BRANCH OF FISHERY BIOLOGY

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GREAT LAKES FISHERY INVESTIGATIONS

The program of the Great Lakes Fishery Investigations is based on the need to curb the abundance of the parasitic sea lamprey and to better understand the factors controlling productivity of the fish stocks of the Great Lakes.

Substantial advances have been made in both areas since the investigations, located at Ann Arbor, Mich., were expanded in 1949. The outlook for a more effective and stable program on the Great Lakes was improved in the latter part of fiscal 1956 by the appointment of the International Great Lakes Fishery Commission. Established by treaty with Canada, the Commission is to function as a coordinating and implementing agency in fishery research and lamprey control.

Sea Lamprey: Lake Superior is the only one of the Great Lakes in which lamprey predation has not reduced the number of lake trout below the level necessary to support commercial fishing operations. In fiscal 1956, as in the preceding year, all known spawning streams on the United States shore were blocked by electromechanical barriers. At the same time, Canadian officials have been extending controls rapidly in the Ontario streams of the lake. The start of runs in new streams and occasional temporary malfunction of barriers prevent complete control, but an extremely high percentage of the sea lamprey spawning runs are now destroyed each year.

Control operations have been concentrated on Lake Superior in the hope that lampreys might be reduced in time to prevent the collapse of the lake trout fishery. This hope has been dimmed by the rate of increase in the abundance of lampreys. A jump from 4,992 lampreys in 1954, to 8,823 in 1955, to a 1956 total of 19,009 was recorded in 30 streams under control in each of the last three years. Since the larval life of sea lampreys in streams is long--five years or more--benefits from the blocking of spawning runs cannot be expected before the end of a similar period. At the present rate of increase the Lake Superior lamprey stock will be enormous before decreases can come from the current program. The fishery is already near collapse because of the scarcity of lake trout and it seems only the development of a means for destroying larval lampreys in streams can prevent failure of the fishery.

Control activities on Lake Michigan are limited to the streams of the northwestern area. Although 46,000 spawning-run lampreys were caught in 17 barrier structures last year, and 54,932 in 19 structures in fiscal 1956, benefits from such local operations are uncertain. Plans call for blocking all Lake Michigan spawning streams before the start of the 1958 run.

Only one barrier has been operated on Lake Huron, and no expansion will be undertaken until installations on Lake Michigan are complete.

Selective Toxicants: Four thousand six hundred compounds were screened at the start of a search for substances capable of destroying larval sea lampreys in streams without injuring fishes. Eight were discovered that exhibited strong differential toxicity toward larval lampreys, and of these, two gave particular promise. Toxicity studies of structurally related chemicals have brought to light four additional compounds of great promise. Investigations have been made of such field problems as the methods of metering and of measuring concentrations in the water.

Other lamprey research has included experimental and descriptive embryology and the histology of the digestive tract.

Fishery Investigations: The research vessel Cisco completed her second season of work on Lake Michigan in the late fall of 1955. Data from the Cisco cruises provided a basis for comparison of the present status of the chub (deep-water cisco) stocks with conditions at the time of a 1930-32 survey.

Lake trout reduction has had three major effects on chub stocks in Lake Michigan: the bloater, smallest and least valuable of the seven chub species, was relieved of the heavy predation it felt as

