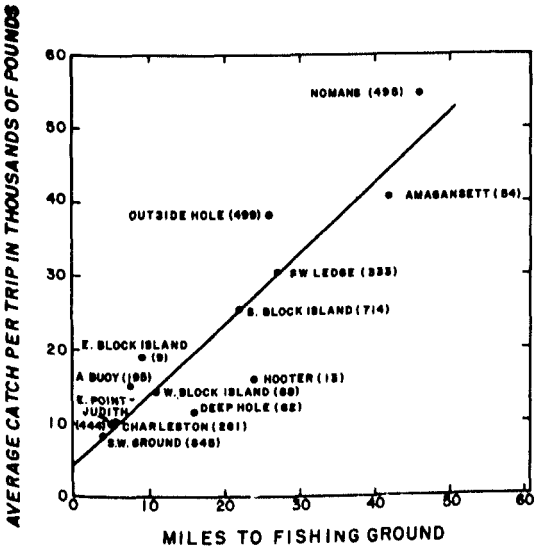

A
RETURN-U.S. FISH
B
C

of plastic tubing, is inserted through the fish's back with a needle and tied. Tag B is a gill cover tag to which has been added a loop of plastic to provide increased visibility. Tag C consists of two plastic discs held on each side of the fish with a stainless steel wire inserted through the back muscles. Types A and B gave promising initial returns. These results are encouraging because otter-trawl-caught haddock have not been tagged successfully previous to these experiments.

Improved tagging methods have contributed to the increased returns from otter-trawl-caught fish. The fish are taken in short hauls from the shoalest water, placed in a large tub of sea water and speedily tagged. Tagging has been carried out during the winter and the spring when the ocean water is cold; it has not been successful in the summer. The studies of the various spects of the behavior of the haddock with underwater television will make further improvements possible.

INDUSTRIAL FISHERY

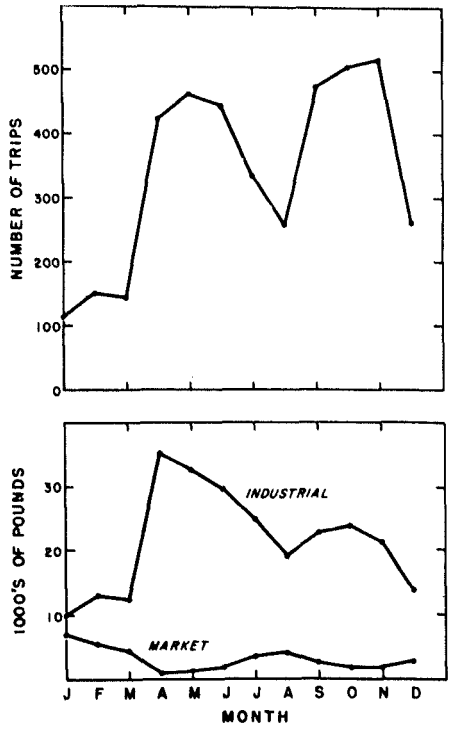
Point Judith is the only New England port geared to the industrial fishery. Its fleet of about 60 ships varies from vessels of less than 5 net tons to those of 50 gross tons. Most of these vessels catch fish for both human consumption and reduction. However, on a few trips catches of market or industrial fish only are made; different vessels make these trips.



RELATIONSHIP BETWEEN THE DISTANCE TO THE FISHING GROUND AND THE AVERAGE CATCH PER TRIP

The present study of the fish communities of southern New England waters is largely based on the catches of the Point Judith fleet. This report is concerned with some of the characteristics of this fleet, economic and otherwise, that will aid in interpreting the landing data collected.

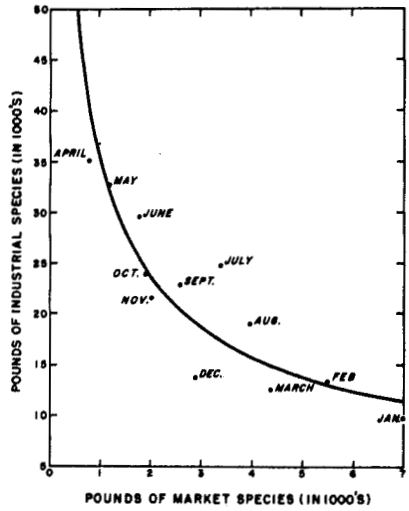
The farther away from port the fishing ground, the higher expenses are likely to be and the larger a vessel must be. This will be reflected in the size of the catch. Even within the range of vessel sizes at Point Judith, this shows up clearly when the catch per trip is compared with the distance from port to the various fishing grounds. The relationship found is shown in the figure below. Roughly speaking, this is 1,000 pounds of fish for each mile away from port. This reflects abundance, it may be said, in that many more smaller vessels consistently fish on the nearer grounds and reduce the population accordingly while larger and more seaworthy vessels venture farther offshore where the fishing is better. This seems to be a part of the answer, but involved also is the weather and the fact that the crew, when a greater distance from home, are less tempted



NUMBER OF TRIPS FOR EACH MONTH OF 1956 (ABOVE). TOTAL POUNDS LANDED OF MARKET AND INDUSTRIAL FISH FOR EACH MONTH OF 1956 (BELOW)

to return before the vessel has been filled to capacity.

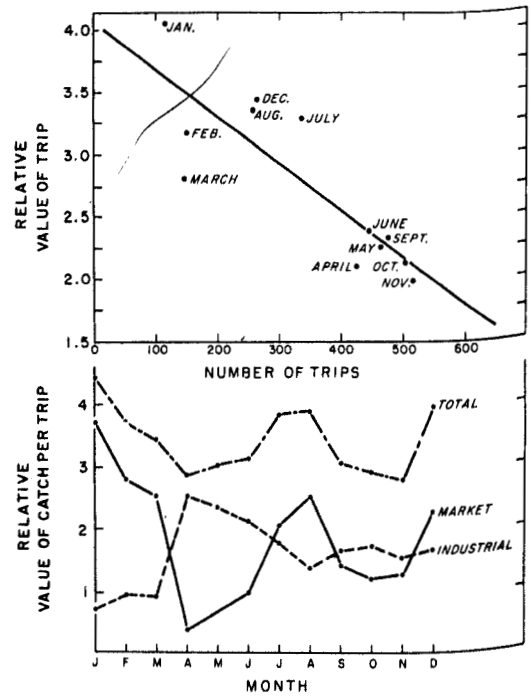
The number of trips made depends in part on the weather but mostly on the availability of the industrial fish. The number of monthly trips is graphed above. The two peaks represent those periods when industrial fish, particularly the red hake, are most available. The close, although inverse, relationship of the catch of market fish to the catch of the industrial species is interesting.



RELATIONSHIP BETWEEN THE POUNDS LANDED OF MARKET AND INDUSTRIAL FISHES

The data were replotted to show better the relationship between the industrial and the market proportions of the catch figure. Despite the fact that the catches are usually not pure trips, i.e. fish for human consumption or reduction but not for both uses, the volition of the skipper shows clearly. At those times of the year when the industrial species are most available, April through June, and September through November, they are the prime interest of the industry. Below a certain level of abundance, industrial fish are still captured, but the trips are oriented more toward market species. The situation is not either this or that however, although the graph suggests that where the industrial catches average less than 20,000 pounds, the interest in market species is predominant. In July and August the vessels are rigged with nets made especially for catching industrial fish but they are more interested in increasing the level of market species in the catch. December and March are months of transition and net changing. In January and February, many of the vessels are rigged with nets designed to catch market species which these vessels pursue to the inner edge of the continental shelf. This is a relatively long trip and many of the vessels do not save what industrial fish they do catch. With the large cod end mesh, their industrial catch is reduced. There are other influences and no one simple explanation will adequately explain all that is going on.

The relative monthly value of the catch per trip is shown for the market and the industrial portions of the catch, as well as the relative total value of the trip. Although the absolute quantities of the market species are often only a small percentage of the total catch, it is obvious that their value largely determines the overall value of the catch per trip. However, the total catch per trip value is surprisingly constant when the marked variations in the changing proportions of the catch are considered. During those periods



CHANGES IN THE VALUE PER TRIP AS IT IS RELATED TO THE TOTAL NUMBER OF TRIPS AND THE MONTH OF THE YEAR (ABOVE). RELATIVE VALUES OF FISH LANDED AT POINT JUDITH FOR EACH MONTH OF 1956 (BELOW)

when the value of the catch per trip is relatively low, the actual number of trips is high and the fleet is really making much more money. It is not surprising that the total catch per trip value changes also in proportion to the number of trips made at any one time.

PLANKTON ECOLOGY

The area of the maximum haddock spawning on Georges Bank during 1953, 1955 and 1956 coincided with the area of minimum drift bottle returns. A few of the bottles released in this area were recovered in Europe and the indications are that the eggs and the larvae were carried off the southern edge of the bank and lost to the fishery. To study this surface drift pattern in more detail, the work in 1957 was confined to a limited area of Georges Bank and attempted to maintain contact with a particular body of eggs and larvae. Transponding drift buoys, developed by the Woods Hole Oceanographic Institution, were released in a concentration of haddock eggs and their drift and the drift of the eggs and larvae hatched from these eggs were followed for two months. The data obtained confirmed the previous conclusions regarding the general non-tidal drift pattern in the area, but revealed hitherto unsuspecteddetails.

Tests were made with new type high-speed, self-closing plankton samples designed to obtain detailed information about the depth distribution of larval and juvenile fish and its diurnal variations. Through use of a 60-pound multiplane kite otter as a depressor and a 1/2-inch towing cable, sampling at 60 meters with but 93 meters of wire out at a towing speed of seven knots was possible. Further modifications of this sampler and the towing methods are necessary; however, the gear appears ideally suited for sampling fast moving organisms.

Analyzing the Hardy Plankton Recorder material and rearing and identifying larval fish continue. No further success was obtained in rearing haddock beyond the yolk-sac stage.

POPULATION DYNAMICS

An early assessment of the effect of the mesh regulation on the yield of Georges Bank haddock shows that the observed results are close to those predicted prior to enactment of the regulation.

A comparison of the haddock catch by small mesh study vessels to the catch by vessels using the regulation mesh shows that the effective selection of the large mesh net is identical to that predicted on the basis of mesh experiments. On the basis of this result, the study vessel program is being suspended for one year.

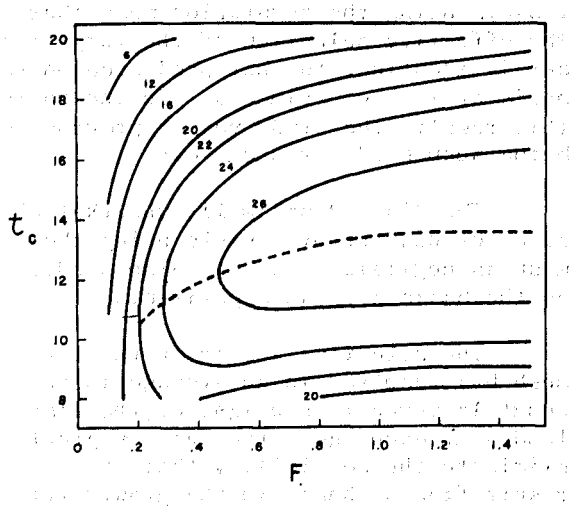
The discard of small, unmarketable sizes of haddock by vessels using the large mesh is negligible, as was also predicted on the basis of mesh experiments.

The selective action of the large mesh has resulted in an average increase of about 15 percent in weight of the fish landed at each age. The data on growth eliminate the possibility that this could result from a change in the growth rate.

The catch and the effort data for both the licensed small mesh vessels and the large mesh vessels show that the 1952 year class equaled in magnitude the 1950 year class and about 90 percent of the 1948 year class. The 1952 year class was the first class to come completely under regulation. During its first three years in the fishery its yield was 86.8 million pounds while that for the 1950 year class was 65.8 million pounds. This indicates a benefit of 32 percent. The amount of fishing expended on the 1952 year class was less than that expended on the 1950 year class. When corrections are made for similar amounts of fishing, the actual benefit resulting from the use of the large mesh is 42 percent.

A preliminary study of the dynamics of the southern Gulf of Maine redfish stock was completed to determine whether the present data are adequate to indicate the conditions for optimum exploitation. Since information on the rate of natural mortality was lacking, assessments of data were made for values of M ranging from 0.0 to 0.20. While increases in yield were indicated by increasing the age of capture, these increases were small, amounting to a maximum of about 9 percent. The study showed, however, that at higher ages of capture the stocks would be more resistant to increases in fishing pressure and that substantial increases in the amount of fishing would not substantially reduce abundance. At the

age of capture effected by the mesh size in use the level of abundance responds quickly to the amount of fishing.



YIELD ISOPLETH DIAGRAM FOR GULF OF MAINE REDFISH. THE NATURAL MORTALITY COEFFICIENT IS 0.10. THE PRESENT AGE OF CAPTURE IS 8 YEARS AND AT A NATURAL MORTALITY OF 0.10 THE PRESENT FISHING MORTALITY COEFFICIENT IS 0.29

PORT SAMPLING

During the past year a new approach to the problem of collecting statistical and biological data at the fishing ports was taken. In the past the individual projects supported their own collectors at the ports. Fishery aids are stationed at Point Judith, Rhode Island; New Bedford, Boston and Gloucester, Massachusetts; and Portland and Rockland, Maine. These persons are under the direction of a port pool supervisor who directs the collections of routine information on fishing activities and assigns additional duties according to the need of the project leaders.

During the past twelve months members of the port pool collected the following biological data:

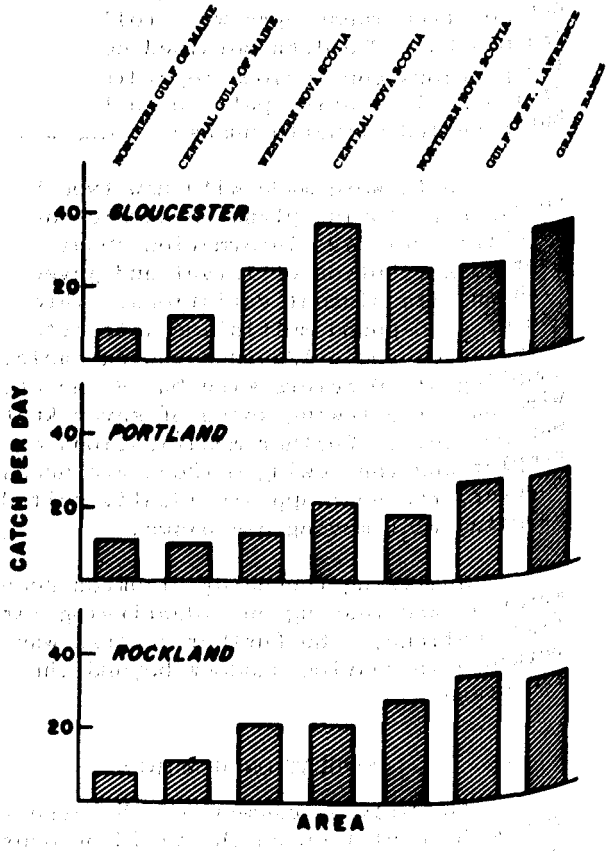
Fish	Length frequencies	Scales	Otoliths
Haddock	43,300	6,450	760
Redfish	26,530		7,200
Whiting	52,900		8,920
Scallops (Shells)	24,784		
Industrial fish	19,100		
Cod	6,437		
TOTAL	173,051	6,450	16,880

REDFISH

Abundance studies.--Redfish are landed at Gloucester, Massachusetts, and Portland and Rockland, Maine. Since there is little interchange of vessels between the ports and since the vessels fish the same general grounds at the same seasons of the year, the statistics of catch and effort collected at each port provide independent estimates of the abundance of redfish on the various fishing grounds.

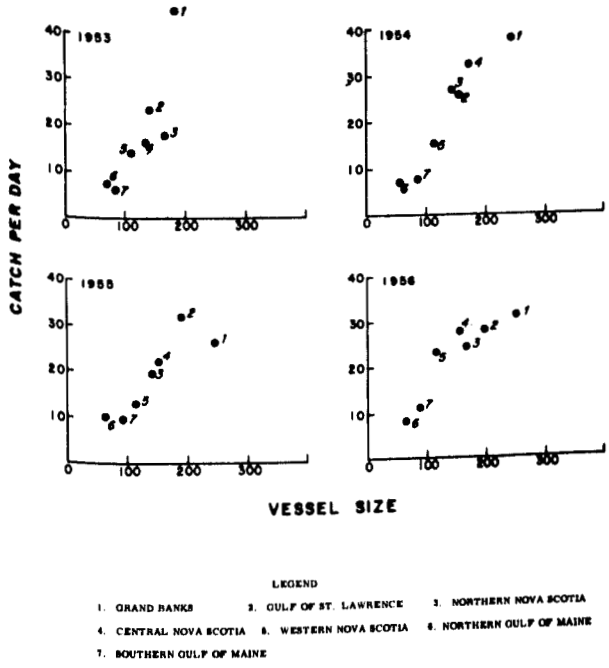
Abundance estimates by fishing area, based on data collected at the three ports, are compared in the figure below. The similarity of the individual port abundance estimates indicates that a reliable measure of abundance is being obtained and that estimates based on the combined port samples are a good measure of trends in abundance of redfish on the fishing grounds.

The estimates of abundance vary with the season and are affected by vessel size.



COMPARISON OF REDFISH CATCH PER DAY ESTIMATES FROM THREE MAJOR REDFISH PORTS DURING 1956 (THOUSANDS OF POUNDS)

There is a considerable range in the size of vessels fishing for redfish. The large trawlers fish the more distant grounds while the medium and the small trawlers fish as far from home as their conditions allow. The highest catch per day is made by the larger vessels fishing the more distant grounds.



SEASONAL VARIATIONS IN CATCH PER DAY OF REDFISH FOR FOUR AREAS DURING 1956

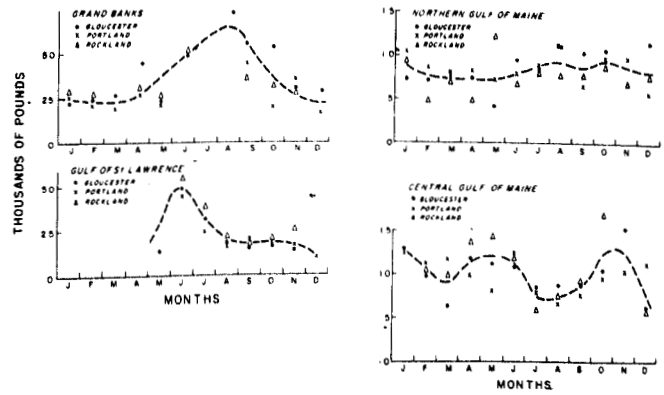
The habits of the fisherman and the effect of the weather influence the seasonal changes in the catch per day. The Gulf of St. Lawrence fishery is limited to the period when ice is not present in the Gulf. The first fishing in May and June usually results in a high catch per day which diminishes as concentrations of fish are thinned until cold weather again closes the area to fishing.

While the Grand Banks are fished throughout the year, a slackening of effort occurs during the peak season in the Gulf of St. Lawrence. The highest catch per day is likely to occur at the resumption of fishing after the summer layoff.

The seasonal changes in the catch per day in the Gulf of Maine are caused by the changes in the efficiency of the fishing fleet. The larger and more efficient vessels fish outside the Gulf of Maine during the better weather and return to the Central Gulf during the winter. The data are less clear than for the more distant grounds, although the trend of lower mid-summer values in the Central Gulf is evident. The fleet fishing the northern Gulf of Maine is more stable and shows comparatively little seasonal change.

The catch per day for the Gulf of St. Lawrence has remained fairly constant as the Grand Banks value has dropped and the Nova Scotia Banks values have increased. The Gulf of Maine has shown a slight annual increase to a point above 10,000 pounds per day's fishing. The fishery in this area has been stabilized at between 7,000 and 9,000 pounds per day since 1949. Under the present fishing conditions the fishery will probably be maintained within the limits which have prevailed since 1949.

Tagging.--Redfish were successfully tagged for the first time at Eastport, Maine, during 1956. From the end of July until mid-November 3,385 redfish were tagged. The continued study of this group of redfish will produce valuable data on age and growth, migration and natural mortality rate.



RELATION OF AVERAGE VESSEL SIZE TO AVERAGE CATCH PER DAY FOR THE MAJOR FISHING AREAS, 1954 TO 1956

Age and growth.--The successful tagging of redfish at Eastport, Maine, has provided the first direct evidence on the growth rate of redfish. Almost 200 tagged fish were recaptured during nine months. The bulk of the recaptures was made during the first three months of the experiment. The growth of the recaptured fish was extremely slow. The average growth recorded at the end of nine months was less than 4 mm. The greatest growth recorded for a single fish was 10 mm. These findings are in accord with the earlier estimates of growth from otoliths.

Tagged fish reappeared at the tagging site in May 1957. A sufficient quantity will probably be recaptured during the summer to further substantiate the present age and growth findings.

Racial studies.--A large number of redfish specimens from all areas within the New England-Newfoundland region were examined for racial comparisons. This study includes enumerating the meristic characteristics and measuring a series of various body proportions. In some instances the meristic characteristics are compared to similar data from small samples of the eastern Atlantic redfish.

The following statements summarize our present knowledge of the North Atlantic redfish stocks and indicate the direction of future work:

1. The original description of Sebastes marinus is too general and encompasses all of the redfish of the North Atlantic.

2. Sebastes viviparus and Sebastes mentella are not described precisely enough to permit their positive separation from the main Sebastes group.

3. Two general body shapes are recognized as extremes with a great range of intermediate variations. European workers roughly group these as marinus and mentella types. The limits of these differences are not established.

4. In recent taxonomic work, differences introduced as specific characteristics (eye size, length of jaw appendage, body shape) may be influenced by environmental factors, such as water depth or temperature.

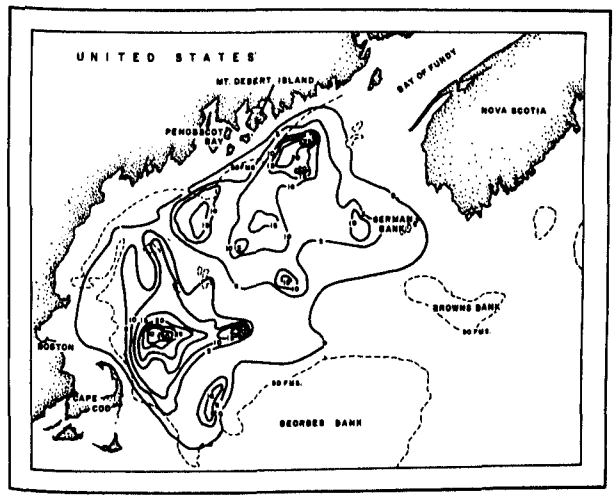
5. Some of the greatest differences observed are in characteristics such as growth rate, body color and size at maturity. These tenuous characters are suitable for identifying stocks of fish but are not exact enough for taxonomic classification and may be influenced by environment.

Because of the inexact nature of the present taxonomy of the Atlantic redfish, evaluating the observed variations in the known redfish stocks is difficult or impossible. The Sebastes marinus group must be defined before a mentella group can be described.

The body proportion studies in the western Atlantic indicate that the majority of the fish are of the same type. Whether this type is closer to the marinus or the mentella group is not clear. Most of the body proportion relations are similar to those of the standard length-body depth. There are slight differences in the slope of the regression lines for different areas, but the deviations around the lines are almost identical. Relationships involving the eye size are similar for all areas in the western Atlantic except the Gulf of St. Lawrence. About two thirds of the specimens there display eye size relationships similar to those of the specimens of the Gulf of Maine and adjacent areas. The other third of the population consists of large-eyed fish that are generally larger than the average for the fish from that area.

Migration.--The fish tagged at Eastport, Maine, during the past year showed no evidence of migration; all returns were from the original tagging site. Earlier studies indicated no organized migrations of redfish, such as are observed among codfish, for example. In the Gulf of Maine, the size composition of the redfish remains stable from year to year within the limits of what appear to be separate populations.

A study of the incidence of the copepod ectoparasite, Sphyrion lumpi (Kroyer), shows that the distribution of the parasitized fish is not homogeneous throughout the Gulf. The pattern is consistent from year to year. Most of the parasitized fish are in the western part of the Gulf; the count decreases toward the east until it becomes zero around the Cape Sable region of Nova Scotia. The localized distribution of the ectoparasite suggests that the redfish do not move much in the Gulf.



PERCENTAGE INCIDENCE OF SPHYRION LUMPI IN THE GULF OF MAINE

SEA SCALLOP

The fishery.--During 1956, 19 million pounds of the sea scallop, Placopecten magellanicus, were landed in the United States and were worth about 10.5 million dollars as landed. About 50 percent, 9.6 million pounds, of the total catch came from eastern Georges Bank. The average catch per boat per day for Georges Bank declined to 1,440 pounds, 9 percent below that for 1955 and 14 percent below that for 1954.

New Bedford, Massachusetts, the main port for the Georges Bank fleet, received landings of 14.0 million pounds. Catches made on trips from Georges Bank were also landed at Gloucester, Massachusetts (1.0 million pounds), Rockland, Maine (0.5 million pounds) and Nova Scotian ports (0.7 million pounds).

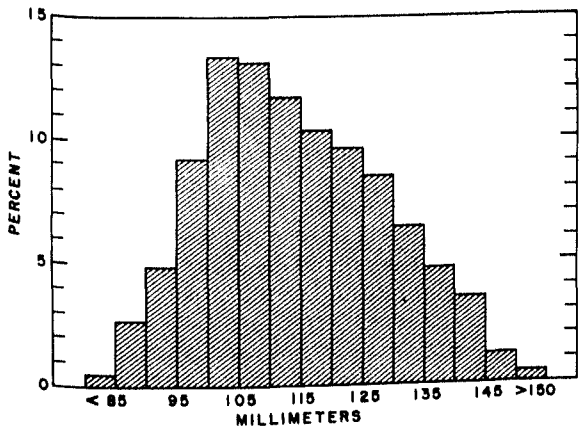
The exploitation of the Georges Bank stocks by the Canadian vessels is increasing. Since 1951 the Canadian offshore sea scalloping fleet has expanded from two to ten boats which fish more or less regularly on Georges Bank. Three new vessels are reported to be under construction for this fishery.

Sizes in the commercial catch.--During the year some 46,000 measurements of sea scallops were made from 93 commercial trips. Six of these were sampled at sea. There has been a general decrease in size since the previous year; fewer large scallops and more small ones were landed in 1956.

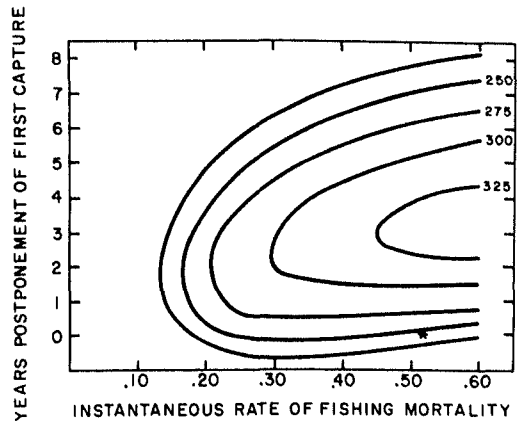
Dynamics of the scallop populations.--The concern of the industry over the decline in the catch per unit of effort and in the average size of the scallops being caught has led to a consideration of the available data on the Georges Bank fishery in the light of possible management procedures. On the basis of these data the following relationships and parameters have been derived:

Growth in length	$L_{n+1} = 38.5 + 0.780\ L_n$
Length-weight conversion	$\log W = 2.72 \log L - 4.379$
Instantaneous total mortality rate	0.67

To compute yield curves, a rate of natural mortality had to be assumed. The



LENGTH FREQUENCY OF GEORGES BANK SEA SCALLOP CATCH JULY 1956 - JUNE 1957



YIELD ISOPLETH IN POUNDS PER 10,000 RECRUITS FOR GEORGES BANK SEA SCALLOPS. THE NATURAL MORTALITY COEFFICIENT IS 0.15

yield isopleths were calculated through the use of a natural mortality rate of 0.15. The asterisk is at the point which was thought to most closely approximate the present condition of the fishery.

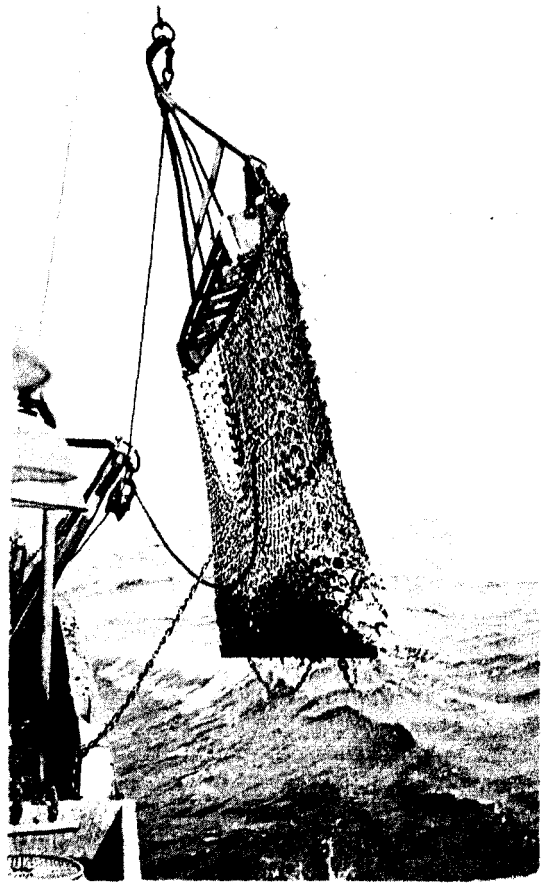
Considerable increases or decreases in the fishing effort apparently would not have a great effect on the yield. On the other hand, a 30 percent increase in the yield is indicated if the age at first capture is increased three years beyond its present value.

These data and conclusions were presented to the scientific advisors to Panel 5 of the International Commission for the Northwest Atlantic Fisheries for their consideration. They decided that while the data indicate the direction which management measures are likely to take they represent too short a time period to be a sound basis for management recommendations and that further information is needed.

Savings gear.--The Canadian investigations have shown that controlling the size of the rings and the links in the bag of the scallop dredge will control the minimum size of the scallops caught. Their results, however, do not strictly apply to our problem because the tests were conducted with a type of dredge different from that used by our fishermen.

To determine the selectivity of dredges with various sizes of rings in the bag, the scalloper Whaling City was chartered in June 1957. The present standard ring used by the New Bedford fleet, 3 inches with a 1 1/8-inch link, was compared with 2-, 3 1/2- and 4-inch rings. Each of the experimental bags had a netting section of the same size square mesh as the inner diameter of the rings. The results of the cruise have not been fully analyzed. Another cruise is planned for July.

Growth rate.--The growth rate used in the population dynamics calculations was established from an analysis of the modes of length frequency distributions. Two other methods of estimating the growth rate, tagging and shell reading, are under investigation. Some 3,000 scallops were tagged and released on Georges Bank last year. Enough recaptaures have not been made to warrant any conclusions on the rate of growth. The Canadian investigators have been able to determine the age and the growth of sea scallops from their stocks by counting and measuring the annual rings on the shells. The annual rings on the Georges Bank scallops are much less distinct than those on the Canadian scallops and are usually masked by many extraneous shock rings. These conditions make them difficult to read. Efforts will be continued to validate the shell reading method of estimating the growth rate.



SCALLOP DREDGE

Mortality rate.--The total mortality rate was estimated by separating the length frequency distribution of the catch sample into year classes on the basis of the estimated growth rate. The accuracy of this estimate depends upon the accuracy of the growth rate. The mortality rate will be tested during the coming year by a large-scale tagging experiment. Several thousand scallops will be tagged and released in an

area that is being actively fished. The rate of return of the tagged shells will provide an estimate of the fishing mortality rate and may furnish data on the magnitude of the natural mortality.

Life history and ecology.--Last year the date and the duration of the spawning of the Georges Bank sea scallop population was observed for the first time. The spawning began on September 21 and 95 percent of it was completed by September 24. This year an attempt will be made to follow the newly fertilized eggs through at least a part of their life in the plankton.

This phase of the scallop's life history is also being investigated. An artificial spawning in the laboratory was successfully fertilized and was under culture for three weeks. This is seventeen days longer than any previous attempt. Compared to the shallow water bivalves, the development has been slow. As of June 30, the larvae were still in the straight-hinge stage.