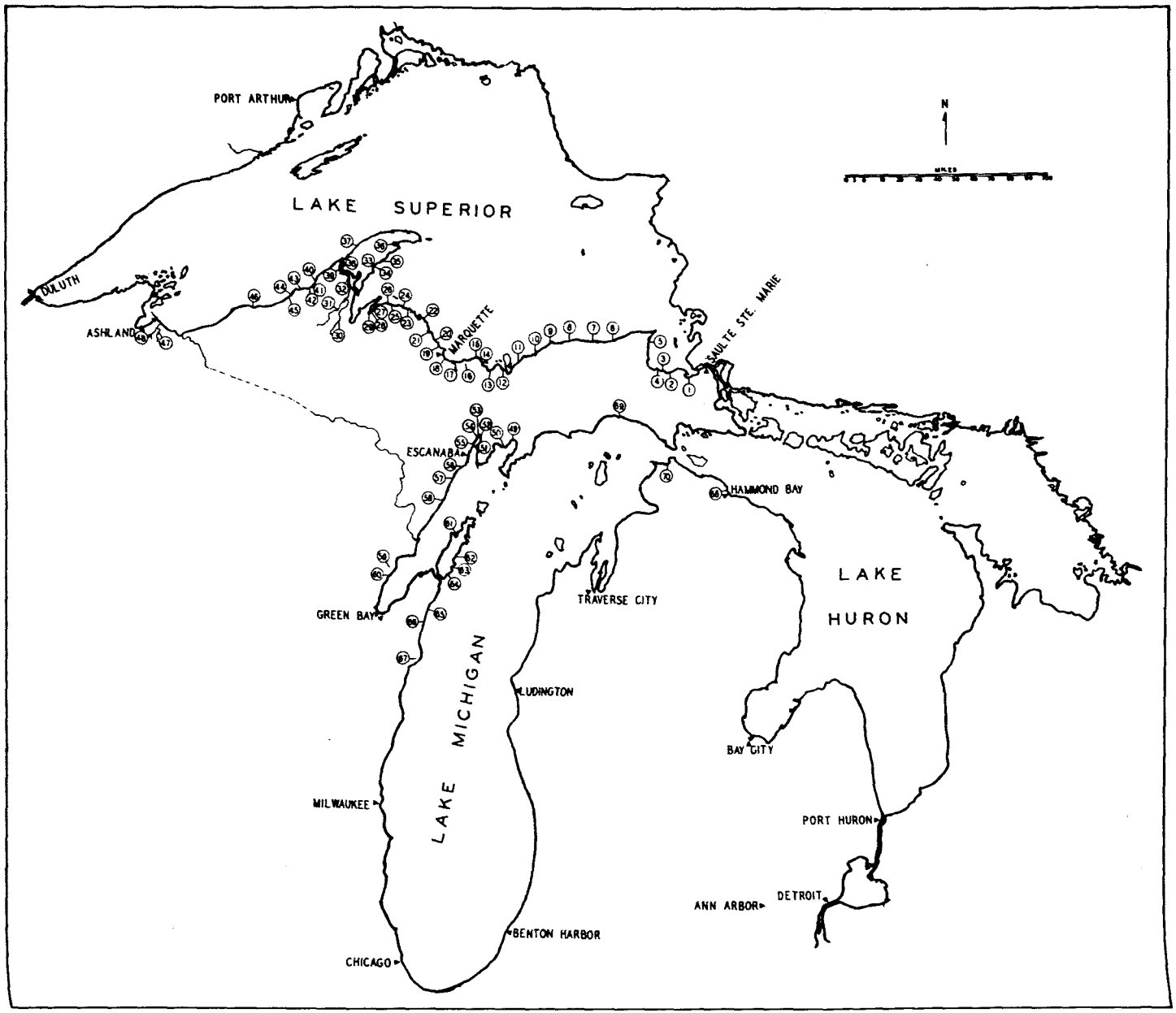


Fig. 1--Map of the Great Lakes showing locations of sea lamprey control devices.

principal food of the trout; the lampreys, having eliminated most of the trout, turned to chubs as food, concentrating on the larger species and individuals; fishermen who formerly took trout changed to chub fishing, placing still more pressure on the larger chubs. These effects created a deterioration of chub stocks. The worthless bloater is three times as plentiful currently than in 1930-32 while marketable chubs are only one-third as abundant. The outlook for the chub stocks is a dark one as long as lampreys are numerous and lake trout scarce.

As part of the study of the physical, chemical and biological conditions of the lakes a limnological-fishery survey was made of Saginaw Bay and adjacent waters of Lake Huron. Included in the schedule was a series of synoptic studies (conducted with the State of Michigan) in which limnological observations are made simultaneously along three transects in the Bay. Data collected from Lake Michigan are being processed in a similar study.

Fishery Research: Publications have been issued, papers are in press or manuscripts are in preparation on nearly all available materials on the natural history of lake trout. Work on the major remaining project, food habits of Lake Superior trout, is nearing completion.

Research in Green Bay, off Lake Michigan, continues to center on yellow perch, the principal commercial species in the southern area and important throughout the Bay. Controversy as to management of this fishery led to the start of the Green Bay Project (with the State of Wisconsin) in 1948. The controversy diminished sharply in 1952 when, on the basis of early findings, the size limit in southern Green Bay was reduced from eight to seven and one-half inches. Population studies since then reveal no significant changes in size, age or rate of growth. The one demonstrated effect has been a more than twofold increase of population.

Saginaw Bay investigations (aside from the 1956 survey) are limited to studies of fluctuations in growth and abundance of walleyes and yellow perch. Findings to date give evidence that growth and year-class strength of both species are influenced strongly by such environmental factors as temperature, precipitation, water level, wind and turbidity.

Work has been resumed on the reading of the accumulation of scale samples from commercial landings of the principal species of Lake Erie fish, collected each fall since 1943. Plans call for an improvement in the sampling procedure to give broader coverage and more useful materials. This change is in accordance with the plan of the Lake Erie Fish Management Committee for a coordinated attack by all interested agencies on the problems of the Lake Erie fisheries.

Fishery Statistics: Tabulations of catch and effort and computations of catch per unit of effort for principal species have been completed for 1955 for the Great Lakes waters of New York, Pennsylvania, Michigan, Indiana, Illinois and Wisconsin. Ontario, Ohio, and Minnesota do this work for their own fisheries, following procedures developed by the Great Lakes Investigations Staff. Also continued has been the tabulation of the pounds and value of the catch in the United States waters of the Great Lakes for publication by the Branch of Commercial Fisheries.

CALIFORNIA-NEVADA INLAND FISHERY INVESTIGATIONS

The California-Nevada Inland Fishery Investigations, headquartered at Reno, Nevada, provides experimental information for improving management of stream-stocked, catchable-sized trout, and bettering management of alpine trout lakes.

A mile long, four section, experimental stream area is used for studies of stream carrying capacity and the trout vitality-viability complex. The stream is subject to complete screen control and, by draining, to population counts. New methods and techniques for assessing lake productivity are tested on alpine lakes of