WHITING

The fishery.--The total annual catch of the silver hake or whiting, Merluccius bilinearis, from the productive inshore New England fishing grounds has declined from its all-time high in 1951 and 1952. In 1956, a fishing ground on the northern slope of Georges Bank was heavily exploited, as it had been in the previous year, to contribute over 30 percent of the total New England landings. These offshore landings combined with the inshore landings raised the total nearly to the level of the 1951-1952 peak.

NEW ENGLAND LANDINGS OF SILVER HAKE
1946-1956

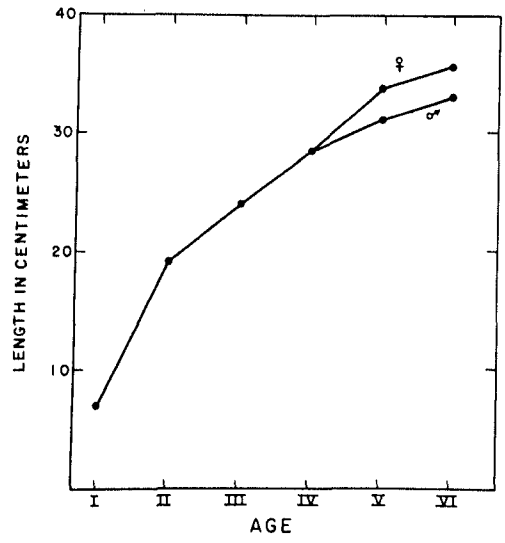
Thousands of pounds

Year	Inshore	Offshore
1946	51,080	
1947	61,982	
1948	80,468	
1949	90,036	
1950	65,464	
1951	118,467	
1952	105,955	
1953	90,550	
1954	90,118	
1955	88,745	24,255
1956	63,118	26,633

An analysis of the catch-per-hour for the inshore and offshore waters show that the latter are more productive than the former. Sampling by the Albatross III since 1948 has shown that the silver hake is one of the most abundant species in the Gulf of Maine and on Georges Bank. There may be offshore areas, other than the area being exploited, where commercial quantities of silver hake are available.

While the number of medium otter trawlers in the silver hake fishery is increasing, the number of small trawlers is decreasing. This trend reflects the shift to exploitation of the offshore grounds and the small otter trawler is not suitable for them.

Growth.--The growth studies indicate that the silver hake in the Gulf of Maine grows rapidly. The growth rate for the males and the females is similar through age IV; after that the females grow larger and live longer than the males. Maturity occurs for both males and females at about age IV. The maximum length of the females in the commercial samples is generally 52 cm. while that of the males usually does not exceed 36 cm.



TENTATIVE GROWTH RATE FOR GULF OF MAINE SILVER HAKE

Racial studies.--At the present time the racial studies of the silver hake, based on the measurements of the body proportions,

suggest that there are northern and southern stocks in the New England waters. A line extending southeast from Cape Cod roughly separates them.

ATLANTIC HERRING INVESTIGATIONS

The Atlantic Herring Investigations is financed by funds provided by the Saltonstall-Kennedy Act and the United States Department of State. The Department of State is interested in the possible effects that a proposed tidal dam would have on the fisheries of Passamaquoddy Bay and Cobscook Bay. These are important fishing areas, particularly for herring. The investigations are closely coordinated with the herring research of the Fisheries Research Board of Canada since the herring occur in the ocean area that bounds both the northeastern coast of the United States and the maritime provinces of Canada.

Population studies.--Vertebral counts of the fish of the same year class have been attempted to determine if there are different races of herring. Difficulties in age determination have hampered efforts to

COLLECTING BLOOD FROM HERRING ANALYSIS

separate the large fish into various year classes; this problem must be solved before the vertebral count data can be analyzed.

Serological studies offer promise of providing identification of the populations. These are being approached through the use of erythrocyte antigens, serum proteins and egg proteins of herring. The work to date has concentrated on the erythrocyte antigens of spawning fish. Definite individual variations in erythrocyte antigens of herring have been found. The next phase of this work is to determine whether quantitative or possibly qualitative differences in occurrence of these variations exist in the herring from different geographic areas.

A survey of the distribution and the abundance of parasites of herring conducted during the past two and one-half years indicates that certain parasites may be useful as "natural tags". The remarkable lack of homogeneity in the occurrence of the fungus infection, Ichthyosporidium hoferi, and the larval cestodes, Trypanorhyncha, in the mature herring sampled from Newfoundland to New Jersey during the past three years indicates little, if any, interchange of the adult fish between the Gulf of St. Lawrence and the Gulf of Maine and a possible discontinuity of exchange between the Gulf of Maine adults and those from south of Cape Cod. An incidence of myxosporidian, Kudoa clupeidae, and the larval nematode, Anisakis sp., in the Gulf of Maine immature herring which were sampled for two and one-half years suggests the existence of at least two subpopulations of such immature fish, with a transition area at Penobscot Bay, and with only minor straying of fish during the second year of life from the western to the eastern Maine coast.

Holding experiments have been carried on at Boothbay Harbor, Maine, to determine the feasibility of the various types of internal and external marks. Plastic opercle tags and tattooing appear to be promising, particularly for the small fish that will be handled individually by the sardine packers. Internal metal tags, which are used successfully elsewhere on large fish that are handled in bulk for fish meal, have a limited value for small fish for the chances of recovering such tags at a sardine cannery are slight.

Disease studies.--Since 1947 a continuing examination has been made of a systemic fungus disease of the herring of the Gulf of Maine where at the present time the disease is at a low endemic level, with the incidences well under 1 percent. The opposite situation has prevailed in the Gulf of St. Lawrence however, where an epidemic peak of this disease occurred in 1954-1956. With the cooperation of the Fisheries Research Board of Canada and the Department of Fisheries of the Province of Quebec, biologists of the Atlantic Herring Investigations have followed this epidemic closely since information gained during this period may apply in the Gulf of Maine. The outbreak has seriously reduced the herring population of the Gulf of St. Lawrence. Sampling disclosed that one fourth of the herring of that area was affected in 1955 and a smaller percent in 1956. The landings of herring declined sharply during this period, probably because of the effects of the disease.

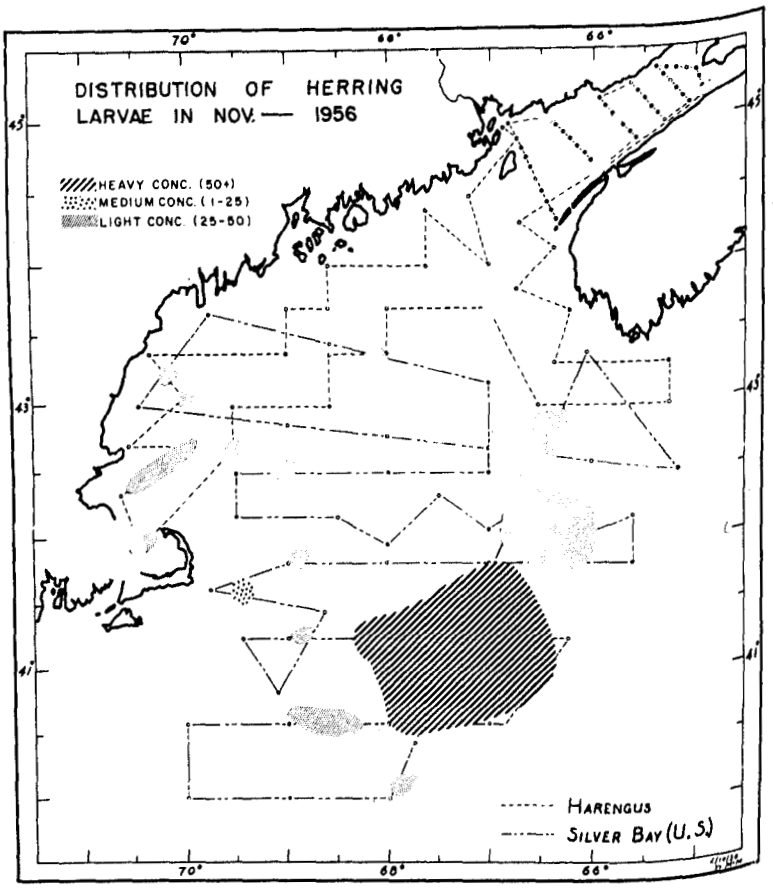
The experimental work conducted during this period at Boothbay Harbor indicated that the incubation period of the disease is from 15 - 30 days, the severity of the infection is directly related to the infective dose, the virulence of the disease organism does not differ at the epidemic peak from that in the trough of the epidemic wave, and the disease may occur in either acute or chronic phase, the acute phase being terminal before 30 days, and the chronic being progressive and sometimes fatal after longer periods.

Year class fluctuations.--The strengths of the year classes directly affect the sardine industry which depends on the supply of the small herring that are available between the ages of about 10 and 22 months. Thus, the poor survival of a year class before it reaches the canning size at an age of about 10 months results in a mediocre pack and a resultant economic disturbance throughout the industry.

In September 1956 the Fisheries Research Board of Canada and the Fish and Wildlife Service began an intensive larval herring study. The plankton collections of cruises from September 1956 to February 1957 yielded considerable information about the distribution of herring larvae. The results of the larval cruises show that the Georges Bank area was a most important spawning ground and that the movement of herring

during the larval period can be treated.

In conjunction with the plankton work and with the cooperation of the Woods Hole Oceanographic Institution, over 4,700 drift bottles were released by the research vessels. The returns from these bottles have confirmed the general theory of circulation in the Gulf of Maine. There are definite limitations in the use of drift bottles, and the use of transponding drift buoys is desirable for a clearer understanding of the surface current patterns.



PASSAMAQUODDY INVESTIGATIONS

The International Passamaquoddy Fisheries Board was established by the International Joint Commission in October 1956 to report to the Commission on the possible effects upon the fisheries in the area of the construction of dams across the outlets of Passamaquoddy Bay to develop tidal power. The responsibility for determinining these effects has been delegated to the herring investigations that are being carried on by the Fisheries Research Board of Canada and the United States Fish and Wildlife Service.

Statistics.--Detailed catch-and-fishing-effort statistics are being collected for the Passamaquoddy area so that the past and the present status of the fisheries may be determined.

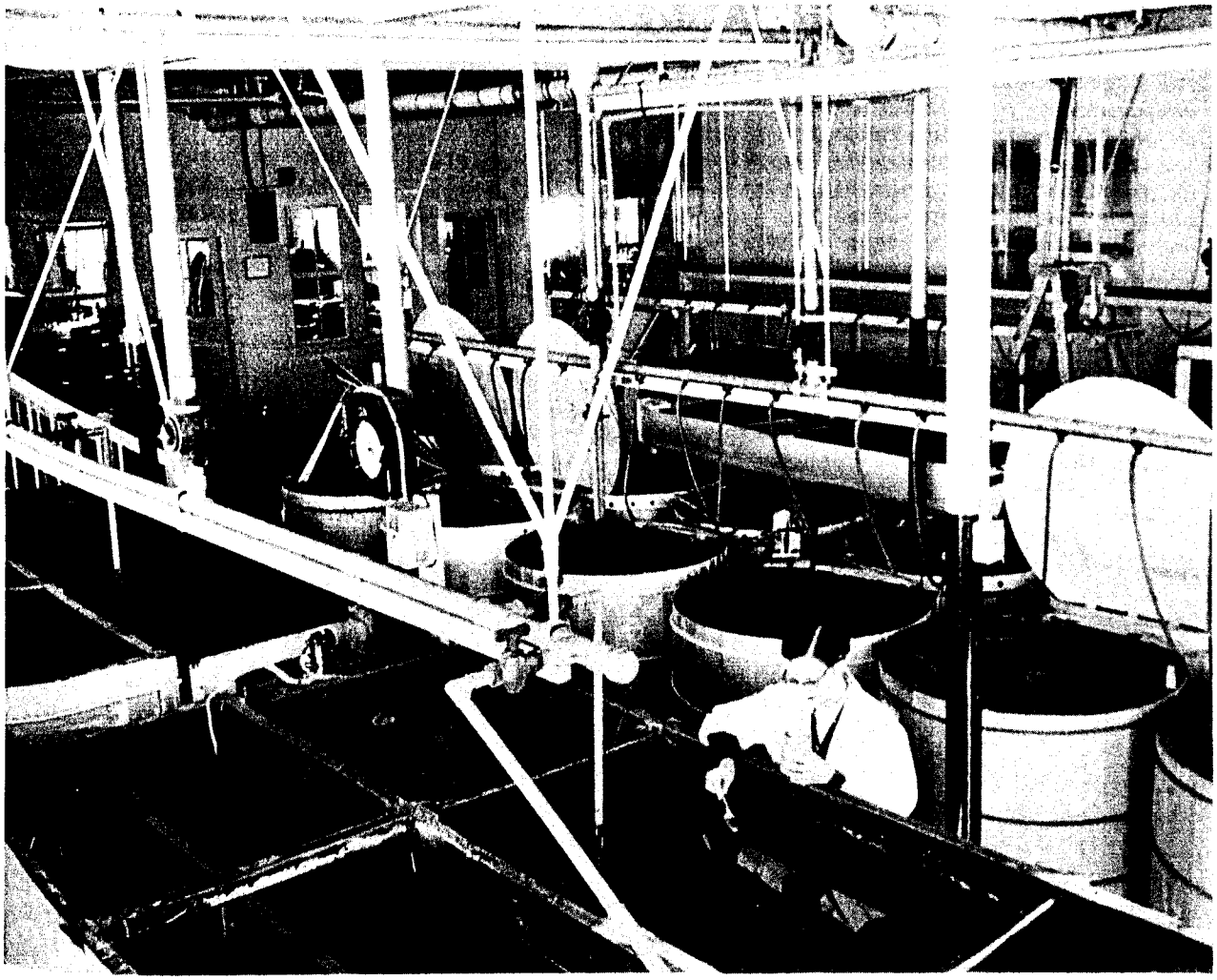
Behavior studies.--Plans have been made for studying the reactions of the herring to the various environmental changes, such as light, temperature, salinity and water currents. How the fish react to these factors may influence the effect of the proposed dams on the herring movements and, consequently, both laboratory and field experiments are being designed to measure the effect of these factors.

Ecological data.--The records of air temperature, precipitation, wind velocity and river discharge are being studied. The monthly plankton collections which have been made since 1930 are being examined. Relating the fluctuations in plankton with the herring catches, climatic factors and the river discharges may be possible.

Populations.--An extensive fish-sampling system has been established and from these collections observations of parasite incidences, meristic characters and growth are being made. These may provide clues as to the population identities of the herring that visit the region.

Explorations.--A series of cruises throughout the area at two-week intervals provide data on the plankton, hydrography and distribution of the fish. The plankton is examined for herring larvae and herring food. The hydrographic observations include temperature, salinity and current measurements at various depths, drift bottle and drift buoy experiments.

Migrations.--In the Passamaquoddy area, several thousand herringshave been



INTERIOR OF LABORATORY, SHOWING EXPERIMENTAL TANKS

marked with plastic opercle tags. The preliminary experiments demonstrated that the tagging mortalities were low and that the tags could be recovered during the processing of the fish. Tagging the herring both inside and outside the Bay to determine the extent of their movements has been planned.

SOUTH ATLANTIC FISHERY INVESTIGATIONS

William W. Anderson
Brunswick, Georgia

As the initial step toward a better understanding of the waters adjacent to the South Atlantic coast of the United States from Cape Hatteras to lower Florida, with respect to potential productivity, the United States Fish and Wildlife Service, in cooperation with the Navy Hydrographic Office, the Office of Naval Research, the Georgia Game and Fish Commission and the Florida State Board of Conservation undertook a general survey of the area. Field work was initiated in 1953 and continued through 1954. Nine cruises were completed. Work has progressed since that time on processing and studying the data and material collected.

The program has three major projects: (1) Biochemestry - the objectives are to

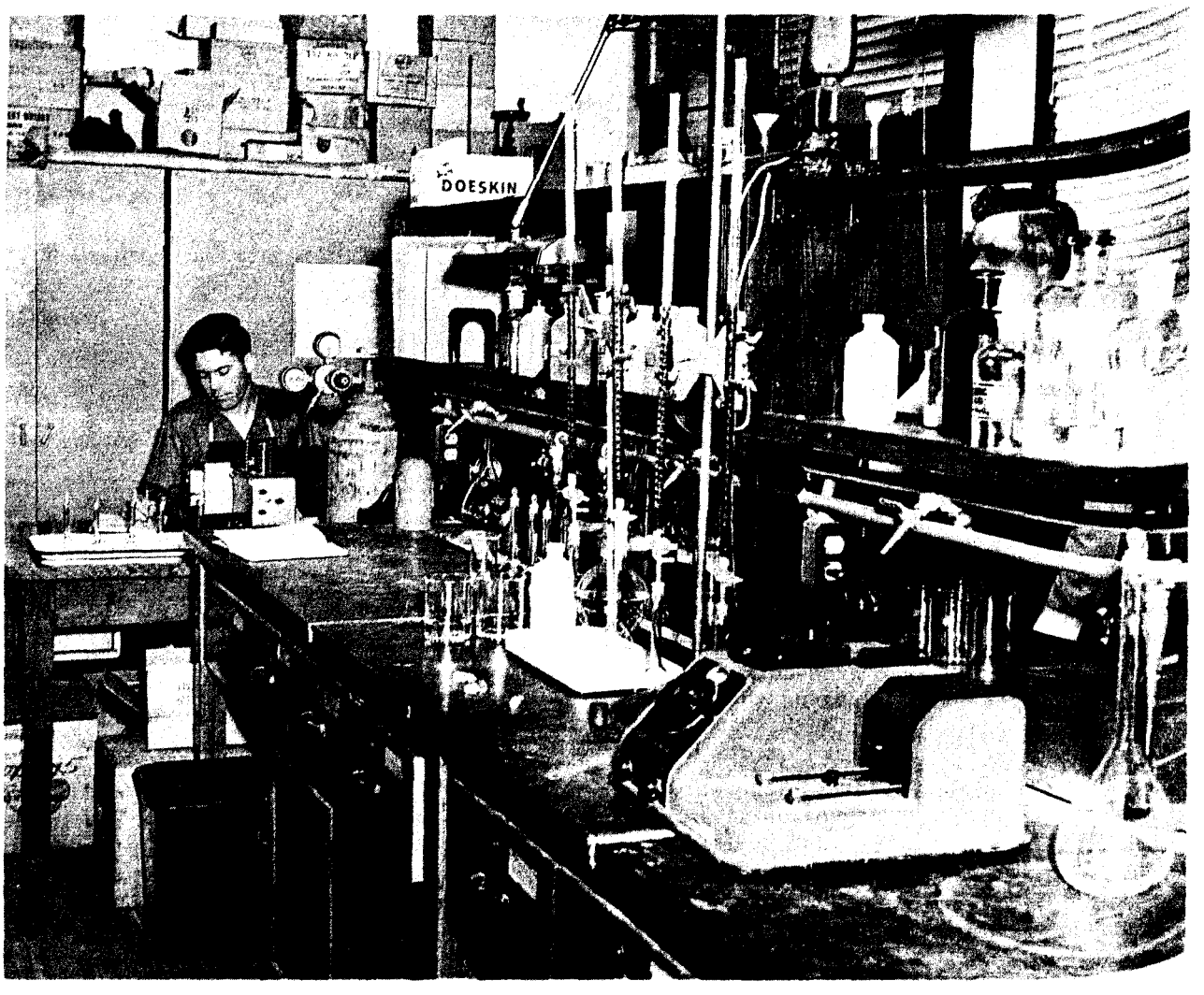
establish the distributions and concentrations of nutrients and the relations between these and the abundance and distribution of marine forms; (2) biological inventory - the objectives are to determine the presence, identity, distribution and interrelationships of the marine forms (special attention being directed toward identity, distribution and abundance of fish eggs, larvae and juveniles) and the early life histories of fishes of the area; and (3) physical oceanography - the objectives are to establish the flow patterns of the currents of the region and trends in temperature and salinity.

The active participants in the program during the year were the Fish and Wildlife Service, the Navy Hydrographic Office and the Woods Hole Oceanographic Institution.

BIOCHEMISTRY

Profiles showing total phosphorus, inorganic phosphate and nitrate-nitrite by seasons and yearly averages were completed.

An analysis of bottom sediment samples, obtained during cruises of the Theodore N. Gill, by means of flame photometry and other methods, was begun. To be determined are percentages of loss on ignition, insoluble residue, chlorides, calcium oxide, ferric oxide, phosphorus pentoxide and manganese dioxide. All analyses of



LABORATORY ANALYSIS OF BOTTOM SEDIMENTS

samples from cruises 1 and 2 and some of the analyses of samples from cruises 4 and 5 have been completed. This work completes about two thirds of the analyses of the bottom samples.

Physical and chemical data for cruises 2, 3, 4, 5, 6, 7, 8 and 9 were processed for publication, except for a final check on physical data from three cruises.

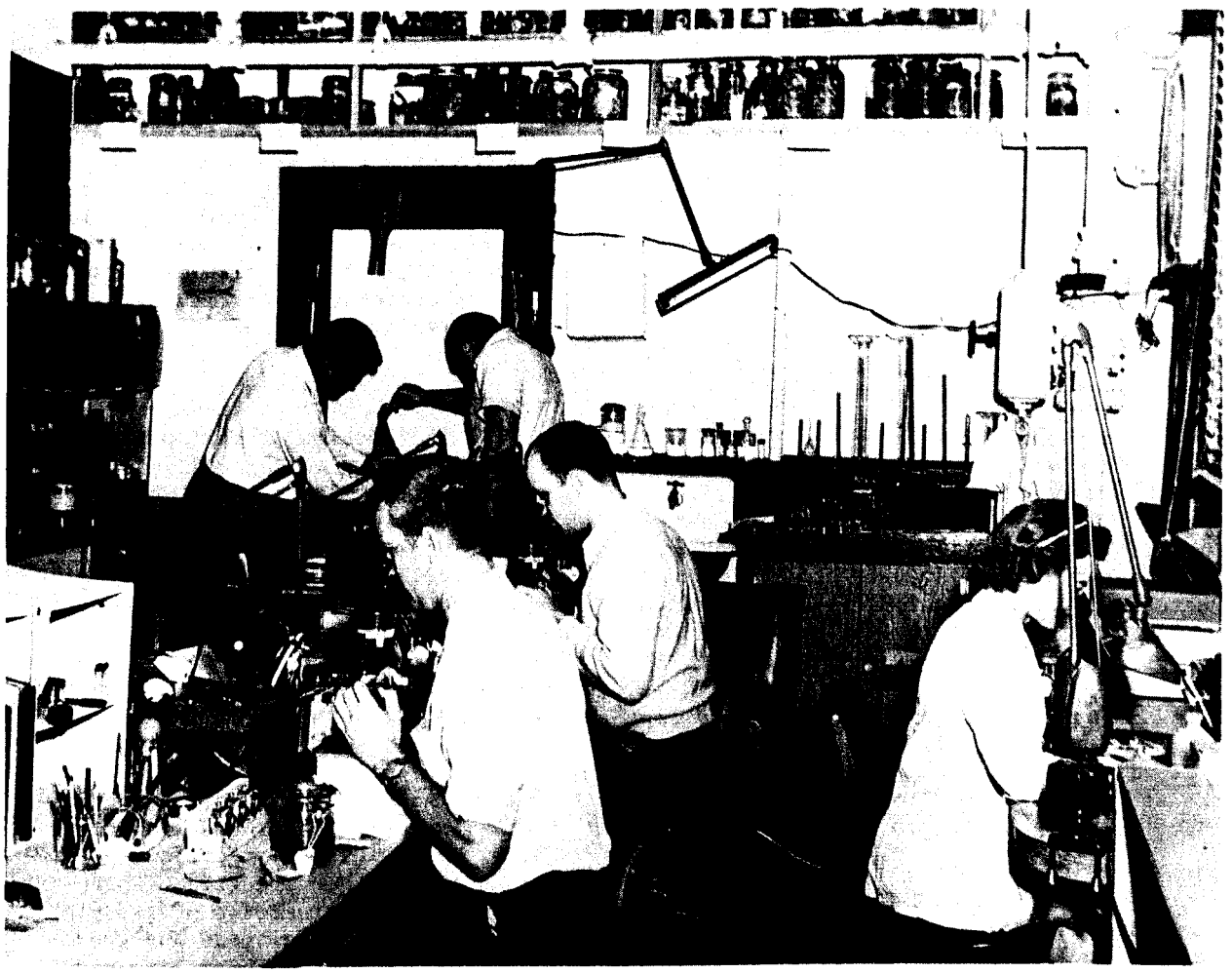
BIOLOGICAL INVENTORY

Sorting the plankton samples from the Theodore N. Gill cruises for fish eggs and larvae and determining the wet volume of plankton were continued. A few samples of one cruise remain to be examined.

Identifying major plankton organisms in high-speed and half-meter samples for cruises 2, 3 and 4 and continous plankton sampler material for cruises 3 and 4 was completed and the data were processed for publication.

Identifying and cataloging dip-net and stomach contents specimens of fishes from all cruises were completed and the data processed for publication.

Samples of mollusk shells were removed from bottom sediment samples taken on Gill cruises for identification.



SORTING AND IDENTIFYING PLANKTON AND FISHES

LARVAL AND JUVENILE FISH STUDIES

Fishery Bulletin 110 was published on the early development of the Atlantic sailfish, Istiophorus americanus, and an unidentified istiophorid. Manuscripts were prepared on the silver mullet, Mugil curema, fresh-water mullet, Agonostomus monticola, the jack crevalles Caranx spp., the tenpounder, Elops saurus, the striped mullet, Mugil cephalus, and Dikellorhynchus tropidolepis (Family Malacanthidae), a new species of fish.

PROCESSING DATA FOR THEODORE N. GILL CRUISE REPORTS

Efforts were directed toward preparing physical oceanographic, chemical and biological data for publication in the Special Scientific Report--Fisheries series. The Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, prepared the profiles of temperature, salinity and density for all cruises. The Navy Hydrographic Office processed the physical oceanographic data for all cruises and furnished them as IBM runoffs to the South Atlantic Fishery Investigations which completed the final tabulation on data and assembled the reports. During the year the reports for cruises 2 and 3 were prepared; the report for cruise 4 is in preparation.

COLLECTIONS OF LARVAL AND JUVENILE FISH

The biweekly seining for larval and juvenile fish in open ocean, marsh and fresh-water habitats continued for the fourth year. The collections supplement material taken offshore and have provided developmental stages (not found in offshore waters) of several marine fishes that have been studied in detail (Caranx, Mugil and Elops).

A preliminary study of the biology of the royal red shrimp, Hymenopenaeus robustus, is being made off the South Atlantic coast. Field collections of specimens and data were begun late in fiscal 1957.

GULF FISHERY INVESTIGATIONS

Albert W. Collier, Jr.
(July 1, 1956 - February 25, 1957)
Thomas J. Costello, Jr.
(Acting, February 26 - June 15, 1957)
Galveston, Texas

Except for shrimp, the Gulf of Mexico is not yielding the poundage of fishery products to be expected from such a large body of water. Because knowledge of the potential productivity of the region is not extensive, these investigations were designed to determine the Gulf's productivity as a guide to the possibilities of extending the present fisheries and of developing new ones.

The Gulf Fishery Investigations is concerned with the fisheries over the vast area stretching from Key West, Florida, to Brownsville, Texas. The chief emphasis is on the shrimp fishery, the most important in point of value in the United States. The menhaden fishery is expanding and requires biological investigation to determine the extent of the resource and to discover the causes of fluctuations in abundance. Another important problem is to find means of predicting and controlling the abundance of the organism, Gymnodinium breve, that occasionally causes extensive fish kills commonly known as red tides.

SHRIMP

Three species of shrimp in the Gulf of Mexico are of commercial importance. These are the white shrimp, Penaeus setiferus, the brown shrimp, Penaeus aztecus, and the pink shrimp, Penaeus duorarum. The seabod, Xiphopeneus kroveri, is seldom exploited outside Louisiana waters. In most areas of the Gulf, however, the catch included at least two of the remaining species, the relative abundance of each varying according to the time of year and the locality.

As with other exploited populations, the maximum yield in the weight of shrimp cannot be achieved by restricting fishing unless during the effective fishing season the total weight increase of the population resulting from recruitment and growth exceeds the decreese by mortality and by migration beyond the effective range of the fishery. In the shrimp fishery, where two

or more species are often caught together, the determination of maximum use is complex. The differences between species in spawning season, spawning areas, growth rates, distribution, movements and behavior must be considered. In short, the biology of the individual species that comprise the commercial catch and their interrelationships must be evaluated before any valid conservation measures can be formulated.

Shrimp bait fishery.--A complex fishery of this type, primarily on the white and the brown shrimp, is being studied in the Galveston area. White shrimp or brown shrimp dominate, depending on the time of the year, while occasionally a few pink shrimp and seabobs enter the catch. In cooperation with the Branch of Commercial Fisheries of the Fish and Wildlife Service, the Gulf Fishery Investigations is collecting detailed statistics of both commercial and bait fisheries in this area. The bait fisheries have been overlooked in former statistics but, since over 200 bait dealers in the Galveston area sell an estimated one million pounds of shrimp annually, the status of the shrimp bait fishery should be accurately established.

The Galveston Bay area has been subdivided into smaller statistical areas than those presently employed by the Branch of Commercial Fisheries to obtain a more detailed survey for this purpose. Samples of live shrimp are also being obtained from both the commercial and bait fisheries.

The statistics and samples are being analyzed to determine for this area the relative abundance of each species by size and species composition, to learn more about the movements of each species, to attempt to define spawning seasons and spawning grounds by gonadal examination, to develop a method of following discrete shrimp populations and to determine the growth of shrimp under natural conditions.

Suitability of shrimp nursery areas.--Studies were initiated in Lufkin Bayou, a natural inlet on Galveston Island, to determine the effects of various environmental factors on the growth and abundance of shrimp in a nursery area and the interrelationships between brown and white shrimp; in particular, the study of comparative movements within the estuary and the degree of competition between species.

Movements of young shrimp.--The final report on shrimp marking under the contract with the University of Texas is in press. Since marking methods developed under this contract were developed chiefly on large shrimp, work in the Galveston laboratory emphasized the feasibility of marking small shrimp.

Seven feedings of chopped fish stained with Trypan Red were required before a pink coloration of the gills was detected in white shrimp of 30 mm. Eleven feedings produced a bright red color in the gills. Although this bright red color was lost after two months, 90 percent of the shrimp showed a recognizable pink color.

Two other dyes, F.D.C. Green No. 3 and F.D.C. Blue No., 1 were similarly tested, and although each stain caused an abnormal color in the digestive tract and heart of the shrimp, neither produced a persistent color.

Shrimp immersed in a dilute solution of riboflavin and shrimp fed with mullet previously soaked in riboflavin became luminescent for approximately three days.

The staining method is being tested in field holding tanks before trial releases of marked shrimp are commenced.

Effect of aerial spraying of insecticides.--In the fall of 1956 mosquito control workers of Galveston County, Texas, received several reports from bait dealers in the Galveston Bay area that several days after aerial spraying of the surrounding marshes with insecticide considerable mortality of live shrimp occurred in their bait pens. Throughout the Gulf of Mexico live shrimp sold for bait are commonly held in wooden pens suspended in the water of the bays and bayous.

Toxicity of various insecticides, especially DDT, to fish and wildlife was investigated by a large number of workers, but the studies were confined largely to fresh-water fish and crustaceans, birds and mammals. Little information is available concerning the effects of insecticides on the estuarine flora and fauna. Since considerable aerial spraying is done over salt-water marshes, which many fish and aquatic invertebrates use as nursery grounds, such studies are especially appropriate.

As shrimp spend several months in the bayous and estuaries shortly after hatching, a limited study was conducted to determine if the material used by the Gulf Fishery Investigations could be considered toxic to shrimp.

The insecticide used in this area is Tri-6 Dust No. 30 (Thompson-Hayward Chemical Company, Kansas City, Missouri). It contains 3.0 percent gamma isomer of benzen hexachloride, 5.1 percent other isomers of benzene hexachloride and 91.9 percent inert ingredients. Benzene hexachloride and BHC are common names for 1, 2, 3, 4, 5, 6-hexachlorocyclohexane, a chemical commonly used in commercial insecticides.

Lethal levels were determined in the laboratory for two size groups of shrimp. The specimens ranging from 29 to 50 mm. in length consisted almost entirely of white shrimp, Penaeus setiferus, and those ranging from 11 to 13 mm. in length consisted entirely of brown shrimp, Penaeus aztecus. A mortality of 83 percent of 50 parts per billion was noted for the larger shrimp compared to 50 percent at 75 parts per billion for the smaller shrimp. The apparent greater sensitivity of the larger shrimp to the insecticide was also demonstrated by estimated 24-hour median tolerance limits of 35 parts per billion compared to 400 parts per billion for the smaller shrimp. Differences in sensitivity were tentatively attributed to size rather than species differences.