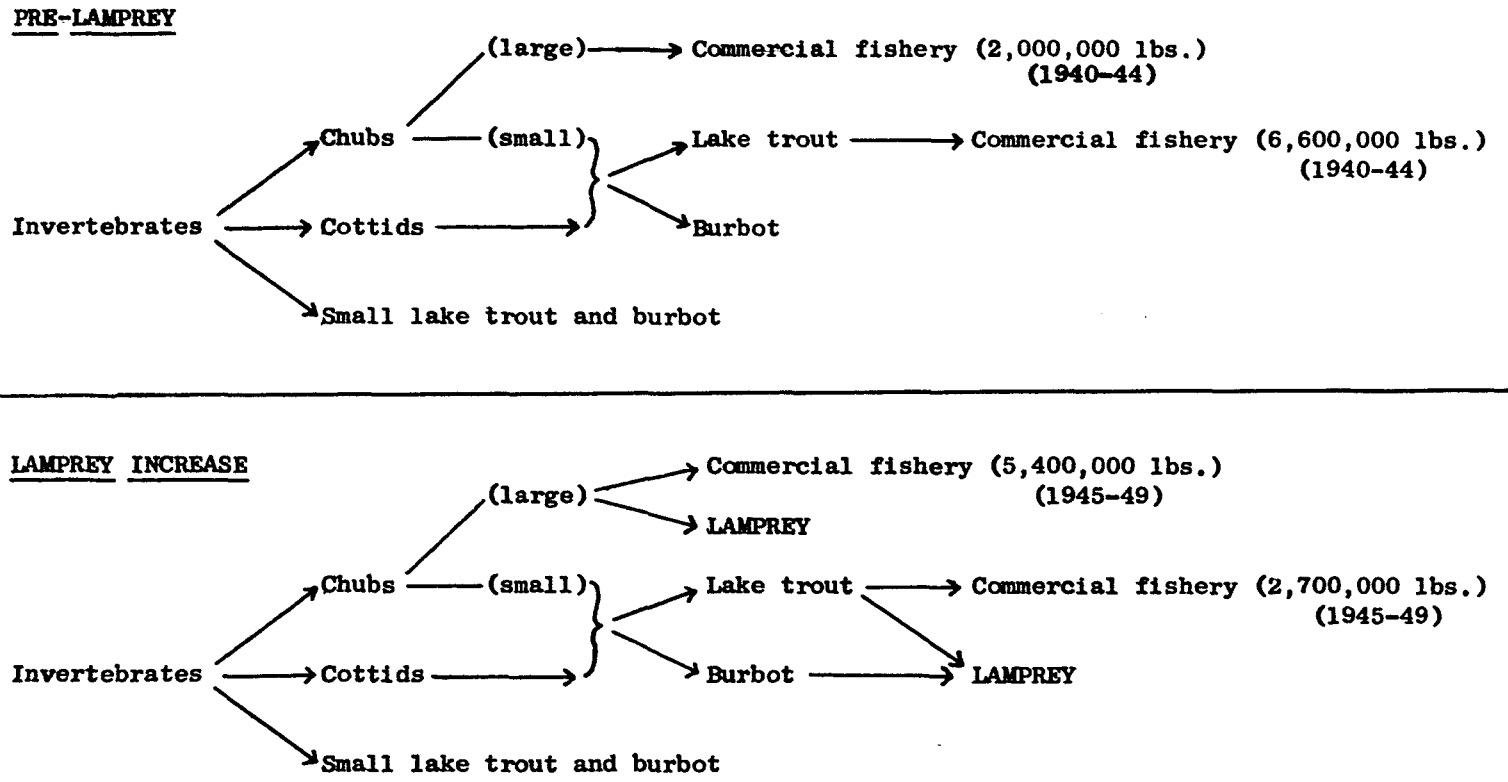


Fig. 2--Diagram of changes in trophic relationships in Lake Michigan resulting from the invasion of the sea lamprey.

the eastern Sierra Nevada range and on lakes in New York State.

Trout Survival: Over-winter survival of catchable-size rainbow trout reared at the Hot Creek Hatchery of the California Department of Fish and Game and stocked in the experimental stream sections at monthly intervals from August 1 to November 1, 1955, was excellent. Stocking was at the observed natural density of 120 pounds per acre, and results indicated that the best over-winter returns can be expected if the trout are stocked after seasonal cooling of the stream has begun. The four lots of trout survived at the following rates: August 1 - 62.6 percent; September 1 - 84.9 percent; October 1 - 88.2 percent, and November 1 - 88.6 percent. Mean water temperatures of these four months were, in order, 64.6, 59.6, 52.4 and 42.6° F. The disparity between survival of the August first lot and that of all three later lots indicates that time in the stream is not the most important determinant of loss over the experimental period.

Each lot of trout was apportioned to the four stream sections on the basis of weight per area to determine relative fitness of the stream areas, which varied in number and quality of pools. Differences in over-winter survival and loss of body condition among stream sections were small and were not related to assessments of pool quality.

All lots of trout declined drastically in body condition (30.7-38.5 percent). These losses were related to decreases in weight more than to increases in length, and were proportional to the respective times of residence in the stream. Nearly all survivors in June were in sufficiently good condition to permit full nutritional recoveries during the growing season.