The stability of the toxic factor or factors was also investigated. Up to 18 days of exposure to sunlight had no effect on the toxicity of the insecticide. A field test was inconclusive, but the results of the laboratory experiments show clearly that the insecticide tested should be considered extremely toxic to shrimp.

Anatomy and histology of shrimp.--The Tulane University contract on the anatomy of Penaeus setiferus was completed and the atlas of illustrations of this work will be published in the near future. Another contract was formulated with Tulane University to describe the anatomy of Penaeus duorarum and Penaeus aztecus, the other two commercially important Penaeids of the Gulf.

The Texas A. and M. Research Foundation under its contract for histochemical and histological studies of shrimp has determined the flow of blood through the gills of shrimp and completed detailed histological studies of the gills. In related studies it established that volume is a more sensitive index of growth than length. Volume measurement can be more easily established with live shrimp and the percent increase is three times greater than the percent increase in length.

MENHADEN

According to the commercial operators, the 1956 menhaden season was excellent but because of adverse weather during the past few months the current yield is below that of the same period in 1956.

Emphasis was placed on determining whether ages of the Gulf menhaden can be derived by scale analysis coupled with length, weight and sex data. The results indicated that this criterion can be used.

During the 1956 season (June-October) 32 samples of menhaden were obtained from the commercial catch at Moss Point and 18 samples from commercial vessels at Sabine Pass from which scale mounts were prepared and read. Forty-five additional collections were obtained from commercial beach seiners and through the seining, cast-net and dip-net operations in 1956 (April-October) of the Gulf Fishery Investigations. The last-named collections include larval, post-larval and juvenile specimens. Pre-adult forms were taken throughout the winter at East Lagoon. Local collections are being continued and commercial samples are being collected weekly from Sabine Pass.

Contracts for special research studies were negotiated with the Gulf Coast Research Laboratory, Ocean Springs, Mississippi, for racial and stock studies of Gulf menhaden and with the Department of Zoology, Tulane University, New Orleans, Louisiana, for life history studies. Both contracts were activated by late spring.

ZOOPLANKTON

Zooplankton forms the basic food of most fishes. Being higher than algae in the food chain, it is a step closer to the fishes and, therefore, its abundance and distribution are much more likely than algae to be reflected in the abundance,

growth and distribution of fish. This applies especially to the herring-like fishes that depend directly on crustaceans to a marked degree. However, over wide areas, their distribution may also coincide with that of the larger piscivorous fishes, such as tunas, which utilize the smaller fishes.

A preliminary analysis of the abundance of the calanoid copepods indicated both the geographic and the inshore-offshore categories of species. In the deeper waters are found vertical associations of species. The number of calanoid species found in the Gulf of Mexico has been increased to 115 and new species have been discovered.

At present the chief emphasis is on completing the study of the copepod material collected by the vessel Alaska; this material, however, is being supplemented by additional material when available.

RED TIDE

For the second consecutive year, the red tide organism, Gymnodinium breve, responsible for mass fish kills near the Florida Gulf coast, has not been present in lethal concentration. A number of red tides were reported during the year, but with one exception all proved to be false or harmless phytoplankton blooms. The exception occurred during December 1956 when a small number of dead fish were observed in the vicinity of the Ten Thousand Islands, but the fish kill was not associated with a G. breve bloom.

The incidence of occurrence of G. breve increased during the latter part of October and early November 1956, but the concentration of organisms remained low. In April 1957 the incidence of G. breve began to increase and this trend continued gradually through May 1957. While the concentrations were small compared to those of a fish killing bloom, fish killing concentrations could develop in the next four to six months if the trend continues. The occurrence of fish killing blooms apparently depends on a delicate balance of several factors, and the trends of increasing incidences and concentration of G. breve have followed a trend of higher than normal precipitation, which is considered a primary prerequisite of red tides.

The float type aircraft was used to good advantage during the past year. Numerous reports of fish kills were investigated by aerial reconnaissance and plane sampling and the results are normally known in three or four hours, although the reports may be from any area of a 250-mile sector of the southern Florida coast. Weekly aerial surveys detected suspected areas of trouble much faster than would otherwise have been possible.

Red tide forecasting.--Studies on the association of red tides with certain climatic and hydrographic conditions were continued for the purpose of developing a red tide forecasting method. Although a method was not developed, the climatic and hydrographic conditions were followed closely during the past year and some tentative conclusions were depicted. This limited study indicated that accurate red tide forecasting may depend to a great extent on accurate long-range weather predictions.

The accurate assessment of the effect of each factor and the interaction between factors was rendered difficult by the inability to determine accurately the fluctuations in abundance of G. breve at low concentrations. This problem is being attacked from two directions; first, from the angle of improvement in sampling and counting techniques and, second, by attempting to discover a method whereby G. breve can be preserved. At present these naked dinoflagellates must be counted while they are alive since they disintegrate almost instantly on dying.

Experimental control of red tides.--During the past year no experiments on control were attempted since the abundance of G. breve was too low for accurate assessment of results. Since concentrations have increased somewhat in recent months experiments are planned to measure the effectiveness of powdered copper sulfate. This will most probably be spread with crop dusting airplanes. Because preliminary tests indicated that the toxicity of copper may vary, laboratory studies were conducted on the factors which may increase or retard the toxicity of copper to G. breve. The outstanding results were that the presence of certain other metal ions, especially iron, nickel, silver, mercury and zinc, increases the toxicity of copper, whereas the presence of suspended matter, chelating substances, soil extract and sulfide ions, decreases the

toxicity of copper. A combination of several factors could drastically change the concentration of copper required to kill G. breve. The results show that a preliminary laboratory test can be conducted in less than 24 hours whenever G. breve concentrations approach the danger point, and it should give an index of the amount of copper sulfate required to effectively kill G. breve in that particular bloom.

Work with chemically defined media to establish the nutritional requirements of G. breve continued during the past year, especially on testing factors which cause erratic growth of replicate aliquots of culture media. Although the results of these tests are inconclusive, they show that conflicting results between experiments result primarily from differences in sea water and also that extreme care must be used in cleaning reagent and culture containers. Quasi-artificial media were developed for the growth of bacteria-free G. breve. The media, all basically the same, are composed of known components except for one addition. The additives that contain the unknown substances are peptone, yeast extract, casein digest, extract of a culture of the dominant bacterium of unialgal G. breve cultures, aged red tide water, extract of an unialgal G. breve culture, Caloosahatchee River water and compost extract. The amounts of these added substances are small and results of experiments testing components of some of the materials (prepared by extraction processes) indicated that the active components are high molecular weight organic compounds.

Studies on the toxic substance or substances produced by G. breve indicate that the toxicity of a culture increases if the cells cytolyse. Preliminary experiments indicated that the toxic components are heat-labile organic compounds. Because the toxicity of the water increases after the death of G. breve organisms killing the organisms before they reach concentrations that kill fish while G. breve is alive may be important in any control work.

A second proposed method for controlling red tides would take advantage of their extreme susceptibility to copper ions. Instead of trying to destroy heavy concentrations, this method would attempt to prevent their forming by raising the copper content of the coastal sea water by placing copper ore in jetties. There are certain difficulties in assessing the value of this method since the copper content of the sea water may often be a poor index of the quantity of copper ions. Galveston Lagoon was selected for testing this method and a physical and partial biological survey of the Lagoon was made.

The waters of Galveston Lagoon differ considerably in quality from those along the Florida coast. Preliminary tests indicated that because of the presence of more chelating substances and organic matter in the Galveston water than in the Florida water the copper in the Galveston water is not as toxic as that in the Florida water. To apply the results attained in the Galveston water to the Florida water, bioassays will have to be made at different copper concentrations and water qualities. Laboratory studies of the toxicity of copper to the organisms that occur in the Lagoon indicated that a copper concentration of 0.25 p.p.m. reduces the life expectancy of young pinfish, Lagodon rhomboides, by at least 50 percent. Young croakers, Micropogon undulatus, and striped mullet, Mugil cephalus, were similarly affected by 0.5 p.p.m. of copper. In similar laboratory studies, G. breve was killed in 24 hours by 0.02 to 0.07 p.p.m. Dilution of sea water seems to augment the toxicity of copper. Grass shrimp, Palaemonetes sp., were more tolerant of copper than the fish tested--a concentration of 10 p.p.m. had no apparent effect on the shrimp after ten days. The ova of Palaemonetes sp. were tolerant of copper concentration as high as 20 p.p.m.

The study of the method will be continued by means of bioassays of the effect of an artificial ore-dike as more and more ore is added, on the survival of typical species, on the setting of larval forms on cement board plates and on the occurrence in the Galveston Lagoon of Gymnodinium splendens. Although non-toxic, G. splendens is similar to G. breve in sensitivity and will serve to show the ranges of copper concentration, if any, that are lethal to Gymnodinium without causing significant damage to other organisms. To obtain an index of total plankton production, an attempt will be made to measure chlorophyll and/or total plankton volume.

SPONGES

The Florida commercial sponge investigation was performed under contract with the

Marine Laboratory of the University of Miami, Coral Gables, Florida.

Sponging up to December 1956 was successful, but poor weather in the Everglades area from January through March 1957 prohibited fishing. Good sponges in quantity were also taken in 7 to 9 fathoms of water off Anclote Key, but good sponge producing areas are widely scattered.

The effects of sponge disease continued to cause serious deformation of the sponges throughout much of the area, and the price of sponges was increased during the past year.

Growth curves were made for sponges of specific areas. It may be possible to project the growth data to estimate the years required to obtain sponges of any given diameter, to examine the productivity of sponge beds and to assess the validity of conservation recommendations.

Present data indicate that the range of spawning temperatures is from 73° to 83° F. A temperature cline appears to be associated with minimum reproduction size. Thus, the minimum diameter of reproducing sponges is 5-1/2 inches in the northern part of their range and 4 inches in the southern areas.

Data on environmental factors which affect the growth, reproduction and distribution of sponges have been compiled and preliminary analyses completed.

SOUTH PACIFIC FISHERY INVESTIGATIONS

John C. Marr
La Jolla, California

The long record of catch statistics, information on length and age composition, on fishing intensity, on the relation of economic conditions to yield, and the history of divers biological studies make the sardine or pilchard, Sardinops caerulea, one of the best-known economically important fishes in the world. Because of this information, the perplexing problem connected with the population dynamics of pelagic fishes seem most likely to be solved through continued studies of sardine biology. A recent decline in landings has increased support for such research.

The primary objective of the South Pacific Fishery Investigations is the description and the understanding of variations in the distribution and abundance of the population of the Pacific sardine. As an aid in gaining this understanding several ecologically associated species also are being investigated in a lesser degree. These include the anchovy, Engraulis mordax, the jack mackerel, Trachurus symmetricus, and the Pacific mackerel, Pneumatophorus diego.

The South Pacific Fishery Investigations is working cooperatively with four other research groups in the California Cooperative Oceanic Fisheries Investigations. The Marine Research Committee sponsors the research which is carried out by the SPFI, the Scripps Institution of Oceanography of the University of California, the California Department of Fish and Game, the Hopkins Marine Station of Stanford University and the California Academy of Sciences. The Scripps Institution of Oceanography and SPFI carry out extensive oceanographic-biological investigations.

PACIFIC SARDINES

Subpopulations.--One of the results of the sardine spawning surveys has been to show the existence of several spawning areas which are more or less discrete in space and/or time. These are a spring spawning area off central Baja California, a spring spawning area off southern California and northern Baja California, a warm-water fall spawning area off central Baja California (particularly in Sebastian Viscaino Bay), and a large area in the Gulf of California. The first two areas may not be inhabited by separate subpopulations, as there appears to be considerable exchange between the two areas in different seasons; the other two areas may be inhabited by separate subpopulations.

Genetic studies of subpopulations of sardines were initiated during the past year. Research is directed toward determining whether genetically isolated or partially isolated groups exist along the Pacific coast. As pointed out above, definite discontinuities are known for spawning areas, but whether these discontinuities are reflected in measurable genetic differences between the individuals which occupy the spawning areas is not known.

Two approaches are commonly used in studying the genetical makeup of biological populations. These are breeding experiments under controlled conditions and the study of discrete inherited individual differences, such as pelage color, erythrocyte antigens, etc., in natural populations. Of necessity, the SPFI is following the latter approach.

A serological study is being undertaken in an attempt to characterize subpopulations of sardines. A large body of precedential information is available in this field, mostly developed on domestic animals. Several species of fish have also been investigated and individual differences with respect to erythrocyte antigens have been shown to exist in catfish (Cushing), goldfish (Hildemann), salmon and trout (Ridgway), opal eye, Girella migricans, and kelp bass, Paralabrax clathretus (Sprague and Stormont). Recently the existence of discrete individual differences with respect to erythrocyte antigens was demonstrated for the Pacific sardine, Sardinops caerulea, by means of antibodies found in the serum of certain wild and domestic animals (Sprague). (The investigation has not proceeded far enough to determine whether such differences can be used to characterize subpopulations.)

Methods and facilities have been developed for capturing and maintaining laboratory stocks of live pelagic fishes for use in the immunological studies as well as in other projects of this investigation.

Collection of spawning sardine.--The August and September 1956 cruises of the Black Douglas were devoted in part to sampling adult sardines for use in fecundity and subpopulation studies and in part to egg and larval surveys of fall sardine spawning. During both months sardines were sampled, mostly by gill nets, in the area between Point San Eugenio and Point Agreojos. Age determinations were made on 89 sardines taken in August and on 70 taken in September. The August material consisted of fish 0 to 4 years old and the September samples of fish 0 to 6 years old. Only about 5 percent of the fish were over two years old, however.

A summary of the age distribution follows:

Fish sampled off central Baja California in August and September 1956

Year-class	No. rings (age)	No. fish sampled	Size range (mm.)	Mean
1956	0	46	86-168	145
1955	1	60	124-196	165
1954	2	45	162-226	182
1953	3	2	178-192	185
1952	4	3	196-226	209
1951	5	1	170	170
1950	6	2	176-182	179
TOTAL	0-6	159	86-226	

The fish were markedly smaller in size than of the same age taken in the California commercial catch. Two-ring fish (1954-class) in the commercial catch ranged in standard length from 208-242 mm., with an average length of 224 mm.; this is 42 mm. larger, on the average, than the two-ring fish sampled off central Baja California. The differences are even more marked for some of the older fish.

The material was examined to determine the state of maturity of the fish. Of the fish collected in August, only a sample of 22 fish from Hipolito Bay were maturing. All females in this collection had yolked eggs and several contained ova in fairly advanced stages of development.

Twenty-seven males and 23 females were examined from the September collections for stage of maturity. Of the females, 17 had yolked eggs and two contained ova that were becoming translucent.

In August, the females containing yolked eggs were between 177 and 222 mm. in standard length; in September they were between 160 and 188 mm. Thus, smaller-sized fish were maturing in the September collections; these fish were mostly one year and two years of age. The high percentage of females that were maturing in September indicated that most of the fish sampled were definitely part of the fall spawning population. The marked difference in size between these sardines and fish of the same age taken off southern California is evidence that they did not enter into the commercial catch in any numbers in the 1956-1957 season. It also supports the thesis that the fall-spawning sardines constitute a separate subpopulation.

Population size.--A preliminary estimate was derived of the amount of sardine spawning during 1956. The number of eggs spawned was estimated to the approximately 200 x 10^{12}. Similar estimates are given by area for the preceding five years for comparison.

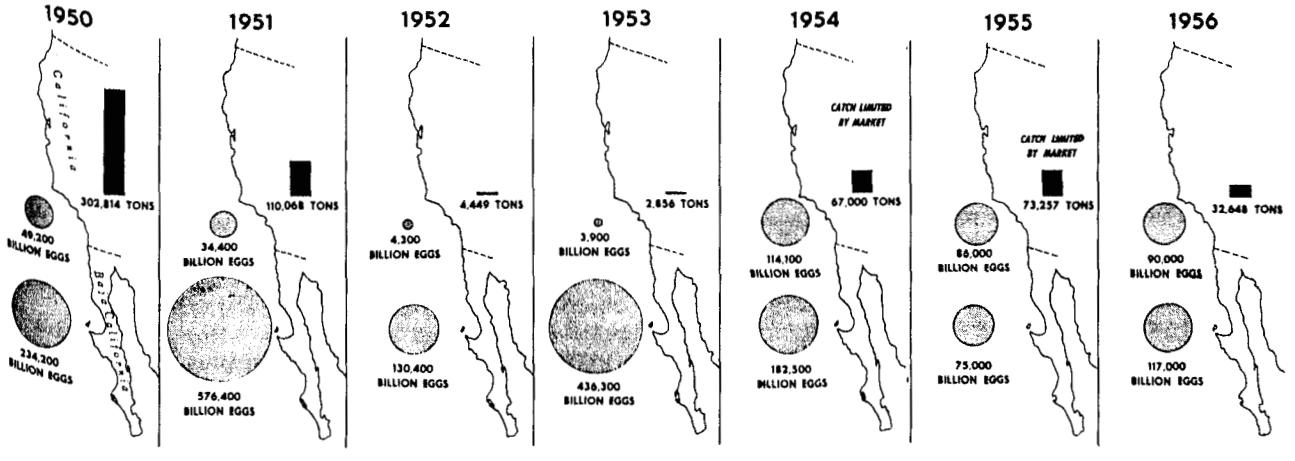
Estimate of number of sardine eggs spawned (x 10^{12})

Year	Central California line 77 and above	Southern California lines 80-93	Northern Baja California lines 97-107	Central Baja California lines 110-137	Southern Baja California and below	Total
1951	0	15.7	18.7	576.4	0.1	610.9
1952	0	2.7	1.6	131.7	0.1	136.1
1953	0	0.7	3.2	436.3	-	440.2
1954	0.1	47.2	89.6	202.6	15.9	355.4
1955	0	18.1	67.7	75.4	1.5	162.7
1956	0	28.3	61.6	116.7	0.1	206.7

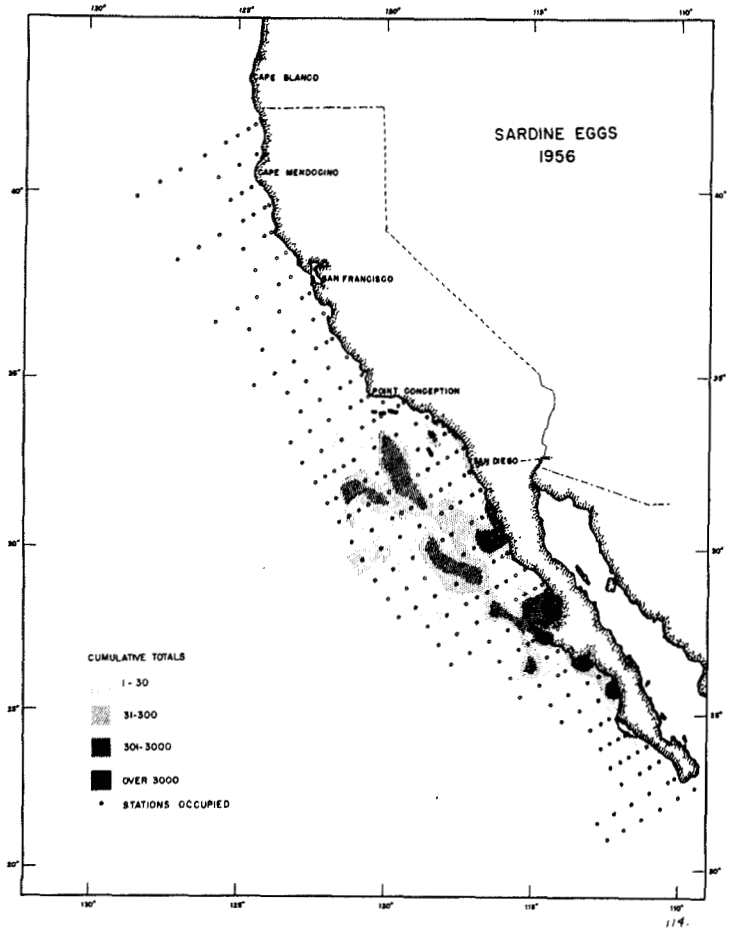
The values given for 1956 are preliminary estimates only while those for the previous years are final estimates.

The ups and downs in the egg estimates appear fairly reasonable when considered in conjunction with year-class strength. The 1949- and 1950-classes were the poorest on record. The sharp decrease between 1951 and 1952 reflects the decrease in spawning strength that occurred when these year classes entered the spawning population. The upswing in 1953 and 1954 reflects the effect of the somewhat more successful 1951- and 1952-classes. The 1951- and 1952-classes are the best of the series since SPFI has been investigating spawning in relation to subsequent year-class strength (although it is not particularly strong when compared to good year classes such as those of 1938, 1939, 1947 and 1948). The decrease in 1955 and 1956 reflects in turn the effect on the spawning population of the weak 1953- and 1954-classes.

In recent years the SPFI has become interested in the relative abundance of sardine spawning in different parts of the spawning range since there appears to be a direct relation between the distribution



EGGS, 1950-1956



SARDINE EGG, 1956

of the population at the time of spawning and the subsequent availability of sardines to the commercial fishery. When there is considerable spawning off southern California and northern Baja California, the availability is markedly better than in the years when there is little spawning in these areas. In 1956, about 43 percent of the spawning occurred in the "northern" center off southern California and adjacent Baja California (station lines 80-107) and the remainder in the "southern" center off central Baja California (station lines 110-137). The 1956 distribution was similar to that in 1954 and 1955, except that a larger portion of the spawning in the "northern" center in 1956 occurred south of Ensenada (Baja California) than in 1954 and 1955.

Sardine spawning in the Gulf of California.--Except for a cruise of the Black Douglas into the southern part of the Gulf of California in late 1852, no work had been done on sardine spawning in the Gulf prior to February 1956. Since then cruises were made in February, April and December 1956 and in February, April and June 1957. The station grid in the Gulf consists of 12 lines on which stations are spaced 15 miles apart, together with a fairly large number of inshore stations located between the station lines. On some cruises, between-line stations are placed in the deeps rather than inshore.

Sardine spawning in the Gulf is heaviest in the middle third, between Carmen and Tiburon Islands. In this area spawning occurs completely across the Gulf. The distribution of spawning in February 1957 was strikingly similar to that in February 1956, with the heavy spawning occurring on the two station lines immediately south of Guaymas.

The Gulf cruises were spaced at bimonthly intervals during the current spawning season so that an estimate of the sardine spawning population in the Gulf could be obtained. The results of the 1956 surveys show that the sardine spawning population in the Gulf must have been large.

Reliability of estimates of sardine eggs.--Studies dealing with the distribution of sardine eggs in a 20 x 20 mile grid have yielded several estimates of error. The grid consisted of 25 equally spaced stations which were occupied on five successive days. An analysis of the variance in the sardine egg counts indicated that the variation between the several days' sampling was highly significant. The variation between N-S sections was also significant, whereas the variation between E-W sections was not significant. The close grouping of stations (four miles apart in each direction) permits a more refined estimate of error than was possible from past data. The pooled residual variance of the logarithms is 0.458, which represents a coefficient of variation of 321 percent. This value is less than the residual variance of 0.687 calculated by Silliman (1946). A striking feature of the data was that though the mean level of the area fluctuated widely, the E-W gradient did not change.

Relation between fish condition and population size.--A relation often investigated by fishery biologists is that between fish weight and fish length. This weight-length relation is generally expressed by the formula $W = CL^n$, in which W = weight, C = a constant determined from the data, and L^n = length raised to an exponent determined from the data. Clark has dealt with this relation in the sardine in several papers. Clark (1928) gives a value of 3.15 for n in the above formula; Clark (1934) reduced the value to 3.07 by omitting fish smaller than 150 mm. from the determination. It will be noted that n approximates 3.

Allied to the weight-length relationship is the concept of "condition factor" or fatness. This is derived from the formula $K = \frac{W \times 10^7}{L^3}$, in which K = condition factor, W = fish weight, L^3 = cube of the standard length and 10^7 converts K from a decimal to a more easily handled three-digit whole number. Under SPFI sampling procedures, fish weight represents the mean weight of a 50-fish sample, fish length and the average length of the fish in the sample.

The condition factors were determined from the data of 15 fishing seasons at San Pedro, 1941-1942 to 1956-1957. The principal months of each season, October through January, were compared. Monthly condition factors generally decrease as the fishing season advances. In each of the 15 seasons, the highest monthly condition factor was obtained for October. During the 15 years the range in condition factors for October was from 126 (1941-1942 and 1942-1943 seasons) to 144 (1953-1954 season). The lowest monthly condition factors ranged from 117 (1941-1942) to 135 (1952-1953), and occurred in either December or January. During three seasons there was an increase in January to as high a condition factor value as in October.

There appears to be an inverse correlation between population size and both fish length and condition factor; high population levels (as indicated by the California catch) are associated with low condition factors and small average length of fish, while, conversely, low population levels are associated with high condition factors and greater average lengths of fish. The two lowest average condition factors of 121 and 122 occurred when the population was at its highest level (1942-1943 and 1941-1942). The highest condition factor of 139 occurred during the season of poorest catch (1953-1954) and the next highest value, 137, occurred during the 1952-1953 and 1956-1957 seasons which rank just above the 1953-1954 season. The high degree of inverse correlation between population size and condition factor may represent a cause and effect relationship; high population levels result in less available food per fish and lower condition factors, while low population levels result in more available food per fish and higher condition factors.

Age composition of the commercial catch for the seasons 1938-1939 through 1940-1941.--Age data based on scale samples are available for San Pedro and Monterey from 1941-1942 to date, and based on otolith samples are available for the period 1932-1933 through 1937-1938. A gap remains in the age data for these ports for 1938-1939 through 1940-1941. Considerable age data are available for these seasons and an age composition of the catch was derived. There are few scale samples for the 1938-1939 season; hence, the age composition derived for this season is probably less reliable than for the other two years.

A manuscript containing a summary of all age data (1932 to date) is being prepared.

Causes of variations in year-class strength.--The 1949- and 1950-classes of sardines were the poorest on record and were apparently of about equal strength. Each has furnished less than 130 million fish to the commercial fishery. The 1951 class has furnished to date three times this number of fish, the 1952 class four times. Such is the relative strength of four year classes that the California Cooperative Oceanic Fisheries Investigations has studied intensively. None is a successful year class when compared to the 1939 class which contributed over 55 times as many fish as either the 1949 or 1950 class, the 1947 class which furnished 24 times as many or the 1948 class which contributed 16 times as many.

The 1949 and 1950 classes were not poor because the size of the spawning stock was low. The 1946, 1947 and 1948 classes were all fairly successful. As a result, the spawning population in the

1949 and 1950 seasons was considerably larger than in the three preceding seasons when successful year classes were produced or in any subsequent season. The moderately successful 1952 class was produced with perhaps the smallest-sized spawning stock in recent years.

"Accumulated age" estimates of the size of the spawning population since 1949 are given below. These values are based on fish two years and older that must have been present on the spawning grounds during each year listed since they were subsequently caught. The estimates are minimal; the actual population size must have been several times as large in every season listed.

Accumulated age estimate of population size (fish two years and older)

Year	Billion	Year	Billion
1949	4.5	1953	0.5
1950	3.7	1954	0.9
1951	1.2	1955	0.7
1952	0.4		

The 1952 class had a higher survival rate as larvae and showed up stronger in the young fish surveys (conducted by the California Department of Fish and Game) than any recent year class. It was known to be more successful than adjacent year classes even before it appeared in the fishery. If a moderately successful year class can be identified as such early in its history, apparently a really successful year class should be obvious. The SPFI has had no chance to test this particular point, as it has not had a successful year class since the initiation of the California Cooperative Oceanic Fisheries Investigations.

This lack of a successful year class has made difficult determining the causes of variations in year-class strength. The SPFI has a mass of information from seasons when spawning was unsuccessful but nothing from seasons with successful sardine spawning.

However, there have been successful year classes of other pelagic species during this period. The anchovy population has shown a marked increase in size, and the year classes between 1952 and 1954 were large. An outstandingly successful year class of Pacific mackerel was produced in 1953. During its first three years in the fishery (ages 0, 1 and 2) it contributed 43 times as many fish as the 1951 class contributed in five seasons and 27 times as many fish as the 1950 class contributed in six seasons.

The fact that pelagic species spawning in the same general area do not necessarily produce successful year classes in the same years makes impossible deriving any simple correlation between productivity (as determined from intensity of upwelling, phytoplankton production or zooplankton volumes) and the survival of pelagic fish larvae.

Determining mortality rates from fishing and other causes.--Total mortality in a fish population consists of fishing mortality and natural mortality. Total mortality rates can be estimated from year-class catch curves. Fishing mortality can be derived from the relation between the size of the population (based on egg censuses) and the number of fish taken in the commercial catch; natural mortality rates can be estimated from the above estimates of total and fishing mortality.

The total mortality rates for the 1955-1956 to the 1956-1957 seasons as estimated from the year-class catch curves follow:

Year class	Total mortality rate (percent)
1954	-25
1953	3
1952	68
1951	85
1950	90
1949	94
1948	67

More individuals of the 1954 class were taken as 2-year-old fish than as 1-year-olds, hence, the "negative" mortality. The 3-year-old fish show only a slight mortality, probably because this year class was only partially available to the fishery as 2-year-old fish. All other year classes show a high mortality rate. This is partly an artifact resulting from different proportions of the total population being available to the fishery in the two seasons. Estimates of total mortality which are derived from the year-class catch curves are much influenced by the factor of availability.

The total population of sardines in 1956 (based on egg censuses) was about 4×10^9 fish. The total catch in the 1955-1956 season was slightly more than 1.9×10^8 fish. Fishing mortality, consequently, was less than 5 percent.

Causes of variations in availability. --In October, November and December 1956 the Black Douglas made nightly plankton and temperature collections in areas scouted and fished by the San Pedro sardine fleet. As soon as the area of most intense fishing was ascertained on any given night, the Black Douglas executed a pattern of observations that included the fishing area as well as some portion of the surrounding area that had been scouted without success. Once started, each pattern was continued until a half hour before dawn.

This survey is a field approach to the problem of sardine availability. Large concentrations of sardines do not necessarily appear in the same spot on successive nights and do not necessarily appear within operating range of the fleet on successive nights. Hypothesizing that such fluctuations are related to variations in one or more features of the environment is reasonable. Not knowing at the outset which environmental factors might be critical, the fishery scientists decided to measure the plankton and the temperature which have been related to fish distribution in a few other fisheries. The plankton was collected with a Hardy continuous plankton recorder, approximately 1-1/2 linear miles being sampled per each 2-inch length of the collecting silk. The surface temperature was recorded continuously and bathythermographs were taken at frequent intervals.

The plankton collections and the temperature data are being processed but the data are not complete enough for analysis. Sixteen to 20 categories of organisms are identified and counted in each collection. Small copepods less than 2 mm. in length are by far the most numerous organisms and they fluctuate by a factor of three to four during a night. In one case the area of highest density for the more abundant categories appeared to be associated with a geographical feature of the adjacent coastline. The center of fishing, however, was in an area of lower plankton density about four miles away.

Since this was a relatively poor season, no really large sardine catches were made while the Black Douglas was operating. Obviously, the significance of plankton and temperature distributions as factors in sardine availability cannot be determined until collections are obtained on some number of good nights as well as poor nights of fishing.

The Scripps Institution of Oceanography's vessel Orca covered a regular grid of hydrographic-biological stations off southern California each month during the period that the Black Douglas was working with the commercial fleet. A striking fact brought out by the Orca cruises was the marked lowering in temperature, amounting to about two degrees over much of the area, that occurred in the southern California area between the October and November cruises. This cooling was associated in time with the southward movement of sardines from the southern California fishing grounds to areas off the coast of Baja California.

PLANKTON

The plankton volumes in 1956 were exceptionally large, averaging 461 cc. per haul. The average volume per haul was over twice as large as the 1951-1955 average. The large volumes were taken throughout the area between Point Conception and San Juanico Bay.

The plankton volumes followed the usual pattern of increasing from spring to summer and dropping off in the fall. The highest average volumes per haul were taken in May (648 cc.), June (655 cc.) and July (783 cc.) and the lowest were taken in March (190 cc.) and December (160 cc.).

Inshore-offshore distribution of plankton (February - August) in 1956

Distance from shore	Point Conception to Punta Baja (lines 80-107)	Punta Baja to San Juanico (lines 110-137)
Inside 100 fm. curve	214	804
40 - 60 miles	215	586
61 - 100 miles	539	371
101 - 140 miles	589	363
141 - 180 miles	483	563
181 - 220 miles	314	608
221 - 260 miles	514	-

Because of the unusual oceanographic features off southern California and Baja California, plankton volumes do not necessarily decrease as one proceeds seaward. In fact, the opposite situation prevailed off southern California and northern Baja California. The plankton volumes average smaller within 60 miles of the coast than farther seaward.

SPECIES OF FISH ECOLOGICALLY ASSOCIATED TO THE PACIFIC SARDINE

Anchovy.--One of SPFI's continuing series of reports deals with the basic data on sardine eggs and larvae and other fish larvae. In this report, larvae of sardine, anchovy, jack mackerel and Pacific mackerel are reported by size for each station occupied during the year; those of hake and rockfish by number only. The report for 1955, submitted during the year, was expanded to include a partial analysis of the results.

The most striking feature of the 1955 collections is the marked predominance of anchovy larvae which is over 39 percent of all larvae collected. The comparative abundance of the other larvae is given in the following tabulation:

Larvae	Standard haul total for year	Percent
Anchovy	140,183	39.03
Sardine	14,121	3.93
Jack mackerel	13,246	3.69
Pacific mackerel	1,950	0.54
Hake	60,090	16.73
Rockfish	29,341	8.17
All other fish larvae	100,224	27.91
TOTAL	359,155	100.00

The distribution of anchovies in the survey area is interesting. Few were taken north of Point Conception on the four cruises that extended into this area and few were taken off southern Baja California during four cruises. The area between Point Conception and San Juanico, Baja California, was covered on nine cruises, excluding NORPAC, and partially on two additional cruises. The relative abundance within the survey areas was as follows:

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Area	Station lines	Number	Percent
Central California	60-77	38	0.03
Southern California	80-93	30,147	21.51
Northern Baja California	97-107	30,092	21.47
Cedros area (central Baja California)	110-120	68,568	48.91
Lower portion (central Baja California)	123-137	11,269	8.04
Southern Baja California	140-157	69	0.05
TOTAL		140,183	100.01

The number of anchovy larvae taken during the first half of 1956 was 107,600 while 129,500 were taken during the first half of 1955.

There was a marked difference in distribution between 1955 and 1956. Instead of the southern Baja California area having negligible numbers, nearly 24 percent of the larvae obtained during the first six months of 1956 were from this area. These were taken on three cruises and undoubtedly the percentage would have been larger if this area had been covered on every cruise. This was the first year that many larvae were taken south of line 137, and they must represent a southward shift of part of the spawning population. Most of the larvae were obtained on lines 140 and 143, so the shift probably represents a distance of 40 to 80 miles. In contrast, the number of larvae obtained off southern California and northern Baja California (lines 80-107) was only a third as many as during the same period in 1955.

Jack mackerel.--Although jack mackerel larvae are routinely identified and measured, jack mackerel eggs are not enumerated routinely. The collections of fish eggs are being rechecked for jack mackerel eggs for selected seasons. Jack mackerel eggs have been identified and counted for 1951-1954. The estimated number of jack mackeral eggs in the survey area (the complete spawning distribution is not covered) for these years follows:

Years	Eggs (billion)
1951	850,000
1952	583,000
1953	808,000
1954	439,000

The lowest estimate is more than half as large as the highest. The coverage was

less extensive in some years, particularly the latter ones above. The estimates of jack mackerel eggs are approximately double those for the sardine.

The rate of development of the eggs in relation to temperature was determined from both rearing experiments and from a study of the routine collections through use of the method developed by Ahlstrom (1943) for the sardine.

The growth of the larvae during the yolk sac stage was investigated, along with the prolarval growth of four other species. A 2-phase growth curve was obtained for all species studied. The increase in length was between five and ten times as rapid during the first two or three days of larval life as during the succeeding week.

Pacific mackerel.--The cruises in the Gulf of California, which were started in 1956 (February, April and December) and continued at bimonthly intervals in 1957, show the distribution and abundance of Pacific mackerel eggs and larvae in the Gulf. In the cruises of February and April 1956 and February 1957, which have been sorted, Pacific mackerel eggs were obtained at the majority of stations occupied. Spawning in February 1957 was most abundant in the area between Guaymas and La Paz. The average number of eggs per haul in this area is 842, as compared to an average of 24 per haul north of Guaymas and of 9 per haul south of La Paz.

Area	Number of stations with eggs	"0" stations	Number of stations occupied	Average number of eggs per haul
North of Guaymas	4	9	13	24
Between Guaymas and La Paz	28	4	32	842
Southern Gulf	6	15	21	9
TOTAL	38	28	66	

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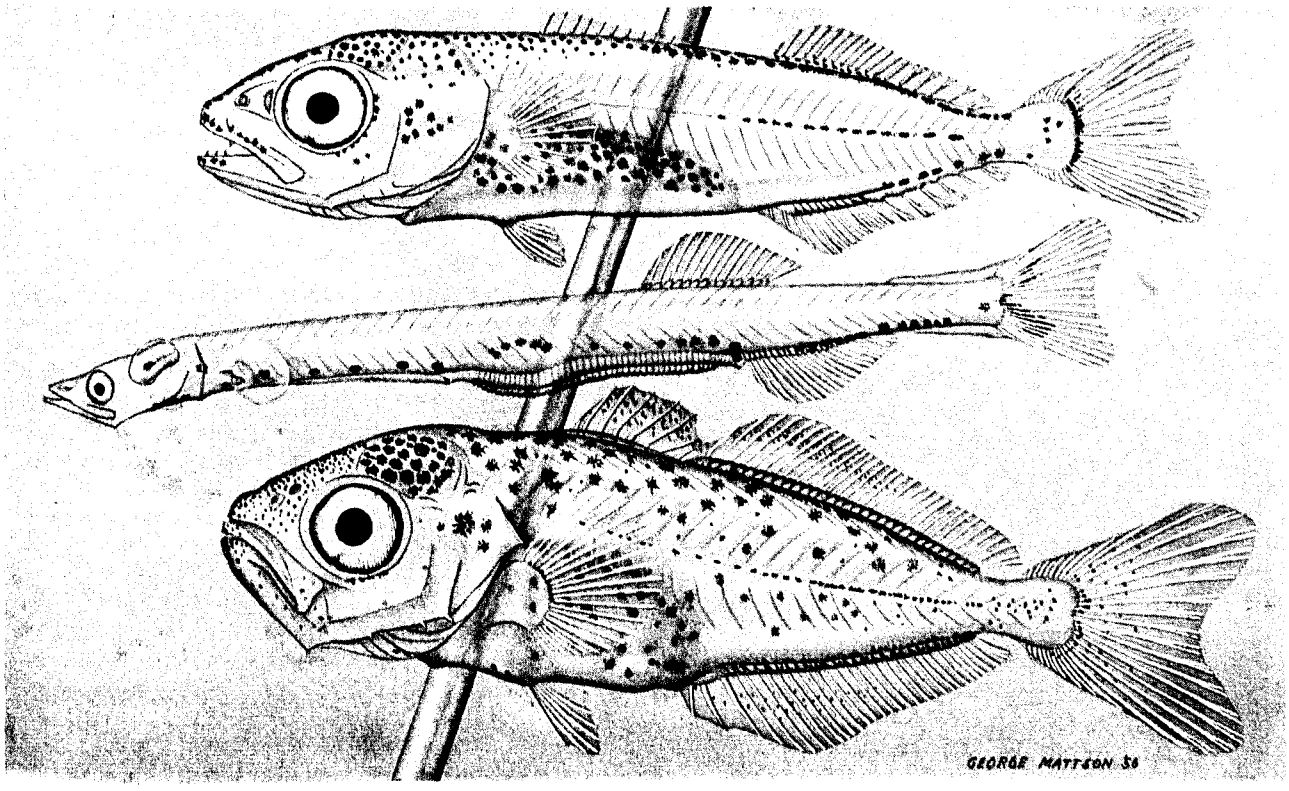
The center of abundance of larvae was below that of the eggs. No larvae were taken above Guaymas; the average number per haul in the area between Guaymas and La Paz was 68 and 31 in the southern end of the Gulf. In the latter area, the larvae occurred near the mainland side of the Gulf.



(UPPER) PACIFIC MACKEREL; (MIDDLE) ANCHOVY; (LOWER) JACK MACKEREL

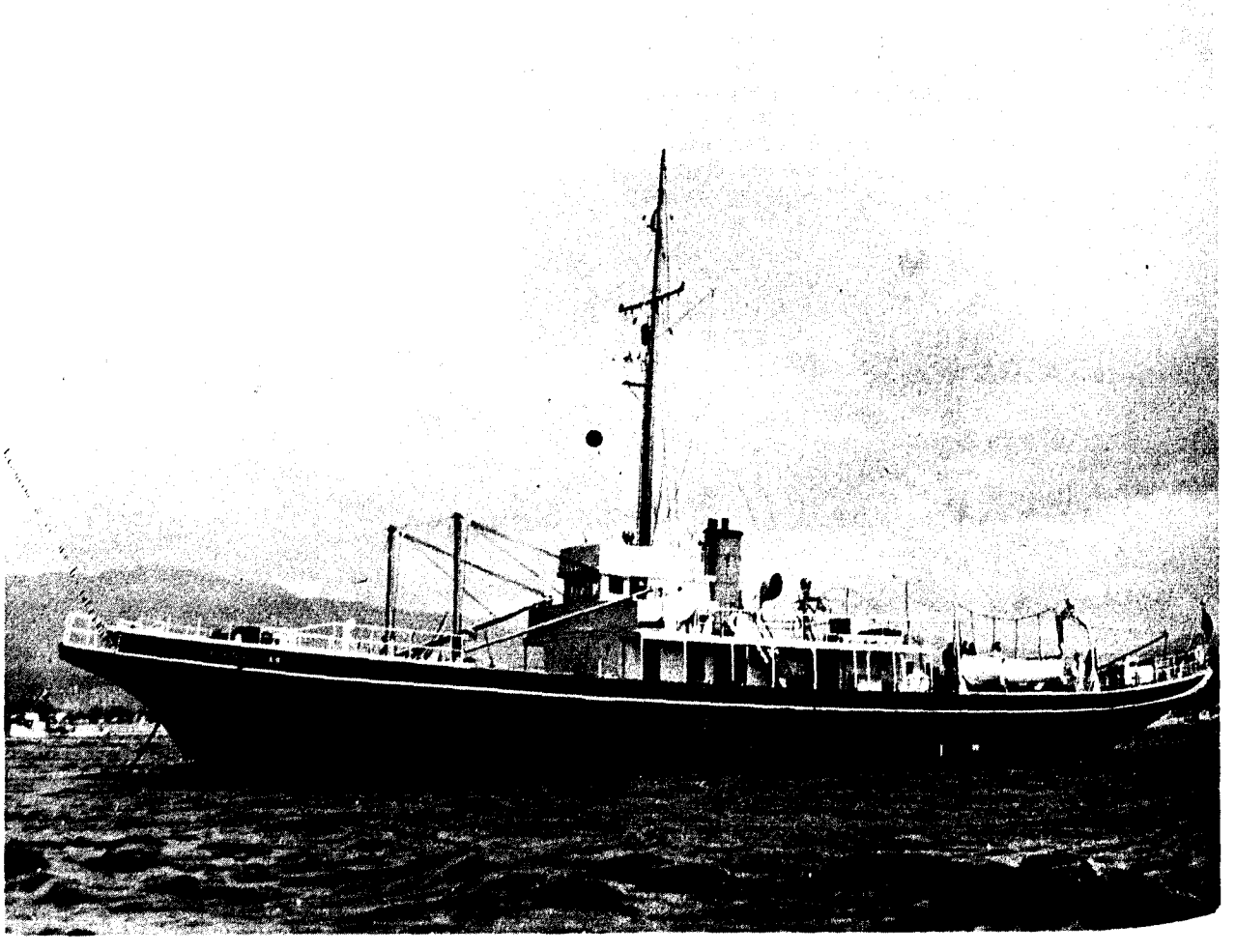
The distribution of eggs and larvae in February 1956 differed little from that described for February 1957, except that larger concentrations of eggs and larvae occurred at the southern end of the Gulf. Eggs and larvae were taken throughout the Gulf in April 1956.

MARINE MAMMALS

Gray whale census.--The count of gray whales made at Point Loma during their annual southward migration was the highest since the census was instituted. An actual count of 1,782 whales was made during the day watches. An unknown number of whales passed by Point Loma during the night or were beyond the range of the observers during the day. The counts were too low during overcast days or rainy weather. A conservative estimate places the number of whales that were not observed at half the migrating population. Hence, the gray whale population before calving would total about 3,600 individuals.

Whaling operations at San Francisco Bay.--The total catch of the whales off central California in 1956 was 145, including 133 humpbacks, 9 sperm and 3 finbacks. During the season three visits were made to the whaling station at Point San Pablo, San Francisco Bay. Twenty-seven whales were examined for physical characters, anatomy, reproduction and age.

Other marine mammals.--Specimens of sea lions, porpoises and, occasionally, whales were examined. Anatomical studies, skeletal preparations and stomach content analyses were made.



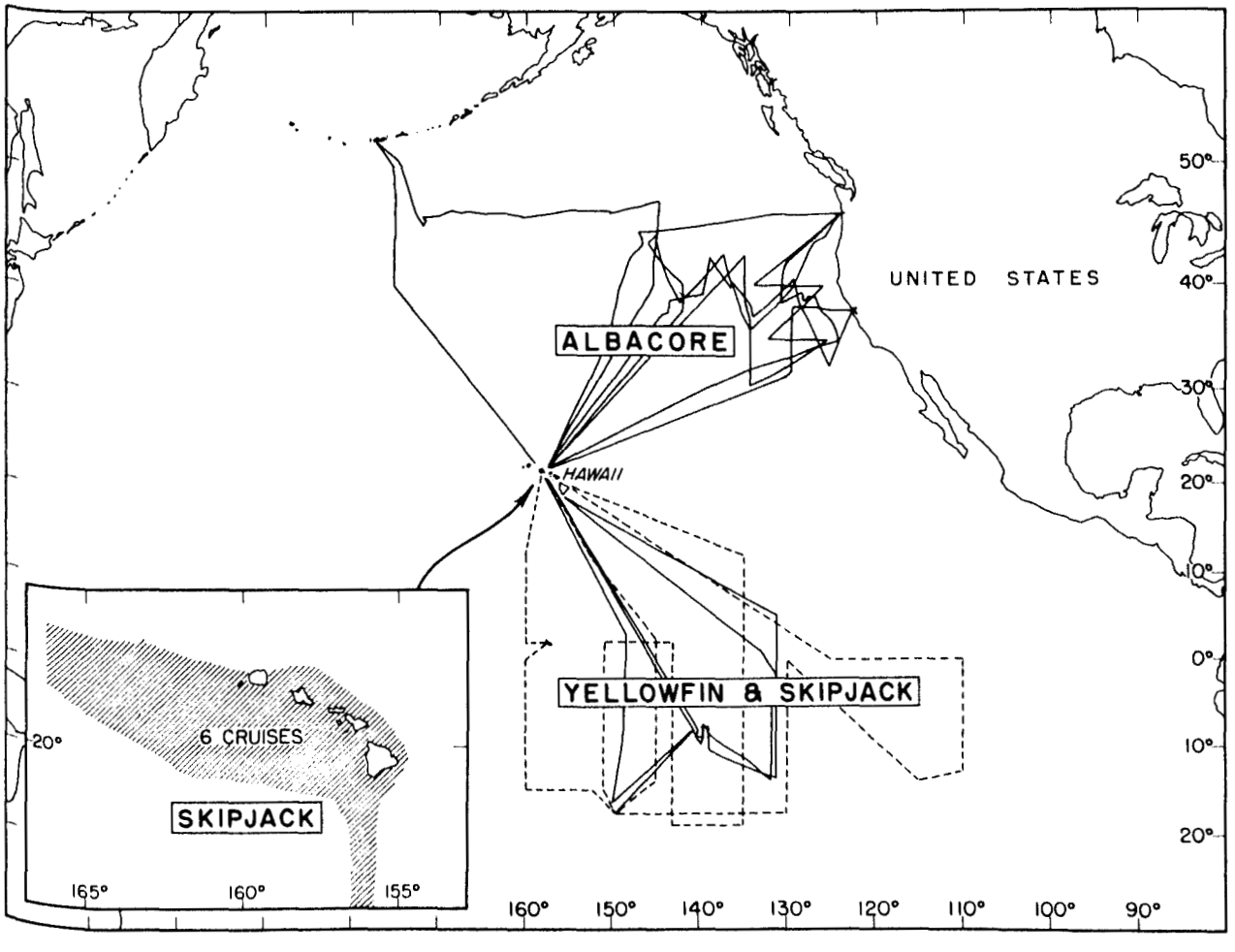
PACIFIC OCEANIC FISHERY INVESTIGATIONS

Albert L. Tester
Honolulu, T.H.

The Pacific Oceanic Fishery Investigations operates under Public Law 329 (80th Congress) which authorizes the United States Fish and Wildlife Service to investigate the high seas fisheries resources of the territories and island possessions of the United States in the tropical and subtropical Pacific Ocean.

In addition to investigating the distribution and abundance of tunas in equatorial waters, POFI began in 1955, under authority of Public Law 466, 83rd Congress (Saltonstall-Kennedy Act), to study the albacore resources in the waters to the north of Hawaii.

During fiscal 1957 POFI's efforts centered around three large programs. The first was a descriptive survey designed to ascertain the tuna resources, especially the skipjack, of the southeastern Pacific. The second major area of operations centered around the skipjack population in the Hawaiian waters. Here, the Hawaiian fishery is being used as a laboratory situation for studying oceanic skipjack in general. Most of the effort during the year revolved around understanding the nature of the population of the skipjack and completing field work designed to show whether fluctuations in the fishery can be rationalized on the basis of changes in the environment. The third major subdivision, albacore research, focused on the newly discovered mid-ocean



POFI OCEANOGRAPHIC (DASHED LINES) AND FISHERY (SOLID LINES) RESEARCH CRUISES MADE DURING FISCAL 1957. THE SHADED AREA IN THE INSERT INCLUDES BOTH OCEANOGRAPHIC AND FISHERY SURVEYS

resources lying between Hawaii and Alaska and the development of an elaborate survey program off the Pacific coast during the summer of 1957. In addition, a number of important studies were conducted independently of the major programs. These projects, aligned by discipline, such as tuna larva studies, are designed to produce results applicable to tuna in general.

A study of tuna behavior was started in a small way by devising a system that permits direct observation of tuna behavior during chumming. This opens the way to developing an intensive research program in this field, which holds great promise of contributing directly to raising the efficiency of tuna fishing.

EQUATORIAL TUNA PROGRAM

The equatorial program in the vicinity of the Line Islands was drastically curtailed. Emphasis was shifted to begin evaluating the tuna resources of northeastern French Oceania, with concurrent broad-scale oceanographic coverage of that area.

Multiple-vessel surveys were conducted during August-September 1956 and January-March 1957, the southern hemisphere winter and summer, respectively. The times of the cruises were selected to afford the greatest contrast of environmental conditions and of tuna availability. The preliminary results of these cruises reveal that:

1. In the immediate vicinity of the Marquesas Islands, skipjack were abundant during the summer. Approximately three times more schools were seen during the summer than winter.

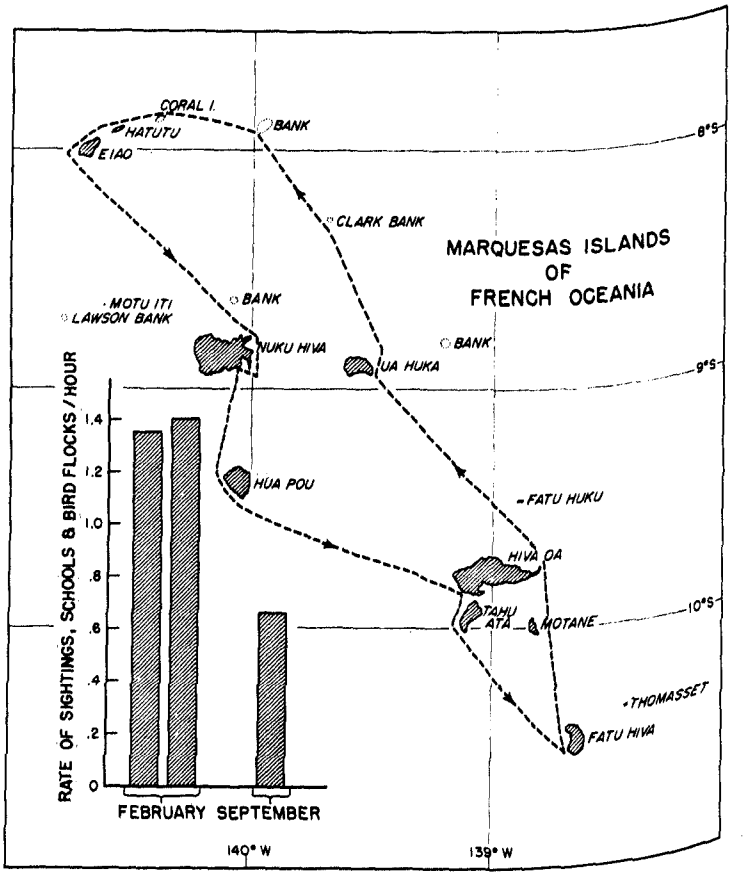
2. During the times of the surveys surface schools of skipjack greatly outnumbered surface schools of yellowfin in the Marquesas area.

3. There are supplies of live bait (Marquesan sardines) in the bays of the Marquesas adequate for a fishery of limited size.

4. Catches of deep-swimming tuna in the Marquesas area also indicated that their availability was about three times greater during the summer than in winter.

5. Surprisingly, one index of the productivity of the area, the volumes of zooplankton from the surface to 200 meters indicates a picture contrary to general expectations: the volumes obtained in winter in the general area of the Marquesas were about twice as large as those collected in summer. To the east of the Marquesas, longitude 130° W., the volumes in winter and summer were about equal. The area south of 18° S. appears to be extremely unproductive, with volumes from the 0-200 meter tows less than 10 cubic centimeters per 1,000 cubic meters in both summer and winter.

6. Another index of productivity, the concentration of inorganic phosphate at the surface, confirms the picture derived



TRACK (DASHED LINE) FOLLOWED BY POFI VESSELS DURING FISHERY SURVEYS IN MARQUESAN WATERS. SOME OF THE RESULTS OF THREE SUCH SURVEYS ARE SHOWN BY THE HISTOGRAM

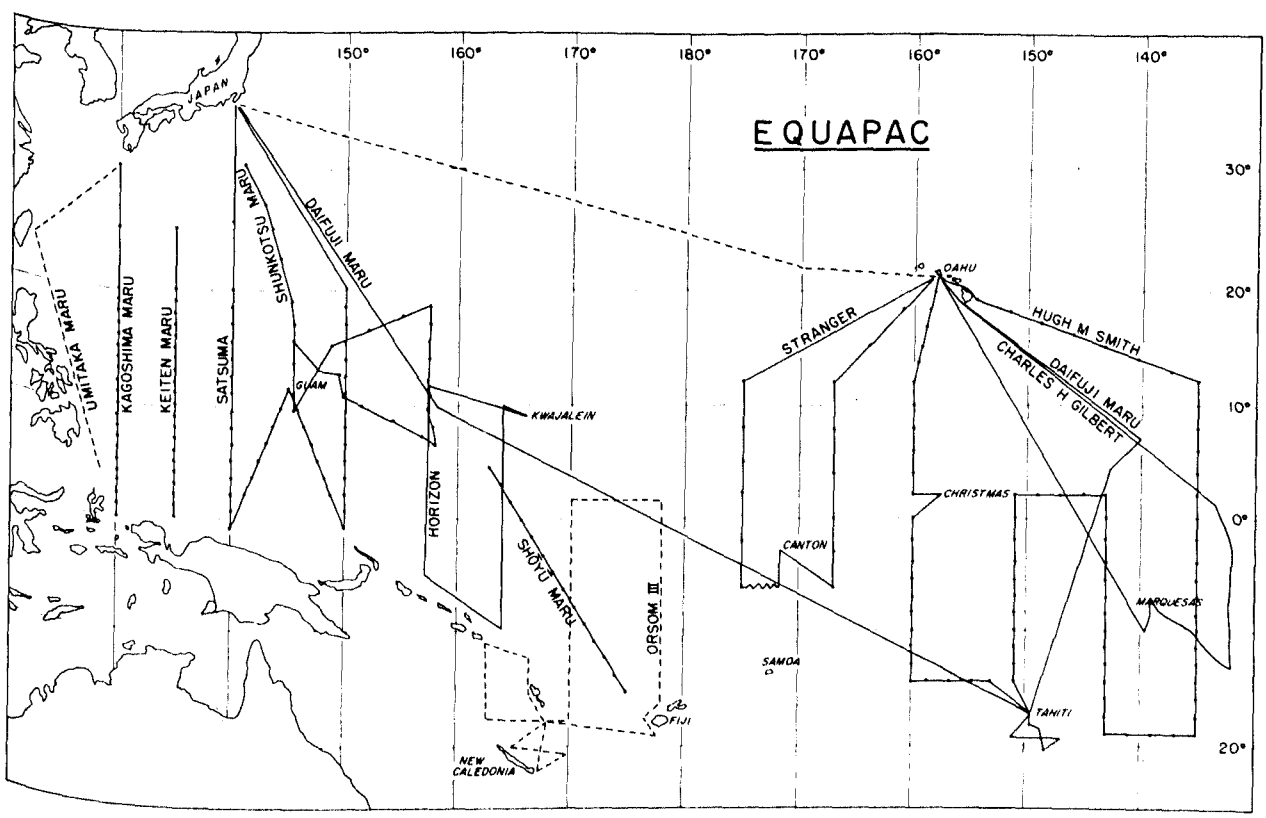
from the study of zooplankton volumes. In the whole broad area covered these values were appreciably lower in the southern hemisphere summer than in winter. The greater variability of inorganic phosphate concentration in winter, especially around the Marquesas-Tuamotus area, than in summer is probably significant. It may indicate the role that these land masses play in bringing enriched water into the euphotic zone.

7. Water flow at the surface through the Marquesas was from the southeast during winter. There was a large clockwise eddy between the Marquesas and Tuamotus. The variability and significance of this feature are not fully known.

The August-September cruises also represented POFI's participation in Operation EQUAPAC, which was a quasi-synoptic oceanographic survey of the entire central and western equatorial Pacific. EQUAPAC was conducted by 11 oceanographic vessels, representing Japan, the United States and France, and included two POFI vessels.

At a conference in Kyoto, Japan, on March 5-6, 1957, POFI was designated Editorial Coordinator for preparing an atlas of data collected by the EQUAPAC cruises. The data from POFI's participation were published as Special Scientific Report--Fisheries 217, "Summary, oceanographic and fishery data, Marquesas Islands area, August-September 1956." A report containing the meteorological, oceanographic and biological data from another quasi-synoptic survey, Expedition EASTROPIC, was published as Special Scientific Report--Fisheries 201, "Preliminary report on Expedition EASTROPIC."

POFI's contribution to the International Geophysical Year (IGY) began on June 21-23, 1957 with the preliminary



TRACKS OF VESSELS WHICH PARTICIPATED IN OPERATION EQUAPAC, THE AUGUST-SEPTEMBER 1956, QUASI-SYNOPTIC, OCEANOGRAPHIC SURVEY OF THE EQUATORIAL PACIFIC

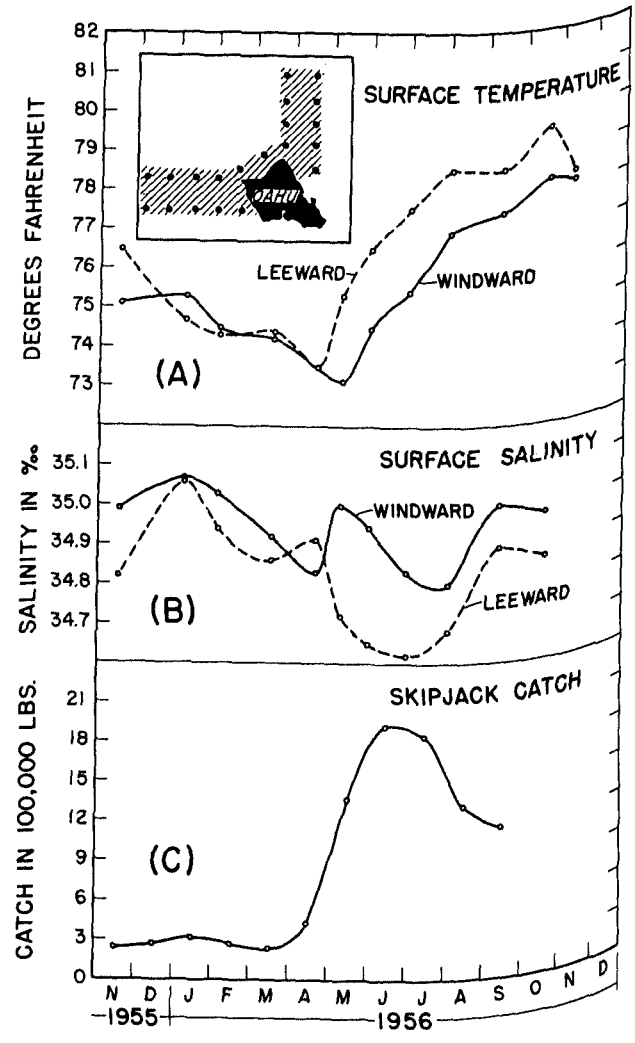
occupation of an oceanographic station offshore from Oahu. The plan is to occupy this station once each month during the 18-month period of the IGY. This station involves determining density conditions between the surface and 300 meters at the time of high and low tides on the day of each station. Biological observations include the rate of carbon fixation as determined with the C_{14} isotope, and the standing crop of zooplankton.

MID-OCEAN SKIPJACK PROGRAM

The fishery.--The commercial fishery had a slightly better than average year in terms of total pounds landed. Between January 1 and December 31, 1956, 11,132,222 pounds of skipjack were landed in the Territory of Hawaii. Since 1948 there have been only three years (1951, 1953 and 1954) in which more skipjack were caught. Estimated landings for January 1 to June 30, 1957 were considerably lower than those of last year or even 1952, the poorest of the past nine years. "Season" skipjack (18-22 pounds) did not appear in quantity in Hawaiian waters up to June 30, 1957.

Existing catch records show only the weight of skipjack landed, the area in which the catch was made and the value of the catch. To obtain more information concerning the skipjack fishery, log books were placed aboard five skipjack sampans. In these books the fishermen record all schools sighted, whether fished or not, and estimates of the fish and school size. From these records information may be gained on the proportion of schools fished and an estimate of the number of schools of small skipjack. Obtaining an estimate of the number of schools of small skipjack is important because the fishermen make considerable selection as to the size of skipjack caught. These books have been on the sampans six months and a preliminary examination shows that most of the desired information is being obtained.

Environmental studies.--The collection of environmental data in the area of the fishery adjacent to Oahu continued. During fiscal 1957 two comprehensive surveys and a number of monitoring surveys by POFI and the Territory of Hawaii Division of Fish and Game were completed. POFI has observations covering a 20-month period and can discern differences in the environment between two skipjack seasons. During the 1956 skipjack season (May-September) mean temperatures off windward Oahu were 1° - 2° F. colder than off leeward Oahu. Salinities were 0.11 °/oo - 0.28 °/oo higher in the leeward areas. During the off season temperature and salinity on the two sides of Oahu were similar. The time at which the divergences in temperature and salinity occurred was also the time at which the 1956 skipjack landings increased sharply. During the early 1957 season no such divergences.

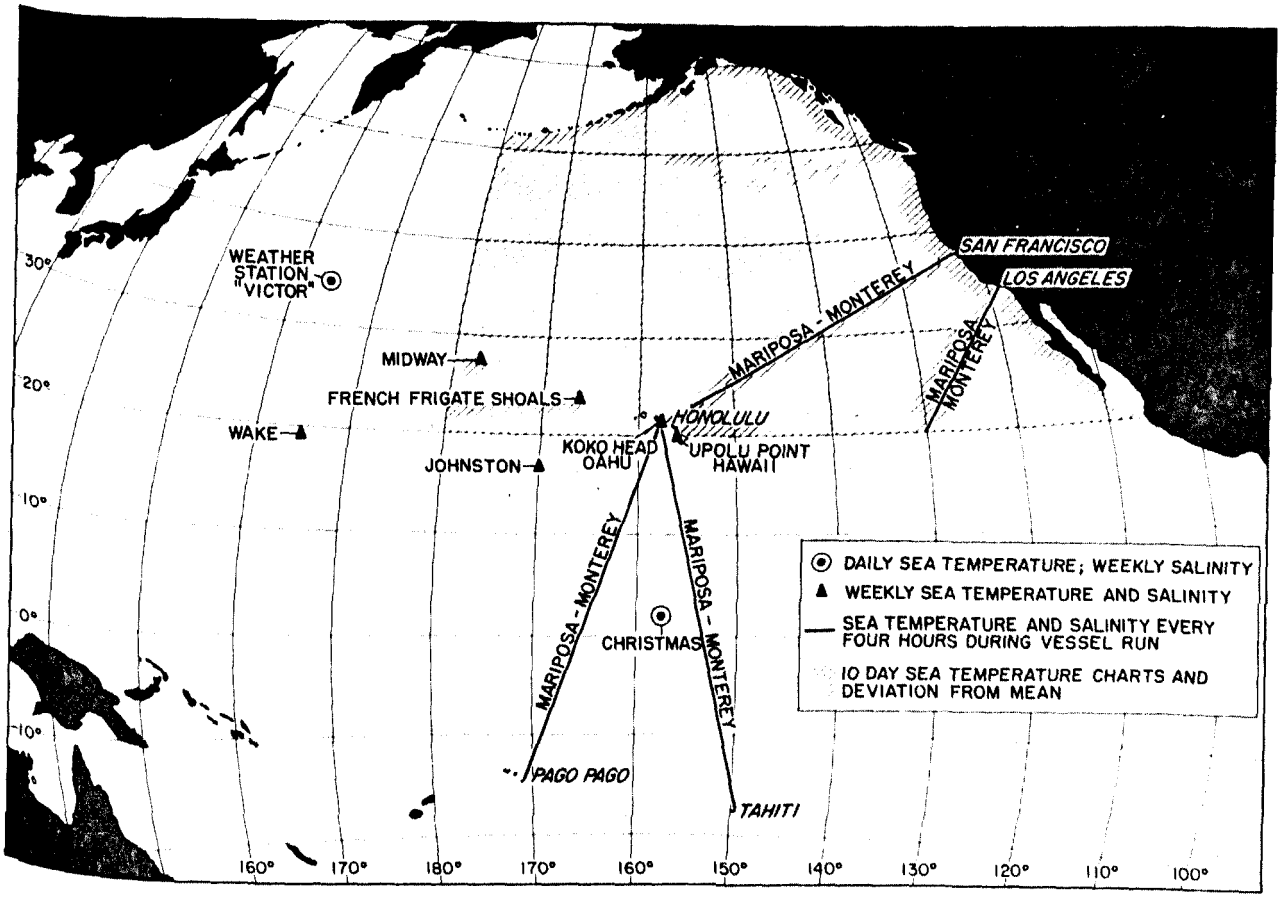


PANELS (A) AND (B) SHOW SOME OF THE RESULTS OF POFI'S ENVIRONMENTAL MONITORING SURVEYS IN WATERS ADJACENT TO THE ISLAND OF OAHU. THE STATION PATTERN IS SHOWN BY THE INSERT. THE SKIPJACK CATCH DATA (PANEL (C)) WERE FURNISHED BY THE TERRITORY OF HAWAII DIVISION OF FISH AND GAME

in temperature and salinity occurred and the skipjack landings were low, with small landings of "season" skipjack (18 - 22 pounds). There was, thus, a strong indication that the appearance of "season" skipjack in 1956 was casually associated with a change in the environment.

Cooperative temperature and salinity sampling program.--During February and March 1957 the collection of sea surface water temperatures and salinity samples was begun at the following locations by the agencies indicated: (1) Ocean Weather Station Victor at 34° N. latitude, 164° E. longitude (United States Weather Bureau); (2) Midway Island (United States Navy); (3) French Frigate Shoals (United States Coast Guard); (4) Upolu Point, Hawaii (United States Coast Guard); (5) Johnston Island (United States Air Force) and (6) Wake Island (United States Weather Bureau). Observations and collections made at these points should enable POFI to anticipate changes in the general circulatory pattern of the waters which bathe the Hawaiian Islands, and the results should eventually permit long-range prediction of mid-ocean skipjack.

In addition to the new sampling sites listed above, observations were continued near Koko Head, Oahu. Temperatures at this site were 0.5° - 2.0° F. colder in 1957 than in 1956 during February to June. In June 1957 water temperatures were higher than in June 1956. Salinities between February and June were from 0.0 °/oo - 0.5 °/oo higher in 1957 than in 1956. This increase is a further indication, in addition to the data from the monitoring surveys, that there was a distinct difference



LOCATION OF COOPERATIVE TEMPERATURE AND SALINITY SAMPLING STATIONS. ALSO SHOWN ARE THE TRACKS OF THE TWO COMMERCIAL VESSELS FROM WHICH SURFACE TEMPERATURES ARE RECORDED AND SALINITY SAMPLES TAKEN ONCE EACH FOUR HOURS

in environmental conditions between 1956 and 1957.

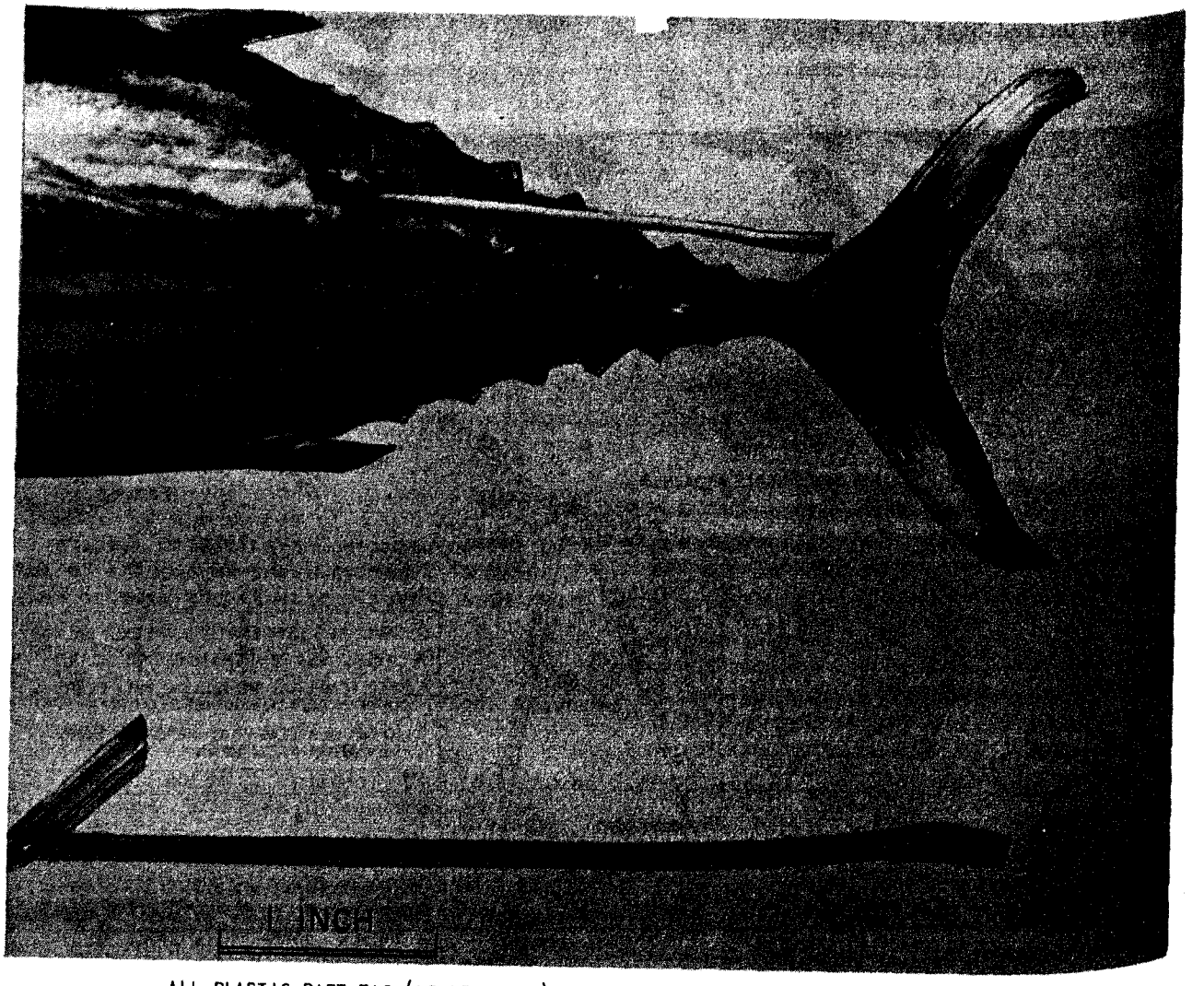
Tagging.--During June 1956 new all-plastic dart tags were placed on a small number of skipjack. In October one of these tags was recovered. The tag was modified and in April and May 1957, 1,978 skipjack were tagged with the D-2 dart tag and released in Hawaiian waters. As of June 30, 1957, nine of these tags had been recovered. This rate of recovery is slightly better than that observed in previous years when the spaghetti-type tag was used.

Previous taggings did not show the movement of the skipjack from one island to another. The skipjack which were tagged this year moved from Oahu to Kauai and from Molokai to Hawaii. Each year of tagging has added to POFI's knowledge of tag construction and growth and migrations of skipjack.

During the period of skipjack tagging, the stomachs of large tuna and marlin were examined at one Honolulu auction market to find out whether there was a loss of tagged fish because of predation. Seven skipjack were found in 176 stomachs and none were tagged fish. Of the seven three were about one pound and four were 3-5 pounds in weight. These results showed no evidence of predation on tagged skipjack.

ALBACORE INVESTIGATIONS

The third year of albacore investigations in the North Pacific under the Saltonstall-Kennedy Act (Public Law 466,



ALL-PLASTIC DART TAG (LOWER PANEL) USED BY POFI AND OF THE POSITION OF THE TAG WHEN INSERTED IN THE TUNA (UPPER PANEL)

83rd Congress) was completed. The keynote of these investigations has been coordinating efforts with those of other interested government agencies through the Albacore Steering Committee of the Pacific Marine Fisheries Commission. This committee has been particularly effective in facilitating the integration of field work and in making efficient use of available vessels and personnel.

Albacore distribution.--Studies were primarily oriented toward (1) mapping the early summer distribution of albacore; (2) further defining the concentrations of albacore lying in a band between Hawaii and the Aleutians during the summer and (3) surveying the fall distribution of albacore from approximately 145° W. eastward to the Pacific coast. Primary emphasis during the year was given to gill netting and surface trolling, both of which have been shown to effectively catch albacore.

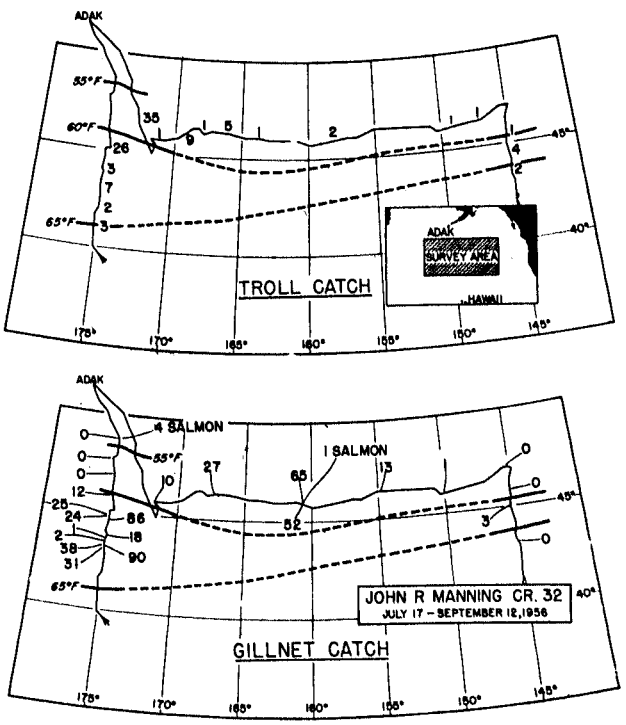
During the summer the John R. Manning took albacore in a narrow zone between 175° W. and 145° W. East of 145° W. the John N. Cobb conducted surveys from there to the coast, capturing widely scattered albacore As is well known, commercial fishermen following up these catches and in part guided by the successful fishing of the Manning off the coast during the summer of 1955, moved offshore and located albacore in commercial quantities. Thus, the first sizable albacore landings developed off the Oregon coast in several years.

The results of the survey of the Manning between Hawaii and Alaska are summarized in the figure below. The Manning took large numbers of albacore from the most western leg of her survey (175° W.) by gill net and trolling; the region of high abundance extended as far east as 160° W. longitude. From this point to 145° W. longitude abundance progressively decreased. During the first part of the survey along 175° W. albacore were most abundant between 41° N. and 46° N., with centers of abundance around 43° N. and 45° N. The second portion of the survey, the eastward trolling and gill net leg, yielded relatively abundant catches somewhat farther north.

The Manning caught 602 albacore, weighing approximately 4-1/2 tons. Of these, 451 were taken in gill nets, 104 on troll lines and 47 in trammel nets. The fish ranged inweight from 7 to 30 pounds. Particularly noteworthy was the large catch by gill net despite the fact that the 12 shackles were not all of suitable mesh size for optimum catch. High catches such as these, made on small amounts of gear, suggest that there are commercial possibilities in this area. These possibilities are enhanced by the proximity of Aleutian bases for logistic support and the fact that the area is readily available to halibut fishermen who have experience with fishing conditions in this general area.

Trolling, which was conducted from dawn to dusk each day, produced fewer albacore than gill netting. However, the catches in general verified the centers of abundance as revealed by the gill nets.

The success during this summer cruise was believed to have resulted at least in part from an exceedingly shallow thermocline in this region. During some days the layer of warm surface water in which the albacore live was so snallow that the ship's propeller brought up the deeper, colder water. Under such environmental conditions



SUMMARY ALBACORE SURVEY

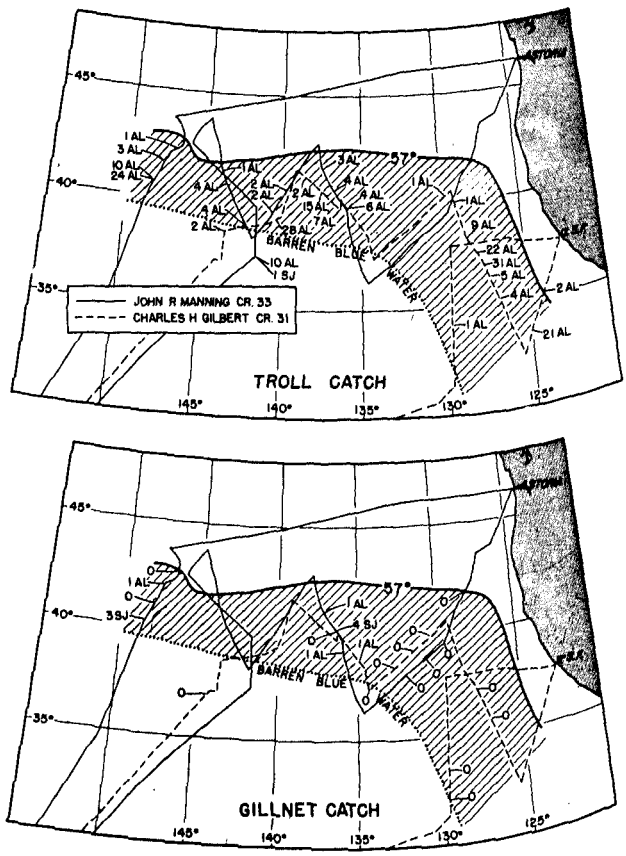
albacore were thought to be restricted to a thin surface layer of water and were particularly vulnerable to gill nets. Some of the evidence for this belief lies in the observation that following a storm, which deepened the thermocline, the gill net catches dropped off. Later, during the fall surveys, when the thermocline was about 200 feet below the surface, the gill net did not catch appreciable numbers of albacore.

The fall surveys by the Manning and Gilbert were designed to describe the distribution of albacore between Hawaii and the west coast at a time when the coastal fishery was diminishing. Trolling was conducted throughout both cruises. When the weather permitted, gill nets were set at night. If the weather were too adverse for gill netting, the vessels either jogged or reduced the speed at night to avoid large gaps in the trolling coverage.

Albacore were taken in significant numbers over a wide area extending from the western border of the survey to the coast a few miles north of San Francisco. The results are gratifying because the distribution of albacore can be rather logically associated with the distribution of environmental properties. All catches were made in an area with well-defined limits. To the north and east catches were confined by the 57° surface isotherm. The southern limit was the northern boundary of the barren, blue, central, northeastern Pacific water as indicated on the chart. This boundary could be readily determined from the bathythermograph sections and also from the clarity of the water.

In the barren central water the color was an intense blue and the Secchi disc could be seen to a depth of 18 fathoms. In the more productive transition zone where albacore were caught the transparency as measured by the Secchi disc was reduced to 10 or 12 fathoms and the color became blue-green. In the coastal water, which did not contain albacore, the Secchi disc could be seen only to depths of 7 to 9 fathoms and the color was green.

The fall distribution of albacore extending from the coast to well offshore in a fairly continuous band suggests that a migration away from the coast is taking place and that it is a gradual exodus rather than a rapid purposeful migration



FALL ALBACORE SURVEYS

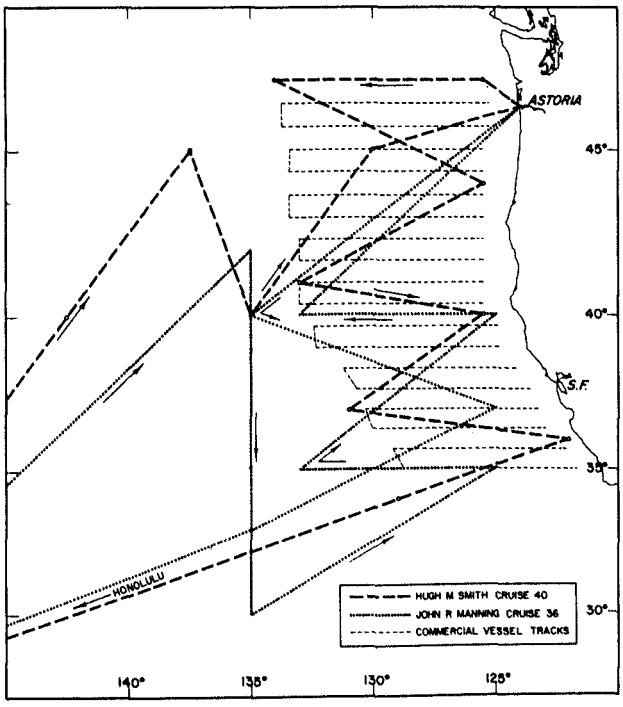
as may have occurred when the albacore were approaching the coast in the spring.

An analysis of data collected since the start of the program in 1954 enabled the postulation of a general hypothesis concerning the migration of albacore in the North Pacific. In the spring these fish perform a rapid and purposeful migration from mid-ocean to the coast of California. During the summer the migration continues with the route gradually shifting to the north. At the same time the albacore now in the coastal waters also tend to move northward following optimum temperature conditions. Toward late summer the migration toward the coast ceases and there is a gap in the oceanic distribution from about 140° W. to 160° W. longitude at about 45° N. latitude. This gap coincides in time with the formation of the well-developed thermocline in the central North Pacific and the associated high concentrations of surface albacore. In the eastern North

Pacific the albacore are scattered along the entire west coast of the United States. During the fall they undertake a gradual westerly movement away from the coast bridging the gap and ultimately appearing in the Japanese winter fishery. The tagging results partly confirmed this hypothesis.

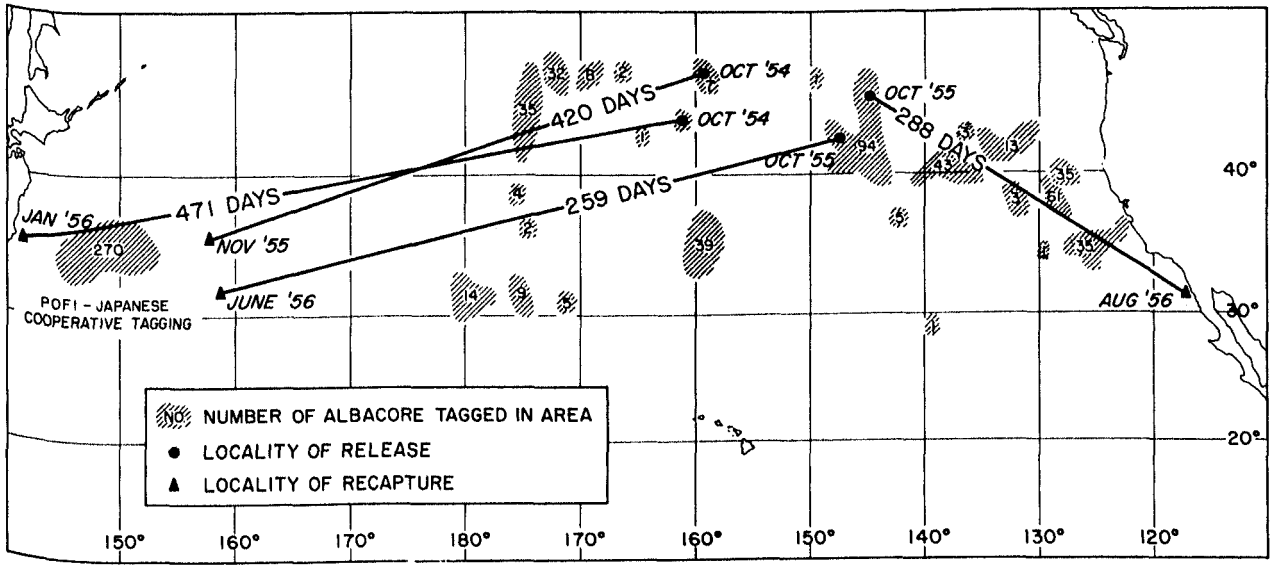
The future field studies will be largely in the areas which have shown commercial promise. Surveys will be continued to ascertain the migration routes into these areas and the oceanographic and biological parameters which govern these movements. Within the areas emphasis will be on the microdistribution and ecology of the albacore.

The Northeastern Pacific Albacore Survey (NEPAS), a concentrated survey of the waters off northern California, Oregon and Washington during the summer of 1957, marks the beginning of such studies. The Manning has begun a survey of the offshore waters and will be joined by the Smith on July 1, 1957. In addition, nine commercial vessels will be utilized in late July and early August 1957 to make a concentrated fishing survey of a band approximately 350 miles wide off the coast between Point Arguello, California, and Grays Harbor, Washington. During this phase of the survey the Smith and the Manning will patrol the area collecting detailed oceanographic and biological data in an attempt to determine the conditions which govern the occurrence and movement of the albacore.



NEPAS SURVEY

Tagging.--Four albacore tag recoveries were reported, the period of release ranging from 259 to 471 days. As shown in the figure below, all four fish were tagged in mid-ocean; three were recovered off the coast of Japan and one was recovered in California coastal waters. The recoveries



ALBACORE TAGGING

give considerable support to the contention that there is only one albacore population in the North Pacific. In particular, the two recoveries from fish tagged in 1955 should be noted. Although they were released within a few miles of each other, one fish was recaptured by a Japanese live-bait vessel about 1,000 miles off Japan on June 24, 1956 and the other one was recovered off Baja California, Mexico, on August 1, 1956. The two recoveries were made about five weeks apart; the distance between the points of recovery is about 4,350 miles. These returns may not seem to be strictly in accord with POFI's hypothesis of migration but their interpretation depends on an unknown factor--their movements in the interval between tagging and recovery.

In line with the policy of attempting to tag albacore over the entire North Pacific, POFI sent two biologists to Japan to conduct tagging and to instruct Japanese technicians in tagging methods. The Japanese showed great interest in this work and with their help POFI tagged 270 albacore in the area indicated in the lower figure on page 129. As a result of this motivation, the Japanese initiated a tagging program in their 1957 albacore live-bait fishery with a goal of 1,500 releases. POFI has no data on the success of this program.

Spawning and maturity.--An examination of all ovary samples collected in the North and Equatorial Pacific was completed. There was no evidence of albacore spawning in the temperate waters in which the Japanese coastal and American coastal fisheries are conducted or in the temperate waters north of Hawaii. In these three areas all of the fish taken were either sexually immature or, in the case of the larger winter-caught fish, without evidence of ovary development.

Good evidence was found of albacore spawning in the subtropical Hawaiian waters and those to the south of the Equator. In these areas the small, immature albacore so typical of the temperate waters were not found.

A hypothesis was made from the above that albacore spawn in subtropical or tropical waters. During their second year of life they migrate to feeding grounds in temperate waters where they remain for two or more years. Following this they return to the tropics to spawn. Thus, an adequate understanding of the albacore fisheries may involve studies of the albacore population and its environment which encompasses the waters of the Pacific Ocean extending from 50° N. to well south of the Equator.

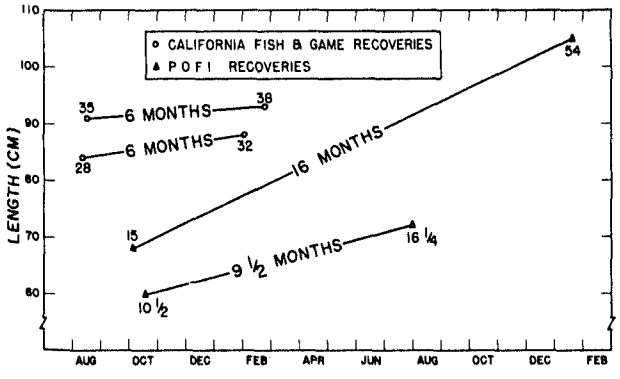
An analysis of the landing records from the tuna cannery in American Samoa of the Van Camp Sea Food Company, Inc. shows that considerable albacore were landed each month from the area, ranging from the Equator south to 28° S. latitude between longitude 160° W. and 180°. These landings offer an opportunity to determine whether and at what season albacore spawn in this area. Arrangements are being made to get a sampling program under way in Samoa.

Age and growth.--Albacore growth studies based on hard parts forced POFI to conclude that the age of albacore cannot be told from their scales or bones for the following reasons: (1) The rings found on the scales and bones cannot be counted with reasonable consistency; (2) the increments that are noted do not appear to give either a reasonable or a consistent pattern of growth and (3) the results are not consistent with growth as evidenced by tag returns.

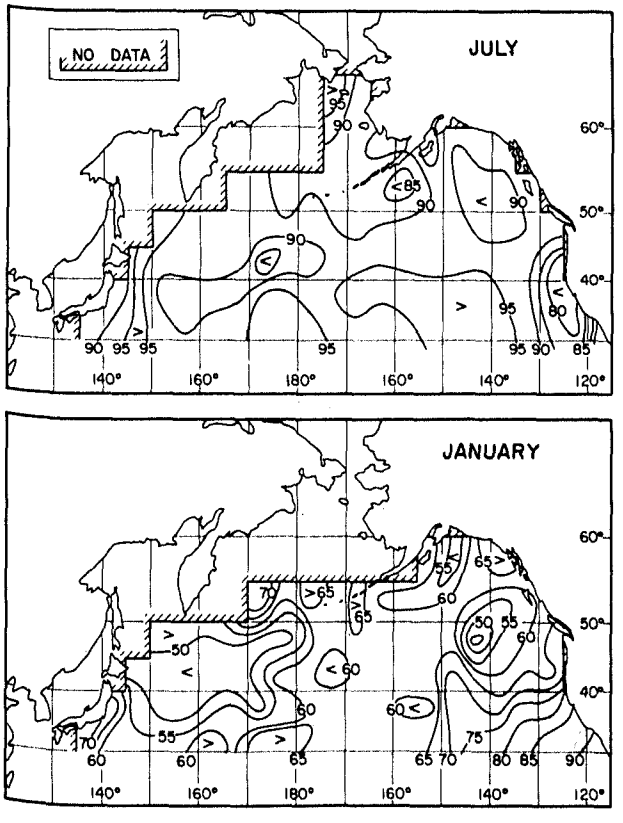
The best estimate of albacore growth stems from the tag recoveries. Even this evidence is not as good as POFI would like for there have been few recoveries and there is always the problem of obtaining reliable measurements at the time of tagging and recovery. The best results that POFI has (upper figure on page 131) suggest a moderately rapid growth rate. The annual rate of increment for the several fish ranges from 6 to 27 pounds with the average closer to the lower value. Checking this material against hard parts shed no light on the interpretation of the rings on the vertebrae and scales.

Perhaps telling the age of albacore from the hard part should not be expected. They are not subject to the same extremes of summer and winter conditions as are most fish of the north temperate zone for they migrate to areas where food is available and water temperatures suitable for growth. Thus, as they seem to spend their life under fairly uniform conditions, "winter" rings would not necessarily develop on their scales and vertebrae.

North Pacific weather and climate.--



ALBACORE GROWTH



FREQUENCY OF FISHING WEATHER

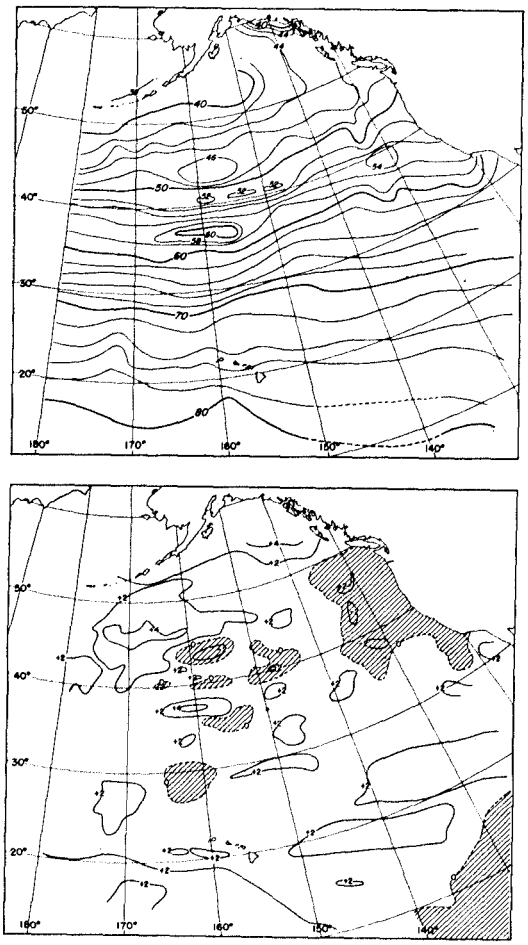
Two studies of North Pacific weather and climate were conducted as a part of the albacore program. They should be of general interest to fishermen and research workers in the North Pacific. The operational analysis of the winds was completed and a pilot study made to determine the feasibility of preparing synoptic charts of the sea surface temperature from the data contained in the ships' weather reports.

The wind analysis was prepared, with the operational requirements of a small research ship or fishing vessel in mind, from unpublished data from the United States Weather Bureau. The aim was to show the expectation of suitable fishing weather in the North Pacific in all areas and months of the year. Sample contour charts for January and July showing the percentage of wind observations of 20 knots or less are illustrated in the lower figure.

As an example of their use, it may be determined from the July chart that in the area from 145° W. to 175° W. longitude between 43° N. and 49° N. latitude, suitable fishing weather is present during 90 percent of the month, i.e., nine out of ten days. The Manning made excellent gill net catches in this area during July and August 1956. Her records showed that 109 out of 121 or 90 percent of the 6-hourly wind observations made on board were 20 knots or less and also that 23 out of 26 or 89 percent of the nights were suitable for gill netting, thus illustrating the reliability of the charts.

The quasi-synoptic charts of sea surface temperature are the result of an attempt to utilize synoptic weather data for mapping the seasonal and annual changes in oceanographic conditions. Surface temperature was selected rather than other parameters, such as wind and pressure, since it appeared to give a more direct measure of the net effect of climate and weather on the ocean. The intensified program of the United States Weather Bureau during recent years to increase the quality and

number of ships' reports made possible preparing accurate and detailed charts, such as the sample chart (below) for the Northeastern Pacific April 11-20, 1957 period. This chart is based on 1,883 individual observations and shows up both ocean-wide and local deviations from normal in detail. The chart is confined to the Northeastern Pacific since the Japanese are issuing similar charts for the Northwestern Pacific.



QUASI-SYNOPTIC CHART OF NORTHEASTERN PACIFIC SURFACE TEMPERATURE IN F. AND DEVIATIONS FROM NORMAL IN F. FOR THE APRIL 11-20, 1957 PERIOD

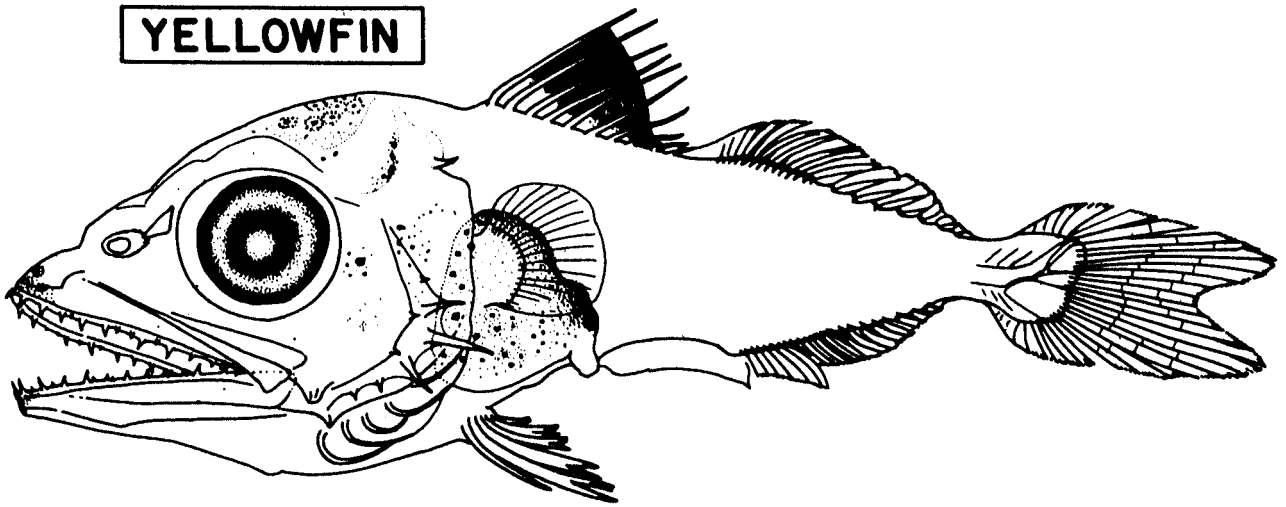
SPECIAL STUDIES

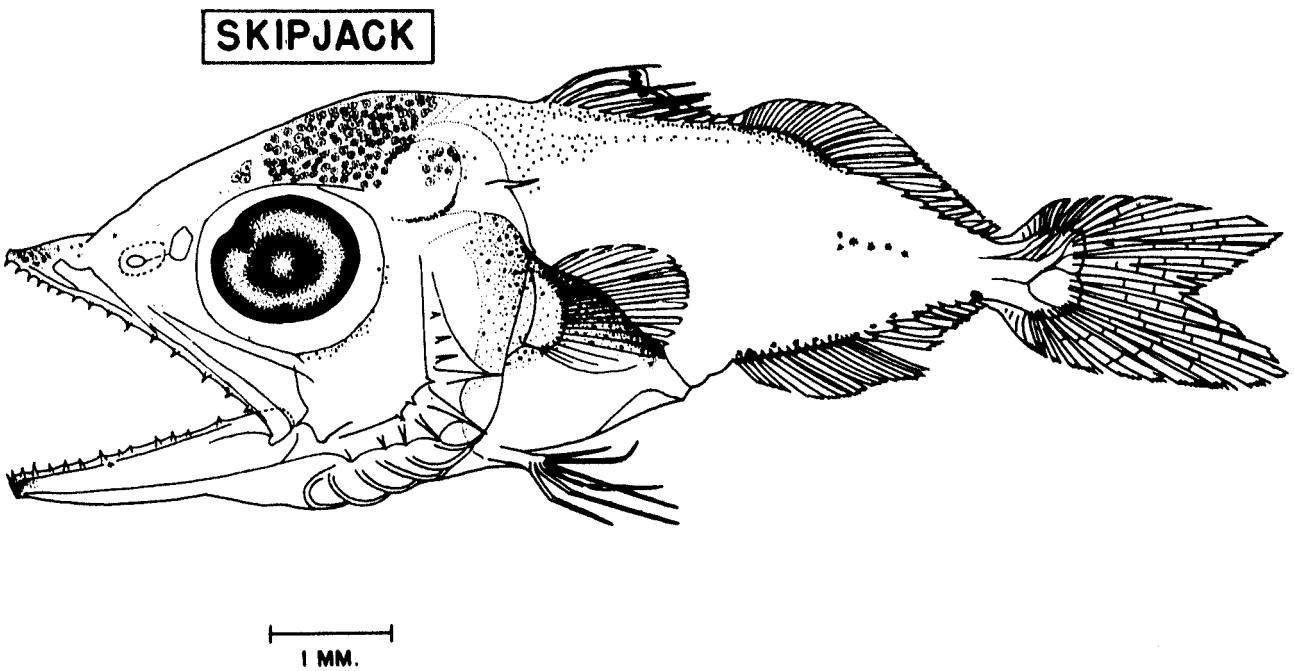
Larval tuna.--Drawings of larval Auxis and Euthynnus and a rough draft of the species descriptions were completed. All specimens were sorted by area of capture and work was started on a world-wide distributional study. In general terms, the larvae of Euthynnus lineatus are distinctive from those of E. yaito and E. alletteratus, but the last named two are not easily separable from each other. So far as is known, there are at least two species of Auxis, only one of which occurs in the Atlantic, but both species occur together in various parts of the Pacific. Two types of Auxis larvae were found in all oceans but these become indistinguishable at a certain size. In addition, larval Scomber japonicus were identified, reducing the number of unknowns by one.

An effort was made to develop more efficient means of sampling larvae in the field. The following special larval tuna tows were made: 14 surface tows between Hawaii and the Aleutians; 71 single, double and quadruple night surface and 19 day surface tows in the Marquesas; 22 surface tows between Hawaii and the West Coast; 88 paired surface and other tows in the southeast Pacific; and 12 surface tows bracketing sunset at the Hawaiian IGY station. All of these except the sunset series have been sorted, along with numerous samples from other times and places.

Tuna forage organisms.--The 53 midwater trawl collections obtained on the EASTROPIC expedition and about half of the collections made on EQUAPAC were analyzed in the laboratory. An initial examination of the EASTROPIC data showed a peaking in volume of forage organisms in the region of convergence and the southern boundary of the Countercurrent, between 3° N. and 6° N. latitude and about 300 miles north of the peak in zooplankton abundance. Longitudinally the largest catches occurred in the central region between 125° W. and 145° W. These results, after further study and analysis, should increase understanding of both the time and space aspects of trophic succession from basic productivity to the tunas.

Food of skipjack.--A first draft of a report on the food of skipjack was completed. This study produced the following interesting results:





1. By volume 703 skipjack ate 73 percent fish, 22 percent mollusks and 4 percent crustaceans. Mollusks, particularly squid, were much less important in the food of skipjack than in the food of yellowfins and bigeyes. In all three species of tuna fish formed 60 to 75 percent by volume.

2. In respect to composition of the

food, the main fish families represented in the food of skipjack were Thunnidae, Carangidae, Molidae and Gempylidae; of yellowfin: Bramidae, Gempylidae, Thunnidae and Sudidae; and of bigeye: Gempylidae, Bramidae and Sudidae, in order of importance. Larval or juvenile skipjack composed 8 percent of the food of skipjack. Juvenile tunas also were prominent in the food of yellowfins but scarce in that of bigeyes.

3. The average volume per stomach increased from 15.5 cc. for skipjack of less than 60 cm. to 27.4 cc. for skipjack over 60 cm. With an increase in size, the feeding shifted from crab larvae to the more pelagic amphipods and euphausiids and from chaetodonts, acanthurids and synodonts to Decapterus, molids and gempylids, the gempylids being the most oceanic in distribution.

4. There was no definite trend in respect to distance from land when captured from land and average volume per stomach, but there was a shift in composition with littoral forms being replaced by more pelagic forms in an offshore direction.

5. Differences associated with the method of fishing were apparently most closely related to the distance from land of the place of capture and the depth of fishing. For example, the frequency of occurrence of fish dropped from 89 percent for surface-caught skipjack to 33 percent for subsurface (longline) caught skipjack. Mollusks (mostly squid) increased from 9 percent for the surface to 59 percent for subsurface-caught fish and Crustacea were less plentiful at the subsurface level. The average volumes by method of fishing were purse seine - 35.2 cc., pole and line - 23.9 cc., longline - 15.6 cc. and surface trolling - 9.9 cc.

6. Judging by the volume of food remains, fishery scientists found that the highest rate of feeding in skipjack took place just before noon and again in the late afternoon. The lowest rate was during early morning and early afternoon. The highest percentage of squid was found in the early morning and late afternoon hours. These data upon further analysis may contribute information on feeding depth and vertical migration.

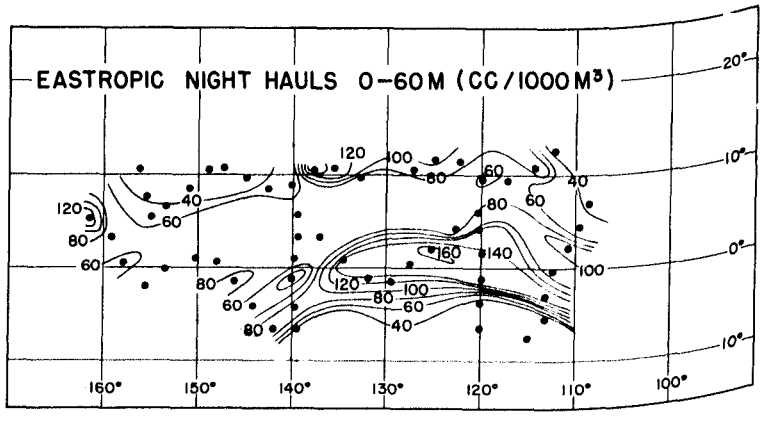
Vertical and horizontal distribution of zooplankton.--Laboratory measurements on approximately 450 zooplankton samples collected on the EASTROPIC expedition were completed and the data published. Although the results have not been thoroughly studied the following points were evident:

1. The day-night variation was only important in hauls that sampled near the surface, and the great bulk of the plankton occurred in the upper 60 meters.

2. The effects of enrichment from such features as the equatorial upwelling and the shallow thermocline along the northern boundary of the Countercurrent were more pronounced in shallow hauls than in deep hauls, and in night hauls than in day hauls.

3. Within the divergent and convergent zones (1-1/2° S. to 5° N. latitude) the abundance of zooplankton decreased from east to west, varying directly with the drop in winds and the degree of upwelling, but inversely with thermocline depth (see figure below).

4. Within the South Equatorial Current between 1-1/2° S. and 8° S., there was an increase in abundance from east to west, thus discounting the importance of the Peru Current as a factor contributing to the enrichment of these latitudes in the central Pacific.



ZOOPLANKTON VOLUMES MEASURED BY THE HUGH M. SMITH DURING THE EASTROPIC EXPEDITION, OCTOBER-DECEMBER 1955

Tilapia culture.--In the spring of 1956, the Hawaiian Tuna Packers, Ltd. and POFI jointly seined supplies of small bait-size Tilapia and tested them at sea to determine their qualities as skipjack bait. Seven full day and 2 1/2-day seining expeditions yielded 630 pounds of small Tilapia. These were obtained principally from fresh-water ponds and, therefore, had to be acclimated to sea water before the sea tests.

The effective use of Tilapia as skip-bait was examined on 14-vessel days at sea in waters off Oahu. The prime objective of these tests was to compare the ability of nehu, the standard bait, and Tilapia in attracting and holding schools of skipjack at the stern of the vessel. A summary of the results shows that 21 (56 percent) of the 37 schools first chummed with nehu surfaced and responded to the bait and that 10 (56 percent) of the 18 schools first chummed with Tilapia gave a favorable response to the bait.

Skipjack were caught from nine schools at the rate of 3.5 fish per minute and 12.2 fish per bucket of Tilapia used. This is not as good as the catch rate of 4.8 skipjack per minute and 15.3 per bucket of bait obtained with nehu from 23 schools. There is, however, reason to believe that with experience chummers will learn to use Tilapia more effectively.

POFI reached the conclusion that Tilapia is an adequate bait for catching skipjack. In some respects it may be slightly inferior to nehu, but it has several compensating qualities. It is an exceedingly hardy fish and can survive in bait tanks for much longer periods than nehu. The larger Tilapia tend to sound when thrown out as chum, but this trait does not prevail in fish 1-1/2" to 2" in length, which is the optimum size for skipjack bait. POFI's studies indicate that if economically feasible rearing methods can be developed, Tilapia can alleviate the great need in the Hawaiian skipjack fishery for additional bait supplies.

TILAPIA REARING TANKS LOCATED ON THE GROUNDS OF OF THE POFI LABORATORY IN HONOLULU

POFI's experiences during the past summer showed that the culture of Tilapia in "natural" ponds or reservoirs is not an efficient method of rearing them. Such ponds do not provide enough natural food for the fish, extra feeding is necessary, cannibalism is a major problem and removing the fish is not easy. Sorting the bait-size fish from the large ones is also a problem.

In October 1956 POFI constructed three redwood tanks on the laboratory grounds to determine if a hatchery-type operation would be biologically and economically feasible in rearing Tilapia as bait. From December 20, 1956, when production of the young fish started, until June 30, 1957, 126 adult females produced about 77,000 fry. A fairly high mortality among the young fish resulted because of cannibalism and probably low oxygen concentrations; both of these factors will be reduced in importance by the improved and enlarged fry rearing facilities which are being constructed.

The practicality of rearing Tilapia as bait in available fish ponds and reservoirs received further study. In February and March 1957, 8,749 adult Tilapia in two ponds, one a natural brackish-water pond and the other an artificial, fresh-water reservoir, were marked by fin-clipping. Seining will be carried out at intervals during the summer of 1957 to determine the production of young and to obtain estimates of the total adult population in each pond.

In December 1956 POFI instigated the formation of a "Bait Fish Research Coordinating Committee". Membership on the Committee includes representatives from POFI, the fishing industry, the University of Hawaii, and the Territorial Division of Fish and Game. The purpose is to coordinate the activities of the various groups in the Territory that are working on different phases of the general bait fish problem and to keep members informed on what the other agencies are doing.

Oceanographic and biological observations.--At the request of the Chief of Naval Research, the Hugh M. Smith made a cruise to the Eniwetok area between November 17 and December 23, 1956 and carried out oceanographic and biological observations. The Scripps Institution of Oceanography, Office of Naval Research and POFI collaborated in executing the cruise. The major accomplishments include 26 hydrographic stations, 29 bottom cores, 11 underwater camera stations, 2 current stations, 13 zooplankton hauls, 38 phytoplankton samples, 41 carbon-14 determinations, 4 midwater trawl hauls, 4 night light collections, 169 BT lowerings, 55 samples (which were frozen for phosphate determinations) and continuous fathometer and thermograph records.

All biological properties measured indicated a low level of productivity for the region. A report was prepared on the biological results of the Eniwetok cruise and submitted to the Office of Naval Research.

Sea birds.--A chart showing the distribution of the sea birds in the North Pacific was prepared for NORPAC records for possible use in the NORPAC Atlas.

Sea Scanar.--In July-September 1956 the Sea Scanar was put through series of experiments and sea trials. Under ideal sea conditions good returns were received from manufactured triplane targets at a maximum distance of 2,180 ft., a dead skipjack at 1,070 ft. and a dead herring at 470 ft. Records of aggregations of skipjack, dolphin (Coryphaena), porpoise and blackfish were obtained. Returns from an albacore school were recorded in the October-December period. The failure of the instrument prevented its further use.

Hawaiian longline fishery.--Bigeye and yellowfin data from the Hawaiian longline fishery for 1948-1956 were analyzed and a draft of the manuscript was completed. The results show that the increase in bigeye landings and the decline in yellowfin landings during this period were associated with the differential availability of these two species in the windward and lee areas and also with a shift in the fishing area by the larger vessels from the lee of the northern islands to the windward waters of the southern islands.

Bigeyes were more available in the windward areas than in the lee, while the reverse was true with the yellowfins which were more available in the lee areas.

The larger vessels showed an annual increase of effort expended in the windward areas of the southern islands from 22 percent of the total trips made during 1948-1949 to 88 percent during 1953-1954.

Introduction of Marquesan sardine.--Approximately 175 pounds of the Marquesan sardine, Harengula vittata, were released in two lots near shore on Oahu. The first lot containing 2,500 individuals was released in Hanauma Bay, Oahu, on September 26, 1956, and the second of about 12,000 individuals in Pokai Bay, Oahu, on March 22, 1957. Eight sardines were recovered by tuna-bait fishermen; the last sardine was recaptured on June 4, 1957. There is no evidence that the species has been established in Hawaiian waters.

CONTRACT RESEARCH
(University of Hawaii)

Tuna vision.--A report on the histology of the retina of small and large skipjack has been received. The retina in both instances appears to differ little from a general vertebrate eye.

Green tuna.--This work is in its closing phases, and a final report for publication has been drafted. There appears to be a well-established relation between "greening" and the presence of fat peroxide. There is some evidence that a green pigment may actually exist in "green" tuna.

Electrofishing.--Some experiments looking toward controlling the field and pulsing with an amplidyne were completed.

MENHADEN INVESTIGATIONS

Fred C. June
Beaufort, North Carolina

The menhaden fishery of the Atlantic and the Gulf coasts is the largest in the western hemisphere in terms of tonnages landed. The seasonal and the annual fluctuations in its yield considerably affect the economy of the Atlantic and the Gulf States. Knowledge of the causes and the magnitude of such fluctuations will greatly assist the menhaden industry in developing and planning its fishing operations. Accordingly, a program of biological research of the Atlantic menhaden resource was undertaken in 1955 to determine the causes of fluctuations in the catch and the extent to which these may be predicted.

Populations.--Detailed examination of many thousands of juveniles and adults, collected over the presently known range of the fish, indicated that two species of menhaden occur along the Atlantic coast of North America, the Atlantic menhaden, Brevoortia tyrannus, and the yellowfin menhaden, Brevoortia smithi. The Atlantic menhaden comprises the vast bulk of the landings of the commercial purse seine fishery and only isolated individuals of yellowfin menhaden occur in the catches south of Cape Hatteras. The yellowfin menhaden rarely, if ever, occurs in the middle Atlantic states and northward. It reportedly was common in the catches around Beaufort, North Carolina, three or four decades ago, but has not occurred in the landings in this area in recent years.

Atlantic menhaden presently are known to occur from Casco Bay, Maine, to Indian River, Florida. Yellowfin menhaden now range from Sapelo Marsh, Georgia, to Indian River, Florida. In the latter area yellowfin menhaden support a commercial bait fishery which operates throughout the year.

As both species occur together in Florida waters during the spawning season, the possibility of hybridization cannot be overlooked; in fact, a number of juneniles resembling both forms were taken from several locations. Because of its restricted range and infrequent occurrence in the purse seine fishery the yellowfin menhaden is now of minor importance to the Menhaden Investigations.

Knowing whether each species is further subdivided into independent or semi-independent populations is necessary. A single population of menhaden freely intermingling, spawning and migrating along the coast would mean that fluctuations would be widespread. If there is a number of semi-independent populations, fluctuations would tend to be localized, and differences in spawning time, feeding grounds and nursery areas would likely result in differences in rates of growth, recruitment and mortality. A great deal, thus, depends on the existence or the non-existence of distinct or semi-distinct populations.

There are two lines of approach to the solution of this problem: the indirect method of counts of various body parts or meristic characters and the direct approach by means of tagging. The problem so far has been attacked from the point of meristics.

During the past two years samples of juvenile fish have been routinely collected from 36 estuarine nursery areas along the Atlantic coast from Gloucester Harbor, Massachusetts, to Indian River, Florida. Meristic data on 1-year old fish also have been collected.

Comparisons of the average numbers of vertebrae, fin rays and ventral scutes of juveniles revealed rather large differences between the juveniles in the estuarine nursery grounds north of Long Island and those in the nursery grounds south of Long Island. Since the juveniles from the northern nursery areas are considerably smaller than those from the nursery areas south of Long Island, they could not have originated from the same spawning.

These findings indicate that the adult

fish segregate into at least two major groups for spawning, and the differences exhibited in the body structure of juveniles are induced either by inherited tendencies which are preserved or differences in environmental conditions at the time of spawning or by both.

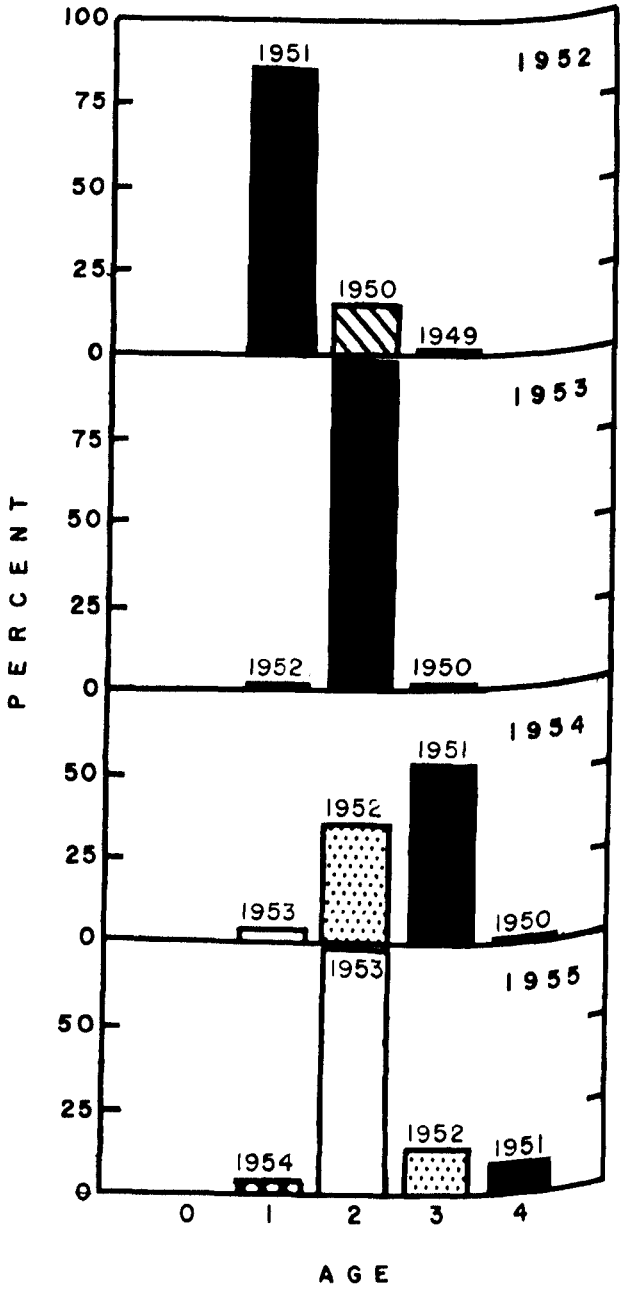
Studies of the distribution of spawning in space and time, based on the degree of sexual maturity of the gonads of the fish, increase the knowledge bearing on the identification of population structure. Differences in temperature and other factors during spawning may give rise to identifiable differences in morphological and physiological characters. Hence, knowledge of the time and the place of spawning and the nature of related environmental factors will aid in interpreting the results obtained from these meristic studies. The results of spawning studies are discussed in a later section of this report.

Persistent differences in the size of menhaden of the same age also are evident. One, 2- and 3-year-old fish are considerably larger, on the average, in the northern limit of the range of a year class, intermediate in size in the central part of the range and smallest farther toward the south. Studies of the growth pattern in scales also show differences among fish of the same age inhabiting different localities. Thus, there is evidence that the fish are not randomly mixed throughout their life span.

Counts of meristic characters of spawning adults also are being made to determine the extent to which they resemble juveniles from adjacent nursery areas. This work continues and within the next year or two reliable estimates may be made of the degree to which fish in various places along the coast intermingle.

Age and size composition.--Knowledge of the age of menhaden is essential for determining growth, recruitment and mortality rates, which are requisite in solving the problem of fluctuations. A large part of the efforts of the Menhaden Investigations during the past two years was devoted to establishing the validity of the marks on the scales as age indicators.

The examination of the scales of many thousands of fish of various sizes showed that clearly defined marks or "rings" occurred on these structures with certain regularity. By following the pattern of scale growth each month that fish of the 1951 year class were available over the past five years researchers established

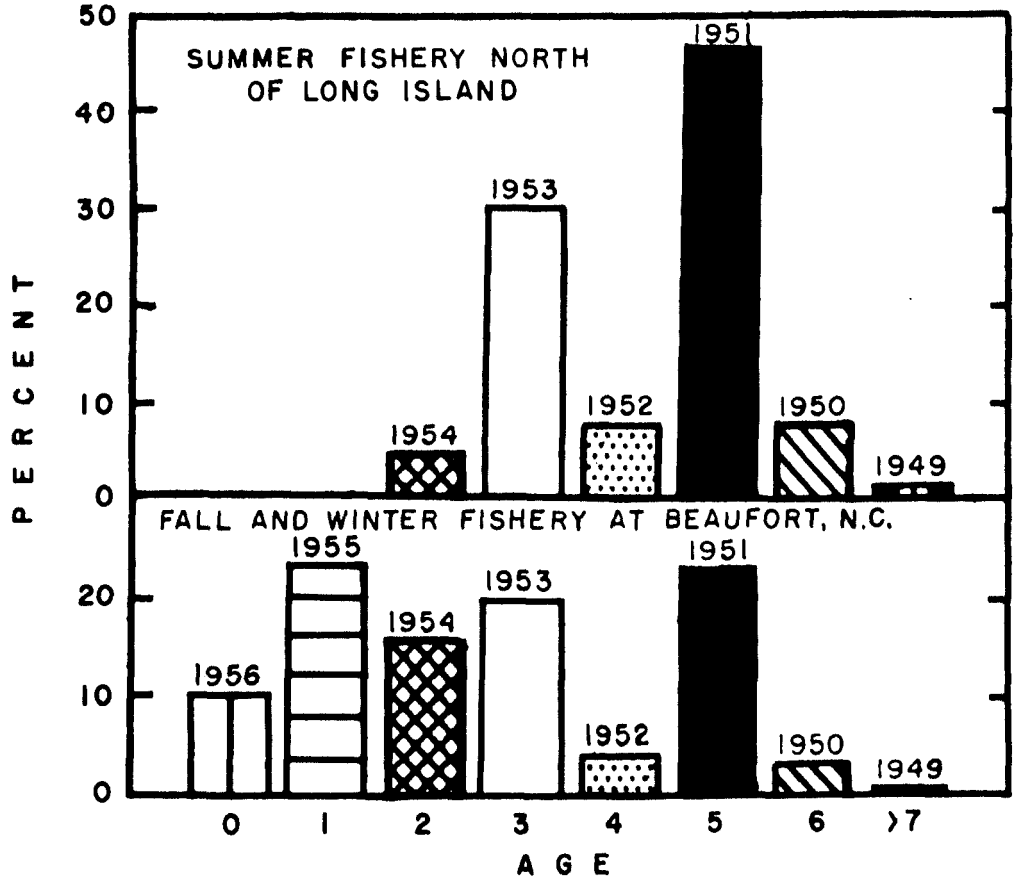


AGE COMPOSITION OF THE MIDDLE ATLANTIC MENHADEN PURSE SEINE FISHERY, 1952-1955

that one "ring", or annulus, is laid down on the scale for each year of life. Similar findings for subsequent year classes further confirmed the interpretation of scale "rings" as being reliable annular marks. The new annulus appears on the scales in the spring.

To discover whether fluctuations in the fishery result from variations in the year class strength, the age or size composition of the menhaden population from year to year must be known in order to connect fluctuations in the catch with changes in the structure of the population. Age composition is being determined routinely from representative samples of the commercial catch. Samples are taken daily throughout the season that vessels are fishing at 10 locations between Portland, Maine, and Fernandina, Florida. The number of daily samples is roughly proportional to the catch in each locality.

Results of this work show conclusively that an unusually abundant or "dominant" year class hashad a terrific impact on the fishery in recent years. The figure on page 138 shows the age composition of the catch in the middle Atlantic area from 1952 through 1955, the only area where ages are available for several years. The progression through the fishery of the dominant 1951 year class is obvious. Its contribution was clearly reflected in the commercial catch in 1953 when production in this area reached an all-time high of over 378,000 tons. The continued effect of this year class on the fishery in 1956 is shown in the figure below where the age composition of the summer fishery north of Long Island and the late fall and winter fishery off the North Carolina coast (the two areas where the 1951 fish were present in the fishery) are presented. Record catches were made in both areas in that year. The contribution of this year class to the 1956 catches can be fully appreciated when it is realized that individual fish in this age

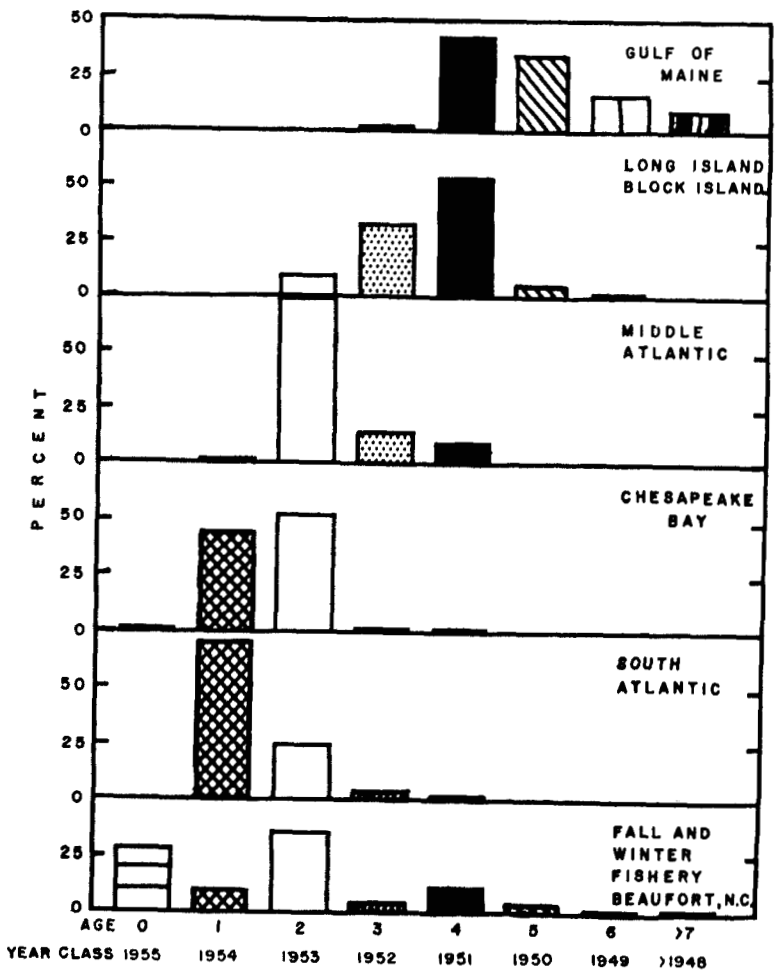


AGE COMPOSITION OF THE MENHADEN PURSE SEINE FISHERY, 1956:
UPPER PANEL - SUMMER FISHERY NORTH OF LONG ISLAND;
LOWER PANEL - FALL AND WINTER FISHERY OFF NORTH CAROLINA

group averaged about 1-1/3 pounds. In other words, the contribution of this year class to the northern fishery comprised over 50 percent of the total catch by weight while in the North Carolina fishery it comprised nearly 40 percent.

The continued study of the annual variations in abundance of age groups for several years may make possible forecasting a year ahead the scarcity or the abundance of the fishery. Such information would be of great value to the industry in indicating the extent of preparation needed for the forthcoming season.

Movements and migrations.--One of the most outstanding characteristics of menhaden is their tendency to congregate in dense schools at the surface at certain times. A second characteristic is the tendency of fish of similar size to school together. Finally, so far as is known, menhaden are generally restricted to the littoral, or coastal, waters inside the 20-fathom contour during the warmer months of the year. Detailed knowledge of these basic features is essential for understanding the seasonal and the annual changes within the populations and their effect on the fishery. Data for following such changes are being obtained routinely from representative sampling of the catch in each locality where the purse seine and pound net fisheries are being pursued.



AGE COMPOSITION OF THE ATLANTIC MENHADEN PURSE SEINE FISHERY, BY LOCALITY, 1955

Results of this work showed a rather consistent pattern in the distribution of the fish. The age composition of the catch in 1955 for each locality along the coast is given in the figure below. The summer fishery in the Gulf of Maine was supported exclusively by fish four years of age and older while the south Atlantic fishery was based on fish in the first four age groups, with the 1-year-olds predominating. Proceeding northward from Cape Hatteras, the researchers found that progressively older age groups were represented in the various localities. Sampling data further indicated that 1-year-old fish usually school separately and that the largest individuals may join schools of 2-year-olds and smaller 3-year-olds. The size and the age distributions of fish in a given locality also indicate a tendency for similar size and age groups to occur together, which are distinct from those of an adjacent but overlapping locality.

Data available over the past five years indicated that in the spring the fish usually first appear in the pound net fisheries in Chesapeake Bay and northern New Jersey in March or April. In April or May they become available to the purse seine fishery south of Cape Hatteras and to the purse seine fishery north of Cape Hatteras in late May or early June. Detailed data further showed that various size and age groups gradually moved northward during the summer, and the fish which contributed to the late summer fishery in a given locality were generally smaller and younger than those which supported the early summer catches. This is clearly evident in the summer fishery at Beaufort,

North Carolina. The 2-, 3- and 4-year-old fish contribute substantially to the catches in May; however, by the end of the summer the smaller 1-year-old predominate.

A southward migration of spawning fish from northern waters and sexually immature fish from Chesapeake Bay and the middle Atlantic areas takes place in early autumn when they disappear from the fisheries north of Cape Hatteras. They later reappear off the North Carolina coast where they support a sizable fishery in late fall and early winter. The juveniles which emigrate from the estuarine nursery area at that time also migrate southward for they appear for the first time in large numbers. in the North Carolina winter fishery.

Slight variations in this generalized pattern of distribution and movements occur from year to year. During the winters of 1952-1953 and 1953-1954, for example, 1-, 2- and 3-year-old sexually immature fish and older sexually mature fish in non-spawning condition apparently did not all move southward for great numbers were taken in the pound net and the gill net fisheries off the Maryland and New Jersey coasts. The range of distribution of 1-year-old fish in the fishery also varies slightly from one year to the next. This age group may occur in the northern New Jersey fishery in some years while in others it appears no farther northward than Virginia.

The foregoing findings show that adequate knowledge of the intra- and interseasonal movements of the fish is one of the more important aspects of the problem of fluctuations. Information bearing on this problem is being gathered routinely from many sources, including logbook records kept aboard menhaden purse seine vessels, records of airplane spotting pilots, interviews with fishermen and samples of catches of various types of fishing gear, such as fyke, pound and gill nets. A great deal remains to be learned and sufficient data are being gathered to provide rather detailed knowledge of these features of the fishery.

Spawning and early life history.--An examination of the gonads of fish sampled from the purse seine and pound-net fisheries throughout most of the year furnished information on sex ration, age and size at sexual maturity, time and place of occurrence of spawning and reproductive capacity of different age groups. A method, based on measurements of ova diameters and ovary weight, was devised for objectively determining the stages of ovarian development.

The results of these studies indicated that the sexes are about equally distributed in all age groups throughout the range of the fishery. Some individuals are capable of spawning at two years of age; however, the bulk of the population reaches sexual maturity in the third year of life. The number of eggs extruded by individual fish vary from, roughly, 40,000 to about 700,000, the number depending on the size of the fish.

The data collected over the past two years indicate that spawning takes place over a wide range throughout most of the year. In the northern area some spawning apparently occurs over the entire period during which fish are present in the fishery; however, it appears heaviest in spring and again in early fall. In the southern area spawning is apparent only in the late fall and early winter when spawning fish from farther northward have moved into the area. These findings indicate that spawning largely occurs from September through May. Commencing in northern waters at the time that a southward movement of the fish takes place in the fall, spawning reaches a peak in southern waters in winter and continues through late spring when the fish reappear in northern waters.

Plankton sampling conducted over the past four years indicates that the hatching of eggs and the early larval development take place entirely in the ocean. Following absorption of the yolk sac, the larvae enter estuaries and bays and spend the following several months in these nursery areas. Routine collections are being made at several localities along the coast to obtain estimates of relative numbers of larvae entering the nursery areas and the period of entry. Size distributions of larvae entering the nursery grounds during the period January to April 1956 at Beaufort, North Carolina, show considerable variation, particularly those entering in January and February. This may result from differential spawning in the area. However, during the peak of larval recruitment in March and April a much more uniform size group is evident.

Studies of the early life of the fish, following their entry into the estuarine nursery areas, are being carried out at the field laboratory on the Indian River, Delaware. The work is designed to determine the growth rate of juveniles within and between the estuaries, the amount of mixing of juveniles within an estuary, the feeding habits and food preferences, the responses of estuarine populations to changes in physical and biological factors in the environment and the natural mortality rate.

Results show that, following their entry into the estuary, the larvae first appear in the upper limits of the intertidal zone where they congregate in groups of many thousands of individuals. Here they soon undergo metamorphosis into juveniles. During this transformation the body deepens, scales are laid down, all of the fins become developed and the fish assumes the color of the adults. This transformation commences at a body length of about 33 mm. (1-1/4 in.) and is completed at about 43 mm. (1-3/4 in.). As the fish increase in size, the schools gradually spread out from the initial intertidal areas and move downstream. Menhaden have been observed schooling at the smallest sizes encountered in the intertidal areas.

After spending the summer in the estuaries, the schools congregate in larger bodies in the fall and move out into the ocean. The time of their departure follows roughly the pattern of disappearance of the adults from the fishing grounds in the ocean. This emigration generally commences in early September in the northern estuaries and in late September and October in the middle Atlantic region while in the southern estuaries they may remain throughout the winter and spring. At the time of their departure from the estuaries the juveniles may range in size from about 50 to 160 mm. (2 to 6-1/2 in.) in length, depending on the locality.

Two important problems concerned with the estuarine work deal with the estimates of the relative size of a year class while it is in the estuary and the mortality sustained during its stay there. In attacking these problems techniques have been developed at the Indian River station which will be extended to other areas along the coast.

A method which gave initial success consists essentially of marking large numbers of juveniles and estimating the size of the nursery population from the proportion that is recaptured. By this method an index may be established eventually for estimating the initial success of a year class. The reliability of this method is being tested by comparing this derived estimate with measures of abundance of the year class in the following summer when it enters the commercial fishery as 1-year-olds. The value of the first estimate is that it will provide a measure of the relative size of a year class before the class enters the purse seine fishery.

Marking individuals also has furnished an estimate of the mortality rate of juveniles in the estuary. It does not, however, cover mortality sustained during their entire estuarine life but only that over the last three or four months of their stay. Results of the first year's work suggest that mortality during this period is low. A technique of estimating the total estuarine mortality is being worked out. The method demands a tremendous amount of effort, is subject to a number of sources of error, and can be applied only in smaller estuaries. However, it can provide the information necessary for determining whether the conditions in the estuary are responsible for the size of a year class. Once the stages in the life history where the greatest mortality occurs are known, attention can be directed to those factors which may be responsible.

Growth, recruitment and mortalities. --Knowledge of the growth rate of menhaden is important because of its many applications. It is essential to an understanding of the general biology of the fish and the fluctuations in the fishery. It is also one of the basic variables which determine the total weight of the menhaden population and the yield from the fishery. The growth of menhaden varies a great deal between sexes, localities, seasons and years. The bimodal nature of the length-frequency distributions of fish of the same age evidences that more than one population of fish may be represented.

For estimating the size of the menhaden population, the amount of increase resulting from the entrance of young fish in the fishery (recuitment) and losses to

the fishery caused by fishing and natural causes (fishing and natural mortalities) need to be known. Since knowing the relative abundance of the population at the beginning of the purse seine fishing season is desirable, knowing the relative contribution of the 1-year-old fish to the fishery and their fluctuations from year to year is important. Mention was made in the previous sections of this report of an estimate of probable recruitment of a year class into the fishery, based on estimates of the size of the population in the nursery areas. Further estimates of the relative size of an incoming year class are being obtained from measurements of its relative abundance in the winter fishery at Beaufort, North Carolina, and the spring pound net fishery in Chesapeake Bay. The reliability of these estimates is not known well enough to permit drawing any conclusions at this time.

A preliminary estimate of the total mortality rate was computed from available age data; however, accumulating data for a number of years before any reliability can be placed in such estimates will be necessary.

Measurements of catch.--Fluctuations in the catch cannot be measured and interpreted without adequate records of the catch from year to year. The menhaden industry has willingly furnished such records.

The preliminary look at the current condition of the fishery is based on empirical methods, i.e., measurements of total catch, apparent abundance, as determined by catch per unit of effort and total fishing effort. Such measurements have been completed for the middle Atlantic fishery from 1939 through 1954. The calculated catch per unit effort (measure of apparent abundance) showed a general upward trend until 1947, when it was followed by a decline which lasted until 1951. A marked increase occurred in 1952 and 1953, doubtless resulting from the impact of the superabundant 1951 year class. The fishing effort increased over the period, reaching a peak in 1954. Similar measurements, together with the total catch, are being completed for other areas by means of automatic computing machine methods. A second measurement of apparent abundance is being calculated based on logbook data furnished by the vessel captains and pilots. The two series of measurements will be compared to determine whether they lead to the same conclusions.

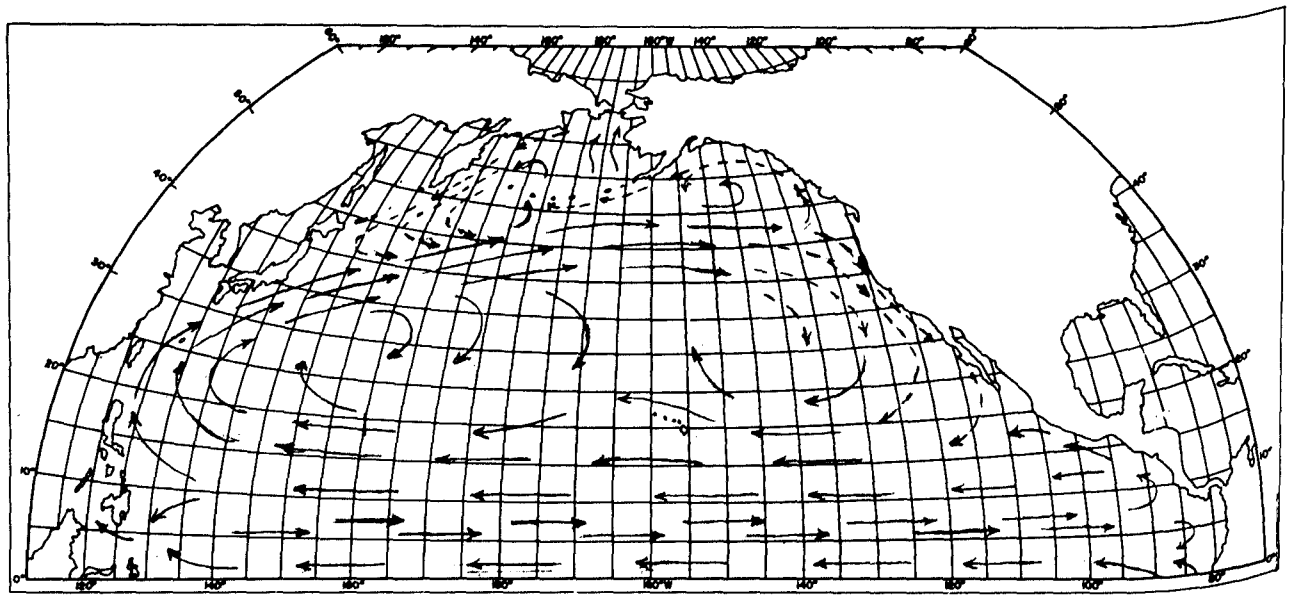
OCEAN RESEARCH

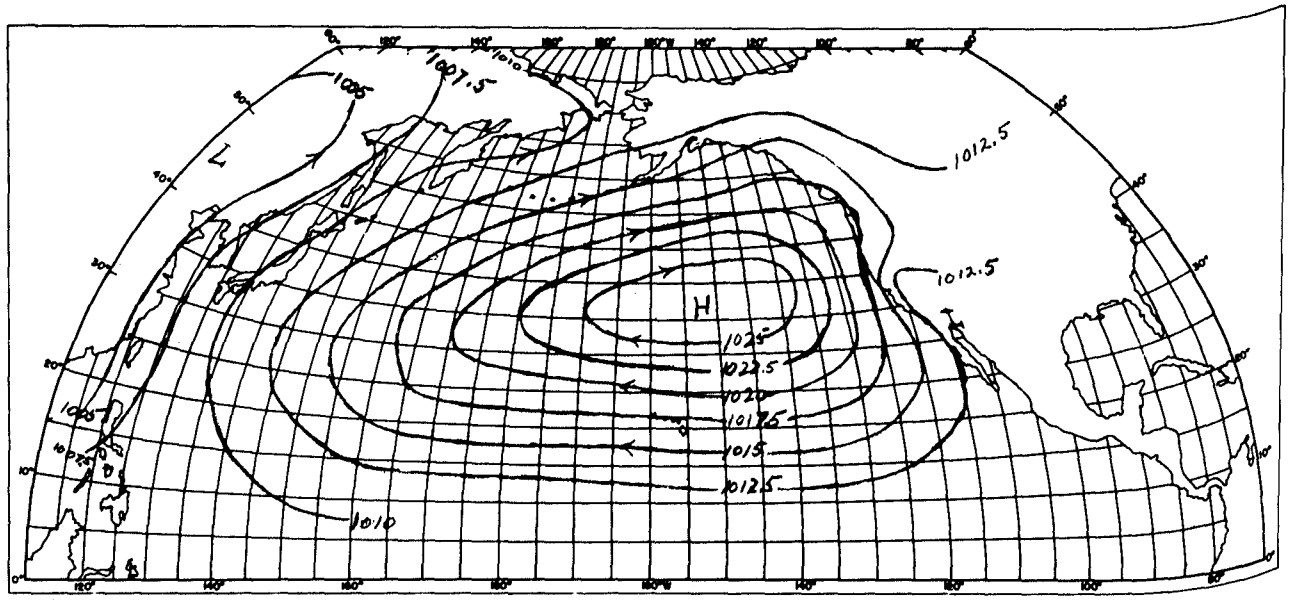
O. E. Sette
Stanford, California

Many important ocean fishes fluctuates widely in abundance or in availability to fishermen. Albacore tuna, for instance, disappeared from the west coast of North America in 1928 and reappeared in 1938. Other important fisheries, such as those for Atlantic mackerel and the Pacific sardines, have suffered less extreme but still serious failures due to fluctuations. Distinguishing between failures resulting from overfishing and those from natural causes is difficult. Through research on broad-scale changes in ocean conditions and their meteorological causes, this project attempts to recognize the naturally caused fluctuations in abundance and distribution of the important stocks of ocean fish and eventually to predict them. Defining man-made and natural causes of fishery fluctuations would materially aid conservation programs and prediction of them would reduce the effect of such fluctuations on the industry.

A new attack on the problem of natural fluctuations in the abundance of the important food fishes of the Pacific Ocean was started in 1955. A major difficulty in discovering the causes of these fluctuations has been the fragmentary nature of oceanographic observations. Those having continuity over considerable sea areas pertain only to conditions during a brief visit or several brief visits by research vessels to a given area. Those having continuity in time are from isolated coastal or island stations and pertain only to local shoal water conditions.

The new attack proposes to overcome this difficulty by using the great volume of weather data reported daily over many years by the world-wide network of weather stations. The ocean is heated by radiation received through the atmosphere and cooled by giving off heat to the atmosphere. The winds, directly or indirectly, drive the major ocean currents. By using the weather data on an ocean-wide scale, the Ocean

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Research staff expects to infer the changes in amount of ocean heating, cooling and circulation which may be expected to affect the living conditions for sea fishes and, therefore, cause their abundance to fluctuate.

To this end, during fiscal 1957, sets of unpublished data for these studies were acquired. These include monthly-mean sea-level atmospheric-pressure charts for the northern hemisphere for the period 1898 to 1957 from the United States Weather Bureau and a set of nearly two million observations of sea surface temperatures of the Pacific Ocean for the 10-year period 1936 to 1945 from the United States Hydrographic Office. Data on fluctuations in a number of Pacific fisheries were secured from published and unpublished sources.

A plan was developed for deriving from monthly-mean atmospheric-pressure charts a set of indices to describe fluctuations in the intensity of atmospheric circulation over the Pacific Ocean. These are designed to reflect the vigor of circulation for the North Pacific Ocean as a whole and also, as may be desired, over its several components, namely, the California Current, the North Equatorial Current, the Kuroshio and the North Pacific Drift. Accessory elements of the plan provide similar coverage for the peripheral system, such as the Gulf of Alaska Gyre and the Oyashio.

Pilot tests employing small segments of the pressure data were made by comparing indices with sea surface temperature series. The results reinforce the hopes of the Ocean Research Unit that its plan, when carried out fully, will give a quantitative description of atmospheric fluctuations which influence the ocean circulation and the physical characteristics of the ocean water masses over large areas of significance to the food fish populations.

The upper chart (on page 144) shows the average July air pressures over the North Pacific Ocean (after U. S. Weather Bureau "Normal Weather Charts for the Northern Hemisphere" 1952). The wind blows approximately along the isobars in the direction indicated by arrowheads (actually somewhat to the left). The lower chart shows the main ocean currents (adapted from G. Schott, Geographie des indischen und Stillen Ozeans, Hamburg, 1935 and U. S. Hydrographic Office, Stream Drift Chart of the World, July). Shifts from month to month and year to year in the weather pattern produce changes in the ocean currents, sea temperatures and other qualities of the water which may strongly influence the distribution and abundance of our important commercial fisheries along our Pacific coast from Alaska to the tropics. Better understanding of how the weather-sea-fishery system operates could lead to successful predictions of fish abundance.

ICHTHYOLOGICAL LABORATORY

Giles W. Mead
United States National Museum
Washington, D. C.

This laboratory conducts research on the classification, distribution and life histories of American fishes and performs service functions related to such studies.

While no research papers resulting directly from the work of this laboratory were published during fiscal 1957, several research projects are in progress and manuscripts are being prepared on them. These projects concern:

1. The morphology, homologies and evolution of the anterior sensory lateral-line system in the American gobies.

2. The taxonomic status of several nominal species of American Atlantic triglid fishes of the genus Prionotus.

3. The Taractes asper and the systematic position of the Steinegeriidae and Trachyberycidae. The Curator of the Museum Municipal do Funchal, Madeira, is collaborating in this work, which is a revision of a subfamily of pelagic fishes.

4. The fishes of the Western North Atlantic--families Chlorophthalmidae, Aulopidae, Ipnopidae, Harpodontidae and Bathypteroidae.

A series effort is being made to identify, relabel and catalog into the collections of the United States National Museum a large collection of animals assembled by the Fish and Wildlife Service during the last 20 years.

Collections of certain groups of fishes were loaned to independent fishery workers.

The laboratory cooperated with the Fish and Wildlife Service's Exploratory Fishing and Research programs, especially in areas in which the fish fauna is poorly known or in situations in which the facilities of the library and reference collections of the Smithsonian Institution and the National Museum were needed.

Much effort was devoted to identifying material sent in by individuals and commercial and governmental organizations, checking research literature for individuals who are without access to adequate libraries, reviewing manuscripts, preparing unpublished research work, etc.

PUBLICATIONS

Administratave Leaflets

14. Reviewing scientific manuscripts in the Fish and Wildlife Service. By George A. Rounsefell. Issued 1957.

Fishery Bulletins

106. Growth, migrations, spawning and size distribution of shrimp, Penaeus setiferus. By Milton J. Lindner and William W. Anderson. Issued 1956.

107. Validity of age determination from scales, and growth of marked Lake Michigan lake trout. By Louella E. Cable. Issued 1956.

108. Comparative study of food of bigeye and yellowfin tuna in the central Pacific. By Joseph E. King and Isaac I. Ikehara. Issued 1956.

109. Life history of lake herring of Green Bay, Lake Michigan. By Stanford H. Smith. Issued 1956.

110. Observations on the development of the Atlantic sailfish, Istiophorus americanus (Cuvier), with notes on an unidentified species of Istiophorid. By Jack W. Gehringer. Issued 1956.

111. Tunas and tuna fisheries of the world; an annotated bibliography, 1930-53. By Wilvan G. Van Campen and Earl E. Hoven. Issued 1956.

112. Yellowfin tuna spawning in the central equatorial Pacific. By Heeny S. H. Yuen and Fred C. June. Issued 1957.

113. A method of estimating abundance of groundfish on Georges Bank. By George A. Rounsefell. Issued 1957.

114. Effects of environment and heredity on growth of the soft clam (Mya arenaria). By Harlan S. Spear and John B. Glude. Issued 1957.

115. Climatic trends and the distribution of marine animals in New England. By Clyde C. Taylor, Henry B. Bigelow and Herbert W. Graham. (Only Mr. Taylor and Dr. Graham are employees of the Branch of Fishery Biology.) Issued 1957.

116. New genus and two new species of Tharybidae (Copepoda calanoida) from the Gulf of Mexico with remarks on the status of the family. By Abraham Fleminger. Issued 1957.

117. New calanoid copepods of the families Aetideidae, Euchaetidae, and Stephidae from the Gulf of Mexico. By Abraham Fleminger. Issued 1957.

118. Zooplankton abundance in the central Pacific, Part II. By Joseph E. King and Thomas S. Hida. Issued 1957.

Special Scientific Report: Fisheries

183. Observations on serology of tuna. By John E. Cusing, Jr. (University of California Santa Barbara College). Issued October 1956.

184. Longline fishing for tuna in the central equatorial Pacific, 1954. By Edwin S. Iversen and Howard O. Yoshida. Issued August 1956.

185. Blueback salmon, Oncorhynchus nerka - age and length at seaward migration past Bonneville Dam. By Raymond E. Anas and Joseph R. Gauley. Issued October 1956.

186. Sardine eggs and larvae and other fish larvae, Pacific coast, 1954. By Elbert H. Ahlstrom and David Kramer. Issued November 1956.

187. Commercial and sport shad fisheries of the Edisto River, South Carolina, 1955. By Charles H. Walburg. Issued October 1956.

188. Relative areal zooplankton abundance off the Pacific coast. By James R. Thrailkill. Issued November 1956.

190. Saury distribution and abundance, Pacific coast, 1950-55. By Elbert H. Ahlstrom and Harold D. Casey. Issued November 1956.

191. Shad fishery of the Ogeechee River, Georgia, in 1954. By James E. Sykes. Issued November 1956.

192. Three Russian papers on northwestern Pacific plankton. Translated by W. G. Van Campen. Issued October 1956.

195. Stream surveys of the Sheepscot and Ducktrap River systems in Maine. By Floyd G. Bryant. Issued December 1956.

197. Nature of green or offcolor condition in precooked yellowfin tuna. By John J. Naughton, Michael M. Prodyma and Harry Zeitlin (University of Hawaii). Issued December 1956.

198. Physical oceanographic, biological, and chemical data--South Atlantic coast of the United States, Gill cruise 2. By William W. Anderson, Jack W. Gehringer and Edward Cohen. Issued December 1956.

199. Gulf-II semiautomatic plankton sampler for inboard use. By Albert Collier. Issued February 1957.

201. Preliminary report on expedition EASTROPIC. By Joseph E. King, Thomas S. Austin and Maxwell S. Doty. (Only Messrs. King and Austin are employees of the Branch of Fishery Biology.) Issued March 1957.

203. Longline and troll fishing for tuna in the central equatorial Pacific, January 1955 to February 1956. By Edwin S. Iversen and Howard O. Yoshida. Issued February 1957.

204. Comparative study of populations of the striped bass. By Robert Minturn Lewis. Issued June 1957.

207. Toxicity of 4,346 chemicals to larval lampreys and fishes. By Vernon C. Applegate, John H. Howell, A. E. Hall, Jr. and Manning A. Smith. (Mr. Smith is a Professor of Chemistry at Bucknell University.) Issued March 1957.

208. Contributions to the study of subpopulations of fishes. Coordinated by John C. Marr. Issued April 1957.

209. Guide to literature on systematic biology of Pacific salmon. By Norman J. Wilimovsky and Warren O. Freihofer (Natural History Museum, Stanford University). Issued April 1957.

210. Physical oceanographic, biological, and chemical data--South Atlantic coast of the United States, Gill cruise 3. By William W. Anderson and Jack W. Gehringer. Issued June 1957.

211. Effects of unialgal and bacteria-free cultures of Gymnodinium brevis on fish. By S. M. Ray and William B. Wilson. Issued April 1957.

212. Central North Pacific albacore surveys May to November 1955. By Joseph J. Graham. Issued April 1957.

213. History of great fishery of Newfoundland. By Robert de Loture. Translated from the French Language by Clyde C. Taylor. Issued April 1957.

214. Surface water temperatures along Atlantic and Gulf coasts of the United States. By Dean F. Bumpus (Woods Hole Oceanographic Institution). Issued April 1957.

215. Chaetognaths and Pteropods as biological indicators in the North Pacific. By Thomas S. Hida. Issued June 1957.

217. Summary, oceanographic and fishery data, Marquesas Islands area, August-September 1956 (EQUAPAC). By Thomas S. Austin. Issued May 1957.

219. Spawning behavior of the channel catfish, Ictalurus punctatus. By Howard P. Clemens (University of Oklahoma) and Kermit E. Sneed (University of Oklahoma Research Institute). Issued June 1957.

211. Zooplankton abundance in Hawaiian waters, 1953-54. By Joseph E. King and Thomas S. Hida. Issued June 1957.

223. The response of tuna and other fish to electrical stimuli. By Iwao Miyake and Walter R. Steiger (University of Hawaii). Issued June 1957.

Article published in outlets other than Administrative Leaflets, Fishery Bulletins and Special Scientific Report: Fisheries series

Note: Where more than one author is shown in a listing, not all of whom are Service biologists, those whose names are underscored are personnel of the Branch of Fishery Biology.

Ahlstrom, Elbert H.
1956. Eggs and larvae of anchovy, jack mackerel, and Pacific mackerels. Progress Report 1 April 1955 - 30 June 1956 of the California Cooperative Oceanic Fisheries Investigations, pp. 33-42.

Austin, T. S., E. D. Stroup, and M. O. Rinkel
1956. Variations in the equatorial countercurrent in the central Pacific. Transactions of the American Geophysical Union, 37(5):558-564.

Broad, Robert D., and Harold A. Gangmark
1956. Establishment of a controlled-flow area and construction of king salmon spawning pens at Mill Creek, California. U. S. Fish and Wildlife Service The Progressive Fish-Culturist, 18(3):131-134.

Bullis, Harvey R., Jr. and Edgar L. Arnold, Jr.
1956. Capture of an immature oar-fish, Regalecus glesne, in the Gulf of Mexico. Copeia, (3):191.

Butler, Philip A.
1956. Production and utilization of seed oysters in the Gulf area. 1956 Proceedings of the National Shellfisheries Association, 47:19-22.

Butler, Philip A., and Alfred J. Wilson, Jr.
1956. A continuous water sampler for estimation of daily changes in plankton. Ibid., pp. 109-113.

Clark, John R.
1956. Georges Bank haddock fishery--changes in scrod abundance in recent years. U. S. Fish and Wildlife Service Commercial Fisheries Review, 18(10):1-3.

Collier, Albert, Sammy Ray and W. B. Wilson
1956. Some effects of specific organic compounds on marine organisms. Science, 124(3214):220.

Combs, Bobby D., and Roger E. Burrows
1957. Threshold temperatures for the normal development of chinook salmon eggs. U. S. Fish and Wildlife Service The Progressive Fish-Culturist, 19(1):3-6.

Cope, Oliver B.
1956. Some migration patterns in cutthroat trout. Utah Academy Proceedings, 33:113-118.

1957. DDT and fish. Proceedings of the ninth annual meeting of the Utah Mosquito Abatement Association, 1956, pp. 4-5.

1957. Six years of catch statistics on Yellowstone Lake. Transactions of the American Fisheries Society, 85 (1955):160-179.

Costello, Thomas J.
1956. Aims and progress in Gulf Fishery Investigations' shrimp research. Proceedings of the Gulf and Caribbean Fisheries Institute, ninth annual session, November, pp. 5-6.

DeLong, D. C., J. E. Halver, and E. T. Mertz
1957. Protein requirements of chinook salmon at two water temperatures. Federation Proceedings, 16:1644.

Eicher, George J., Jr. and George A. Rounsefell
1957. Effects of lake fertilization by volcanic activity on abundance of salmon. Limnology and Oceanography, 2(2):70-76.

Eschmeyer, Paul H.
1956. The early life history of the lake trout in Lake Superior. Miscellaneous Publication No. 10 of the Michigan Department of Conservation, Institute for Fisheries Research.

Eschmeyer, Paul H.
1957. The near extinction of lake trout in Lake Michigan. Transactions of the American Fisheries Society, 85 (1955):102-119.

Evans, John E.
1956. Red tide: A report to the Floridians. The All Florida Weekly Magazine, Pensacola News-Journal Magazine Section, October 7, pp. 8-9, 14; October 14, pp. 6-7, 13, 15.

Fleminger, Abraham
1957. New calanoid copepods of Pontella Dana and Labidocera Lubbock with notes on the distribution of the genera in the Gulf of Mexico. Tulane Studies in Zoology, 5(2):19-34.

Galtsoff, Paul S.
1956. Simple method of making frozen sections. Stain Technology, 31(5): 231-233.

Ganaros, A. E.
1957. Marine fungus infecting eggs and embryos of Urosalpinx cinerea. Science, 125(3259):1194.

Gangmark, Harold A., and Robert D. Broad
1956. An experiment with Vibert boxes. U.S. Fish and Wildlife Service The Progressive Fish-Culturist, 18(3): 143-144.

Gilmore, Raymond M.
1956. Rare right whale visits California. Pacific Discovery, 9(4):20-25.

1957. Whales aground in Cortes' Sea. Ibid., 10(1):22-27.

1957. The sea otter. Pan American Fisherman, 11(10):8.

Glude, John B.
1956. Copper, a possible barrier to oyster drills. 1956 Proceedings of the National Shellfisheries Association, 47:73-82.

Graham, Joseph J.
1956. A mortality of the sand launce, Ammodytes americanus. Copeia, (3): 192-194.

Halver, John E.
1957. Nutrition of salmonoid fishes. III. Water-soluble vitamin requirements of chinook salmon. Journal of Nutrition, 62(2):225-243.

1957. Nutrition of salmonoid fishes. IV. An amino acid test diet for chinook salmon. Ibid., 245-254.

Halver, J. E., D. C. DeLong and E. T. Mertz
1957. Nutrition of salmonoid fishes. V. Classification of essential amino acids for chinook salmon. Ibid., 63: 95-105.

Hanks, James E.
1957. The rate of feeding of the common drill, Urosalpinx cinerea (Say), at controlled water temperatures. Biological Bulletin, 112(3):330-335.

Holmes, Robert W., and Theodore M. Widrig
1956. The enumeration and collection of marine phytoplankton. Journal du Conseil Permanent International pour l'Exploration de la Mer, 22(1):21-32.

Jensen, Paul T.
1957. An extension of the range of the long-finned smelt. California Fish and Game, 43(1):99.

Joeris, Leonard S.
1957. Structure and growth of scales of yellow perch of Green Bay. Transactions of the American Fisheries Society, 86(1956):169-194.

June, Fred C.
1956. Biological investigation of Atlantic coast menhaden. Proceedings of the Gulf and Caribbean Fisheries Institute, ninth annual session, November, pp. 99-106.

Kelly, George F.
1957. Maine redfish discovery led to first successful tagging. Maine Coast Fisherman, 11(9):12.

King, Joseph E.
1956. A trip on a sampan. The Elepaio, 17(1):3-4.

King, Joseph E., and Robert L. Pyle
1957. Observations on sea birds in the tropical Pacific. The Condor, 59(1): 27-39.

Laakso, Martin
1956. Body-scale regressions in juvenile cutthroat from Yellowstone Lake. Utah Academy Proceedings, 33:107-111.

Lander, Robert H.
1956. Sequential analysis in fishery research. Copeia, (3):151-154.

Lennon, Robert E., and Phillip S. Parker
1956. A collapsible live-car for field use. U. S. Fish and Wildlife Service The Progressive Fish-Culturist, 18(4): 191-192.

Loosanoff, V. L.
1956. On utilization of salt water ponds for shellfish culture. Ecology, 37 (3):614-616.

1957. Electric shocker developments on southeastern trout waters. Transactions of the American Fisheries Society, 85(1955):234-240.

Loosanoff, V. L., James E. Hanks, and Anthony E. Ganaros
1956. Chemical control of shellfish enemies promising. National Fisherman, 37(11):16, 40.

1957. Control of certain forms of zooplankton in mass algal cultures. Science, 125(3257):1092-1093.

Loosanoff, V. L., and C. A. Nomejko
1956. Relative intensity of oyster setting in different years in the same areas of Long Island Sound. Biological Bulletin, 111(3):387-392.

McLain, Alberton L.
1957. The control of the upstream movement of fish with pulsated direct current. Transactions of the American Fisheries Society, 86(1956):269-284.

Milne, H. Bayard, John E. Halver, Don So Ho, and Michael S. Mason
1957. The oxidative cleavage of phenylhydrazide groups from carboallyloxy-β-amino acid phenylhydrazides and carboallyloxydipeptide phenylhydrazides [1,2]. Journal of the American Chemical Society, 79(3):637-639.

Moffett, James W.
1955. Fisheries of the Great Lakes. In The Great Lakes and Michigan, Great Lakes Research Institute, University of Michigan, pp. 36-37.

1956. Great Lakes Fishery Commission: Role of the Commission in the solution of fishery problems. In Great Lakes--Programs and Problems, Great Lakes Fishery Commission, pp. 14-16.

1957. Recent changes in the deep-water fish populations of Lake Michigan. In Symposium on the Great Lakes. Transactions of the American Fisheries Society, 86(1956):393-408.

Naughton, John J., Michael M. Frodyma and Harry Zeitlin
1957. Spectral reflectance applied to the study of heme pigments. Science, 125(3238):121-122.

Nielson, Reed S., Norman Reimers and Harry D. Kennedy
1957. A six-year study of the survival and vitality of hatchery-reared rainbow trout of catchable size in Convict Creek, California. California Fish and Game, 43(1):5-42.

Otsu, Tamio
1957. Development of "honeycombing" in Hawaiian skipjack tuna. U. S. Fish and Wildlife Service Commercial Fisheries Review, 19(1):1-8.

Otsu, Tamio, and Howard O. Yoshida
1957. Another record of the rare shark, Euprotomicrus bispinatus, from the Pacific Ocean. Copeia, (1):58.

Phillips, Arthur M., Jr.
1956. The nutrition of trout. I. General feeding methods. U. S. Fish and Wildlife Service The Progressive Fish-Culturist, 18(3):113-119.

Phillips, Arthur M., Jr., and Donald R. Brockway
1956. The nutrition of trout. II. Protein and carbohydrate. Ibid., 18 (4):159-164.

Phillips, Arthur M., Jr., Donald R. Brockway and George C. Balzer, Jr.
1956. The chemistry of developing brown trout eggs. Ibid., 18(3):104-107.

Phillips, Arthur M., Jr., Donald R. Brockway, Floyd E. Lovelace and Henry A. Podoliak
1957. A chemical comparison of hatchery and wild brook trout. Ibid., 19(1): 19-25.

Phillips, Arthur M., Jr., and Henry A. Podoliak
1957. The nutrition of trout. III. Fats and minerals. Ibid., 19(2):68-75.

Reimers, Norman
1957. Some aspects of the relation between stream foods and trout survival. California Fish and Game, 43(1):43-69.

Scattergood, Leslie W.
1956. Informe al gobierno de la Republica de Panama sobre investigacion de los recursos camaroneros Octubre 1952-Octubre 1953. Food Agric. Org. U. N., ETAP Report No. 326.

1957. Cod fishing at the Lofotens. Maine Coast Fisherman, 11(6):21-23.

Silliman, Ralph P., and James S. Gutsell
1957. Response of laboratory fish populations to fishing rates. Transactions of the Twenty-second North American Wildlife Conference, pp. 464-471.

Sindermann, Carl J.
1956. Diseases of fishes of the western North Atlantic. IV. Fungus disease and resultant mortalities of herring in the Gulf of Saint Lawrence in 1955. Research Bulletin 25 of the Maine Department of Sea and Shore Fisheries, August.

1956. The ecology of marine dermatitis-producing schistosomes. I. Seasonal variation in infection of mud snails with larvae of Austrobilharzia variglandis. Journal of Parasitology, 42(Suppl.):27.

Smith, Stanford H.
1957. Limnological surveys of the Great Lakes--early and recent. Transactions of the American Fisheries Society, 86(1956):409-418.

Snieszko, S. F.
1957. Use of antibiotics in the diet of salmonid fishes. U. S. Fish and Wildlife Service The Progressive Fish-Culturist, 19(2):81-84.

Snieszko, S. F., E. M. Wood and W. T. Yasutake
1957. Infectious pancreatic necrosis in trout. A.M.A. Archives of Pathology, 63:229-233.

Starr, Theodore J., and Mary Elizabeth Jones
1957. The effect of copper on the growth of bacteria isolated from marine environments. Limnology and Oceanography, 2(1):33-36.

Starr, Theodore J., Domingo Martinez and Walter Fosberg
1957. The vitamin-B_{12} activity of mullet and shark serum. Ibid., 2(2):111-113.

Starr, Theodore J., Mary E. Jones and Domingo Martinez
1957. The production of vitamin B_{12}-active substances by marine bacteria. Ibid., 2(2):114-119.

Stickney, Alden P., and Louis D. Stringer
1957. A study of the invertebrate bottom fauna of Greenwich Bay, Rhode Island. Ecology, 38(1):111-122.

Strasburg, Donald W.
1957. Notes on the respiration of small Remora remora. Copeia, (1):58-60.

1957. Sharks of the central Pacific . . . nuisance or resource? Pan American Fisherman, 11(9):6-7, 14-15.

Strasburg, Donald W., and Robert W. Hiatt
1957. Sexual dimorphism in the labrid fish genus Gomphosus. Pacific Science, 11(1):133-134.

Stunkard, Horace W.
1956. Studies on parasites of the green crab, Carcinides maenas. Biological Bulletin, 111(2):295.

Talbot, G. B.
1955. Conservation of an east coast shad fishery. Proceedings of the Gulf and Caribbean Fisheries Institute, Eighth Annual Session, November, pp. 92-99.

Tanonaka, George K.
1957. The occurrence of the squaretail, Tetragonurus cuvieri, on the high-seas

south of the Aleutian Islands. Copeia, (1):53-54.

Thompson, Paul E.
1957. Should areas be set aside as fish nursery grounds? Texas Game and Fish, 15(6):10-11,31.

Trefethen, Parker S., John W. Dudley and Myron R. Smith
1957. Ultrasonic tracer follows tagged fish. Electronics, 30(4):156-160.

Uzmann, J. R., and M. N. Hesselholt
1957. New host and locality record for Triaenophorus crassus Forel (Cestoda: Pseudophyllidea). Journal of Parasitology, 43(2):205.

Van Campen, Wilvan G.
1957. Review of "Fish physiology/Gyoriu Seirigaku" by N. Y. Kawamoto. Ishizaki Shoten, Tokyo, 1956, 319 pp. Copeia, (1):67.

Van Campen, W.G., and Garth I. Murphy
1957. Tagging albacore on a Japanese bait boat. Pacific Fisherman, 55(3): 37, 39, 41-43.

Van Landingham, John W.
1957. A modification of the Knudsen method for salinity determination. Journal du Conseil Permanent International pour l'Exploration de la Mer, 22(2):174-179.

Van Oosten, John
1957. Great Lakes fauna, flora and their environment. A bibliography. Great Lakes Fishery Commission, Ann Arbor, Michigan.

1957. Chapter V, The skin and scales, of The physiology of fishes, Volume I - Metabolism, pp. 207-244. Edited by Margaret E. Brown (New York City: Academic Press, Inc.).

Walburg, Charles H.
1957. Observations on the food and growth of juvenile American shad, Alosa sapidissima. Transactions of the American Fisheries Society, 86(1956):302-306.

Wolf, Ken
1957. Experimental induction of blue-sac disease. Ibid., pp. 61-70.

1957. Blue-sac disease investigations: microbiology and laboratory induction. U. S. Fish and Wildlife Service The Progressive Fish-Culturist, 19(1): 14-18.

Wood, E. M.
1956. Urethane as a carcinogen. Ibid., 18(3):135-136.

Wood, E. M., and W. T. Yasutake
1956. Tissue damage in salmonids caused by Halisidota argentata Packard. Journal of Parasitology, 42(5):544-546.

1956. Histopathology of kidney disease in fish. American Journal of Pathology, 32(4):845-857.

1956. Histopathology of fish. IV. A granuloma of brook trout. U. S. Fish and Wildlife Service The Progressive Fish-Culturist, 18(3):108-112.

1957. Histopathology of fish. V. Gill disease. Ibid., 19(1):7-13.

Wood, E. M., W. T. Yasutake and Harlan E. Johnson
1957. Acute sulfamethazine toxicity in young salmon. Ibid., 19(2):64-67.

Wood, E. M., W. T. Yasutake, A. N. Woodall and J. E. Halver
1957. The nutrition of salmonoid fishes. I. Chemical and histological studies of wild and domestic fish. Journal of Nutrition, 61(4):465-478.

1957. The nutrition of salmonoid fishes. II. Studies on production diets. Ibid., pp. 479-488.

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Hall, Albert E.	Fish. Biol.	Great Lakes	Rogers City, Mich.
Halver, John E.	Chemist	Sal. Nutr. Lab.	Willard, Wash.
Hampton, Karl A.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Hanavan, Mitchell G.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Hanks, James E.	Fish. Biol.	Milford Lab.	Milford, Conn.
Hanks, Robert W.	Fish. Biol.	Clams	Boothbay Harbor, Me.
Healy, Dan C.	Fish. Aid	Pacific Salmon	Seattle, Wash.

Name	Title	Investigations	Location
Hebard, J. Frank	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Hiatt, Robert S.	Fish. Biol.	Marine Section	Honolulu, T. H.
Hida, Thomas S.	Fish. Aid	POFI	Honolulu, T. H.
Higham, Joseph R., Jr.	Fish. Biol.	Menhaden	Beaufort, N. C.
Hile, Ralph O.	Fish. Biol.	Great Lakes	Ann Arbor, Mich.
Hodge, Melvin H.	Psy. Sci. Aid	Gulf	Galveston, Texas
Holmes, Leslie H.	Research Tech.	Sal. Nutr. Lab.	Anacortes, Wash.
Honey, Kenneth A.	Fish. Biol.	South Atlantic	Brunswick, Ga.
Horrell, Harry C.	Fish. Aid	North Atlantic	Boston, Mass.
Howell, John J.	Fish. Biol.	Great Lakes	Ann Arbor, Mich.
Hunter, Charles J.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Hunter, Lois E.	Fish. Aid	South Pacific	La Jolla, Calif.
Huntley, Julian L.	Fish. Aid	Menhaden	Beaufort, N. C.
Ikehara, Isaac I.	Fish. Biol.	POFI	Honolulu, T. H.
Inglis, Anthony	Fish. Biol.	Gulf	Galveston, Texas
Iverson, Robert T. B.	Psy. Sci. Aid	POFI	Honolulu, T. H.
Jambor, McKinley W.	Biol. Aid	Gulf	Naples, Fla.
Jensen, Albert C.	Fish. Biol.	North Atlantic	Woods Hole, Mass.
Joeris, Leonard S.	Fish. Biol.	Great Lakes	Ann Arbor, Mich.
Johnson, James H.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Johnson, James H.	Fish. Biol.	Great Lakes	Ann Arbor, Mich.
Johnson, James S.	Fish. Aid	Pacific Salmon	No. Bonneville, Wash.
Johnson, Lucius, Jr.	Phy. Sci. Aid	Gulf	Naples, Fla.
Jones, Everet C.	Fish. Biol.	POFI	Honolulu, T. H.
Kallio, John R.	Fish. Aid	North Atlantic	Gloucester, Mass.
Karlos, Lester S.	Fish. Aid	Great Lakes	Marquette, Mich.
Kelly, George F.	Fish. Biol.	North Atlantic	Woods Hole, Mass.
Kennedy, Harry D.	Fish. Biol.	Calif.-Nev.	Convict Creek, Calif.
Keyser, Joseph E.	Lab. Elec.	Pacific Salmon	Seattle, Wash.
King, Everett L., Jr.	Fish. Biol.	Great Lakes	Ludington, Mich.
King, Joseph E.	Fish. Biol.	POFI	Honolulu, T. H.
Kirkland, Leon F.	Fish. Biol.	Menhaden	Beaufort, N. C.
Kitchel, Maude Alice	Biol. Aid	Gulf	Galveston, Texas
Klontz, George W.	Research Tech.	Pacific Salmon	Seattle, Wash.
Kodama, Robert M.	Phy. Sci. Aid	POFI	Honolulu, T. H.
Kramer, David	Fish. Biol.	South Pacific	La Jolla, Calif.
Krcma, Richard F.	Fish. Aid	Great Lakes	Oconto, Wis.
LaLanne, John J.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Lander, Robert H.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Landers, Warren S.	Fish. Biol.	Clams	Kingston, R. I.
Lansford, Larence M.	Phy. Sci. Aid	Gulf	Galveston, Texas
Larson, Robert M.	Fish. Biol.	Atl. Herring	Boothbay Harbor, Me.
Lennon, Robert E.	Fish. Biol.	East. Fed. Waters	Leetown, W. Va.
Lewis, Robert D.	Fish. Biol.	Middle Atlantic	Beaufort, N. C.
Lewis, Robert M.	Fish. Biol.	Middle Atlantic	Beaufort, N. C.
Liscom, Kenneth L.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Livingstone, Robert, Jr.	Fish. Biol.	North Atlantic	Woods Hole, Mass.
Long, Clifford W.	Fish. Aid	Pacific Salmon	Seattle, Wash.
Loosanoff, Victor L.	Fish. Biol.	Milford Lab.	Milford, Conn.
Lowe, Jack I.	Fish. Biol.	Gulf Oysters	Pensacola, Fla.
Lozier, Lewis J.	Stat. Clk.	Atl. Herring	Boothbay Harbor, Me.
Lucash, Joseph F.	Lab. Mechanic	Milford Lab.	Milford, Conn.
Lucich, George M.	Physicist	Pacific Salmon	Seattle, Wash.

Name	Title	Investigation	Location
Lux, Fred E.	Fish. Biol.	North Atlantic	Woods Hole, Mass.
Lynn, Albert C.	Fish. Aid	Middle Atlantic	Beaufort, N. C.
McGary, James W.	Oceanographer	POFI	Honolulu, T. H.
McLain, Alberton L.	Fish. Biol.	Great Lakes	Marquette, Mich.
McLaughlin, Patsy Ann	Fish. Aid	Pacific Salmon	Seattle, Wash.
MacGregor, John S.	Fish. Biol.	South Pacific	La Jolla, Calif.
MacGregor, William A.	Fish. Biol.	Great Lakes	Oconto, Wis.
Macy, Paul T.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Major, Richard L.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Malone, John C.	Fish. Aid	North Atlantic	Boston, Mass.
Manion, Patrick J.	Fish. Aid	Great Lakes	Marquette, Mich.
Mann, Herbert J.	Fish M. & E. Sp.	POFI	Honolulu, T. H.
Marak, Robert R.	Fish. Biol.	North Atlantic	Woods Hole, Mass.
Marquette, Willman M.	Fish. Biol.	Great Lakes	Marquette, Mich.
Marr, John C.	Fish. Biol.	South Pacific	La Jolla, Calif.
Martin, Thomas W.	Fish. Biol.	North Atlantic	Woods Hole, Mass.
Marvin, Kennth T.	Chemist	Gulf	Galveston, Texas
Mason, James E.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Matsumoto, Walter M.	Fish. Biol.	POFI	Honolulu, T. H.
Mattson, George M.	Illustrator	South Pacific	La Jolla, Calif.
Maxfield, Galen H.	Fish. Biol.	Pacific Salmon	Seattle, Washington
May, Billie Z.	Chemist	Gulf	Galveston, Texas
Mead, Giles W., Jr.	Zoologist	Ichthy. Lab.	Washington, D. C.
Medford, Royston Z.	Fish. Biol.	Chesapeake	Annapolis, Md.
Mendiola, Ella W.	Stat. Clk.	POFI	Honolulu, T. H.
Meyer, William A.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Miller, David	Fish. Biol.	North Atlantic	Woods Hole, Mass.
Miller, Richard G.	Fish. Biol.	Great Lakes	Marquette, Mich.
Miyahara, Takashi	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Moffett, James W.	Fish. Biol.	Great Lakes	Ann Arbor, Mich.
Moore, Donald	Fish. Biol.	South Atlantic	Brunswick, Ga.
Moore, Harvey L.	Fish. Biol.	Marine Section	Washington, D. C.
Moore, Harry H.	Fish. Biol.	Great Lakes	Marquette, Mich.
Moore, Joseph E.	Chemist	South Atlantic	Brunswick, Ga.
Moreau, Gilbert W.	Phy. Sci. Aid	Gulf	Naples, Fla.
Morgan, Reginald E.	Fish. Aid	Pacific Salmon	Seattle, Wash.
Mosher, Kenneth H.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Murai, Sueto	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Murphy, Garth I.	Fish. Biol.	POFI	Honolulu, T. H.
Murray, Harriett E.	Stat. Clk.	North Atlantic	Woods Hole, Mass.
Nakamura, Eugene L.	Fish. Biol.	POFI	Honolulu, T. H.
Nakata, Tomatsu	Illustrator	POFI	Honolulu, T. H.
Nakatsu, Lorry M.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Nelsen, William V.	Fish. Equip. Sp.	POFI	Honolulu, T. H.
Nelson, Philip R.	Fish. Biol.	Chesapeake	Annapolis, Md.
Newman, H. William	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Nichols, Paul R.	Fish. Biol.	Middle Atlantic	Beaufort, N. C.
Nicholson, William R.	Fish. Biol.	Middle Atlantic	Beaufort, N. C.
Nichyparowich, Fred W.	Fish. Biol.	North Atlantic	Woods Hole, Mass.
Nickerson, Samuel R.	Fish. Biol.	North Atlantic	Woods Hole, Mass.
Nielson, Reed S.	Fish. Biol.	Calif.-Nev.	Reno, Nevada
Nomejko, Charles A.	Biol. Aid	Milford Lab.	Milford, Conn.
O'Connell, Charles P.	Fish. Biol.	South Pacific	La Jolla, Calif.

Name	Title	Investigation	Location
Ordal, Erling J.	Collaborator	W. Fish. Diseases	Seattle, Wash.
Otsu, Tamio	Fish. Biol.	POFI	Honolulu, T. H.
Parker, Philip S.	Fish. Biol.	East. Fed. Waters	Gatlinburg, Tenn.
Parsons, John W.	Fish. Biol.	Great Lakes	Ann Arbor, Mich.
Patten, Benjamin G.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Paulus, Jo Ann	Biol. Aid	Great Lakes	Rogers City, Mich.
Pearson, Roger E.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Perkins, Frank E.	Fish. Aid	Atl. Herring	Boothbay Harbor, Me.
Peterson, Alvin E.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Philbrook, Charles L.	Fish. Aid	North Atlantic	Rockland, Me.
Phillips, Arthur M., Jr.	Fish. Biol.	Trout Nutr.	Cortland, N. Y.
Podoliak, Henry A.	Chemist	Trout Nutr.	Cortland, N. Y.
Posgay, Julius A.	Fish. Biol.	North Atlantic	Woods Hole, Mass.
Prafke, Verlon E.	Fish. Biol.	Great Lakes	Marquette, Mich.
Price, Thomas, Jr.	Fish. Biol.	Beaufort Lab.	Beaufort, N. C.
Pugh, John R.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Purvis, Harold A.	Fish. Biol.	Great Lakes	Marquette, Mich.
Pycha, Richard L., Jr.	Fish. Biol.	Great Lakes	Ann Arbor, Mich.
Raney, Edward C.	Fish. Biol.	Middle Atlantic	Ithaca, N. Y.
Ray, Sammy M.	Fish. Biol.	Gulf	Galveston, Texas
Raymond, Howard L.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Reid, Charles F.	Fish. Aid	South Pacific	La Jolla, Calif.
Reimers, Norman	Fish. Biol.	Calif.-Nev.	Reno, Nevada
Reintjes, John W.	Fish. Biol.	Menhaden	Beaufort, N. C.
Rice, Theodore R.	Fish. Biol.	Beaufort Lab.	Beaufort, N. C.
Rick, Alan J.	Fish. Biol.	Great Lakes	Rogers City, Mich.
Ridgway, George L.	Chemist	Pacific Salmon	Seattle, Wash.
Rinkel, Maurice O.	Oceanography	POFI	Honolulu, T. H.
Robertson, Oswald H.	Collaborator	Sal. Cult. Lab.	Stanford, Calif.
Rockwell, Julius J.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Roithmayr, Charles	Fish. Biol.	Menhaden	Beaufort, N. C.
Ropes, John W.	Fish. Biol.	Clams	Kingston, R. I.
Ross, Avron J.	Bacteriologist	W. Fish. Diseases	Seattle, Wash.
Rounsefell, George A.	Fish. Biol.	Marine Section	Woods Hole, Mass.
Royce, Rodney D.	Fish. Biol.	W. Fish. Diseases	Seattle, Wash.
Rucker, Robert R.	Fish. Biol.	W. Fish. Diseases	Seattle, Wash.
Sakuda, Henry M.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Sanderson, Imogene A.	Phy. Sci. Aid	Gulf	Galveston, Texas
Scattergood, Leslie W.	Fish. Biol.	Atl. Herring	Boothbay Harbor, Me.
Seckel, Gunter R.	Oceanographer	POFI	Seattle, Wash.
Seidl, A James	Fish. Biol.	Great Lakes	Marquette, Mich.
Sette, Oscar E.	Fish. Biol.	Ocean Research	Stanford, Calif.
Shanks, Warren E.	Med. Biol. Tech.	Sal. Nutr. Lab.	Willard, Wash.
Shaw, William N.	Fish. Biol.	Woods Hole Lab.	Woods Hole, Mass.
Shea, John F.	Fish. Biol.	North Atlantic	Woods Hole, Mass.
Shearer, Lloyd W.	Fish. Biol.	Milford Lab.	Milford, Conn.
Sherman, Kenneth	Fish. Aid	North Atlantic	Boston, Mass.
Shippen, Herbert H.	Fish. Biol.	POFI	Honolulu, T. H.
Shomura, Richard S.	Fish. Biol.	POFI	Honolulu, T. H.
Silliman, Ralph P.	Fish. Biol.	Anad. & Shell.	Washington, D. C.
Sindermann, Carl J.	Fish. Biol.	Atl. Herring	Boothbay Harbor, Me.
Skud, Bernard E.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Slusser, George F.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Smith, Bernard R.	Fish. Biol.	Great Lakes	Marquette, Mich.
Smith, Manning A.	Chemist	Great Lakes	Lewisburg, Pa.

Name	Title	Investigation	Location
Smith, Rebecca J.	Fish. Biol.	Beaufort Lab.	Beaufort, N. C.
Smith Robert R.	Fish. Aid	Sal. Nutr. Lab.	Hagerman, Idaho
Smith, Stanford H.	Fish. Biol.	Great Lakes	Ann Arbor, Mich.
Snieszko, Stanislas F.	Bacteriologist	Micro. Lab.	Leetown, W. Va.
Sprague, Lucian M.	Geneticist	South Pacific	La Jolla, Calif.
Starr, Theodore J.	Fish. Biol.	Gulf	Galveston, Texas
Stewart, Dorothy D.	Fish. Aid	POFI	Honolulu, T. H.
Stickney, Alden P.	Fish. Biol.	Atlantic Salmon	Boothbay Harbor, Me.
Stoddard, Ruth R.	Stat. Clk.	North Atlantic	Woods Hole, Mass.
Strasburg, Donald W.	Fish. Biol.	POFI	Honolulu, T. H.
Stringer, Louis D.	Fish. Biol.	Clams	Kingston, R. I.
Stroud, Charles W.	Phy. Sci. Aid	Gulf	Galveston, Texas
Stunkard, Horace W.	Fish. Biol.	Clams	New York, N. Y.
Sullivan, Leo J.	Fish. Biol.	Great Lakes	Ludington, Mich.
Sutherland, Doyle F.	Fish. Biol.	Menhaden	Beaufort, N. C.
Sykes, James E.	Fish. Biol.	Middle Atlantic	Beaufort, N. C.
Taft, Bruce A.	Stat.	South Pacific	La Jolla, Calif.
Tagatz, Marlin E.	Fish. Biol.	Middle Atlantic	Beaufort, N. C.
Talbot, Gerald B.	Fish. Biol.	Middle Atlantic	Beaufort, N. C.
Tanonaka, George K.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Taylor, Bonnie Jean M.	Fish. Aid	South Pacific	La Jolla, Calif.
Taylor, Clyde C.	Fish. Biol.	North Atlantic	Woods Hole, Mass.
Temple, Robert F.	Fish. Biol.	Atl. Herring	Boothbay Harbor, Me.
Tester, Albert L.	Fish. Biol.	POFI	Honolulu, T. H.
Tetzloff, Clifford L.	Fish. Biol.	Great Lakes	Marquette, Mich.
Thibodeau, Albert F.	Fish. Aid	North Atlantic	Portland, Me.
Thompson, Clark S.	Fish. Biol.	Pacific Salmon	No. Bonneville, Wash.
Thompson, Paul E.	Fish. Biol.		Washington, D. C.
Thompson, Richard B.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Thorne, Donald L.	Lab. Elec.	Pacific Salmon	Seattle, Wash.
Thrailkill, James R.	Fish. Biol.	South Pacific	La Jolla, Calif.
Torblaa, Richard L.	Fish. Biol.	Great Lakes	Ludington, Mich.
Trefethen, Parker S.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Uchida, Richard N.	Fish. Biol.	POFI	Honolulu, T. H.
Uzmann, Joseph R.	Parasitologist	W. Fish. Diseases	Seattle, Wash.
Van Campen, Wilvan G.	Translator	POFI	Honolulu, T. H.
Van Landingham, John W.	Phy. Sci. Aid	POFI	Honolulu, T. H.
Van Meter, Harry D.	Fish. Biol.	Great Lakes	Sandusky, Ohio
Van Oosten, John	Fish. Biol.	Great Lakes	Ann Arbor, Mich.
VanHaagen, Richard H.	Elec. Sci.	Pacific Salmon	Seattle, Wash.
Vickery, Roy N.	Fish. Aid	Menhaden	Cape May, N. J.
Volz, Charles D.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Von Ark, Ruth L.	Illustrator	Woods Hole Lab.	Woods Hole, Mass.
Vorobiov, Alexander V.	Fish. Aid	South Pacific	La Jolla, Calif.
Vrooman, Andrew M.	Fish. Biol.	South Pacific	La Jolla, Calif.
Wahl, Roy J.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Walburg, Charles H.	Fish. Biol.	Middle Atlantic	Beaufort, N. C.
Walford, Lionel A.	Fish. Biol.		Washington, D. C.
Waldron, Kenneth D.	Fish. Biol.	POFI	Honolulu, T. H.
Ward, George E., Jr.	Fish. Aid	Chesapeake	Franklin City, Va.
Watson, Clinton E.	Fish. Aid	North Atlantic	Boston, Mass.
Watson, Frank H.	Fish. Aid	South Pacific	La Jolla, Calif.
Weaver, Charles R.	Fish. Biol.	Pacific Salmon	Seattle, Wash.

Name	Title	Investigation	Location
Weber, Douglas D.	Fish Biol.	Pacific Salmon	Seattle, Wash.
Weber, Kingsley G.	Fish. Biol.	Pacific Salmon	Seattle, Wash.
Webster, John J.	Fish. Biol.	Chesapeake	Annapolis, Md.
Welch, Walter R.	Fish. Biol.	Clams	Boothbay Harbor, Me.
Wells, LaRue	Fish. Biol.	Great Lakes	Ann Arbor, Mich.
Wentworth, John Philip	Fish. Biol.	Atl. Herring	Eastport, Me.
Wheeler, Ray S.	Fish. Biol.	Gulf	Galveston, Texas
White, Effie L.	Fish. Aid	Sal. Nutr. Lab.	Willard, Wash.
Wieberg, Nels R.	Fish. Aid	Great Lakes	Marquette, Mich.
Wigley, Roland L.	Fish. Biol.	North Atlantic	Woods Hole, Mass.
Williams, Ray G.	Fish. Biol.	Great Lakes	Marquette, Mich.
Wilson, Alfred J.	Phy. Sci. Aid	Gulf Oysters	Pensacola, Fla.
Wilson, Melba C.	Fish. Aid	South Atlantic	Brunswick, Ga.
Wilson, Robert C.	Fish. Biol.	POFI	Honolulu, T. H.
Wilson, William B.	Fish. Biol.	Gulf	Galveston, Texas
Wise, John P.	Fish. Biol.	North Atlantic	Woods Hole, Mass.
Wolf, Kenneth E.	Bacteriologist	Micro. Lab.	Leetown, W. Va.
Wolf, Robert S.	Fish. Biol.	South Pacific	La Jolla, Calif.
Wong, Stanley H. S.	Mech. Engr.	POFI	Honolulu, T. H.
Woodall, Arthur N.	Chemist	Sal. Nutr. Lab.	Willard, Wash.
Worlund, Donald D.	Statistician	Pacific Salmon	Seattle, Wash.
Yamashita, Daniel T.	Fish. Biol.	POFI	Honolulu, T. H.
Yasutake, William T.	Histologist	Sal. Nutr. Lab.	Willard, Wash.
Yoshida, Howard O.	Fish. Biol.	POFI	Honolulu, T. H.
Yuen, Heeny S. H.	Fish. Biol.	POFI	Honolulu, T. H.
Zein-Eldon, Zoula P.	Chemist	Gulf	Galveston, Texas

FISHERY RESEARCH VESSELS

SECTION OF INLAND FISHERIES

Cisco: Great Lakes Fishery Investigations
Built in 1950 at Kewaunee, Wisconsin.
Steel construction; 60' long; 74 gross tons; 175 HP; diesel-powered.
Home port: Grand Haven, Michigan.

Musky: Great Lakes Fishery Investiations
Purchased used (1951).
Wood construction; 55' long; twin-screw, gasoline-powered; trap-net type.
Home port: Cheboygan, Michigan.

Siscowet: Great Lakes Fishery Investigations
Purchased used (1952)
Steel construction; 50' long; diesel-powered; gill-net tug model.
Home port: Marquette, Michigan.

SECTION OF MARINE FISHERIES

Albatross III: North Atlantic Fishery Investigations
Built in 1926 at Boothbay Harbor, Maine.
Purchased used (1939); rebuilt by Navy 1942; converted by FWS 1946; *commissioned* 1948.
Steel construction; 179' long; 400 gross tons; 800 HP. converted trawler.
Home port: Woods Hole, Massachusetts.

Black Douglas: South Pacific Fishery Investigations
Built in 1930 at Bath, Maine.
Purchased by FWS in 1941 for fur seal research; transferred to Fishery Biology 1949.
Steel construction; teak decks; 118' long; 371 gross tons; three-masted schooner.
Home port: San Francisco, California.

Theodore N. Gill: North Atlantic Fishery Investigations (herring)
Built in 1941 at Antioch, California; transferred from Office of Foreign Activities.
Wood construction; 97.08' long; 186.85 gross tons; 800 HP.
Home port: Brunswick, Georgia.

Kingfish: Gulf Fishery Investigations
Built in 1954 at Algonac, Michigan.
Wood construction; 43' long.
Home port: Ft. Myers, Florida.

Charles H. Gilbert: Pacific Oceanic Fishery Investigations
Built in 1952 at Tacoma, Washington.
Steel construction; 84.16' long; 640 HP.
Home port: Honolulu, T. H.

John R. Manning: Pacific Oceanic Fishery Investigations
Built in 1950 at Seattle, Washington.
Wood construction; 86.6' long; 231 gross tons; 320 HP.
Home port: Honolulu, T. H.

Hugh M. Smith: Pacific Oceanic Fishery Investigations
Built in 1945 at Seattle, Washington. Transferred from Navy (1948).
Steel construction; 128' long; 700 gross tons; 560 HP.
Home port: Honolulu, T. H.

SECTION OF ANADROMOUS AND SHELLFISHERIES

FWS 1227: Middle Atlantic Fishery Investigations.
Transferred from Branch of Game-fish and Hatcheries.
Wood construction; 35.4' long; 30 HP; gasoline-powered.
Home port: Beaufort, North Carolina.

Alosa: Chesapeake Shellfish Investigations.
Built in 1941 at College Park, Md. Transferred from Navy.
Wood construction; 48' long; 25 gross tons; 77 HP; diesel-powered.
Home port: Annapolis, Maryland.

Phalarope II: Clam Investigations
Built in 1932 at Newport, R. I. Transferred from Milford Shellfish Laboratory.
Wood construction; 40.5' long; 12.5' beam; 225 HP; diesel-powered.
Home port: East Greenwich, Rhode Island.

Shang Wheeler: Milford Shellfish Laboratory.
Built in 1950 at West Haven, Connecticut.
Wood construction; 50' long; 140 HP; diesel-powered.
Home port: Milford, Connecticut.

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