Results of four one-year-long trout survival studies using catchable-size, hatchery-reared rainbow trout alone and in combination with stream-resident brown trout of the same size, at stocking densities ranging from 50 to 250 pounds per acre, and two years of fall stocking experiments with rainbow trout have demonstrated that:

1. Hatchery-reared rainbow trout have physical vitality and stamina equal to that of the wild brown trout.

2. Hatchery-reared trout are fully capable of competing with wild trout for 12-month or shorter periods even though they are compelled to make rather drastic adaptations to the wild and entirely foreign environment.

3. Stocking density is not an influential factor on survival within the time periods and population density ranges tested.

4. Fall-stocked, hatchery-reared rainbow trout have higher survival levels than those stocked during the spring months, considering equal stream residence periods.

Food Survival Relationship: Two experiments were completed during the year in a continuing investigation of specific factors influencing survival of catchable-size trout in streams, with emphasis on food problems. Groups of 50 wild brown trout and hatchery rainbow trout were starved for periods of four and six months through warm-water and cold-water seasons. Starvation trials initiated July 1, 1955, resulted in decimation of wild brown trout (82% mortality in 120 days) but slight loss of well-nourished hatchery trout (2% mortality in 120 days) with comparable losses in body condition (20 and 26 percent respectively). Over-winter starvation tests initiated October 14, 1955, resulted in eight percent mortality of brown trout and two percent mortality of hatchery rainbow trout in 180 days, with a 20 percent reduction of body condition in both species. Regular feeding, initiated at 180 days, resulted in almost complete nutritional recoveries after 56 days.

One hundred hatchery rainbow trout held over-winter in a quiet pool survived at the rate of 100 percent as contrasted

with rates of 62.6-88.6 percent for groups of hatchery rainbows tested in the exposed stream area for equivalent periods. Available natural food was scarce in both situations, but the stream groups were exposed to added physical hazards (crushing, stranding, freezing--resulting in exhaustion and suffocation) brought about by ice action and streamflow stoppages.

Organization of data from three years of winter food studies, trout digestion experiments and several starvation experiments provided these conclusions on trout food-survival relationship:

1. In streams exposed to heavy snow and various stream-ice formations, available trout food may be very scarce for two to four winter months.

2. In such streams, feeding continues in critical winter months at lowest possible water temperatures; but trout stomachs contain very little food and a large proportion of nonnutritious debris.

3. Digestion of food by trout is very slow at low water temperatures, and the ability of stream trout to maintain body condition in cold winters (assuming food is available) is controlled to a considerable extent by the rates of digestion and assimilation.

4. Trout are adapted to and are capable of several months of fasting or partial fasting in the cold-water season. Under starvation conditions, fat and well-nourished hatchery trout are superior to seasonally stream-conditioned wild trout in vitality and viability.

5. Food is indicated as a secondary and qualitative factor in winter trout survival. Physical deterioration of the habitat (low water, drying, freezing, snowbank collapse) is indicated as the most important trout mortality agent in swift streams which are subject to cold winters.

Because the literature abounds with evidence contrary to the results of these experiments, it seems apparent there must be something unique, or at least unusual, in the rainbow trout stocks, or in the hatchery and its operational procedures, or both, that resulted in the production of trout of superior quality. Continued experiments will seek to determine the factors contributing to these differences.

Studies to identify and determine distribution of periphyton organisms among the 10 lakes of the Convict Creek Basin have thus far led to identification of 40 genera, representing 20 families. These include 10 families and 20 genera of diatoms; five families and 15 genera of green algae, and four families and five genera of blue-green algae. Two genera of rotifers and one genus of a ciliate protozoan have been found and 15 organisms have not been identified.

A detailed study of the role of trace elements in the productivity of alpine lakes is being conducted in collaboration with the Service's Trout Nutrition Laboratory at Cortland, New York. Involved is the analysis of water and periphyton samples collected from the lakes in Convict Creek Basin.

ROCKY MOUNTAIN FISHERY INVESTIGATIONS

The Rocky Mountain Fishery Investigations at Logan, Utah, is concerned with the development of biological knowledge necessary for the recommendation of sound fishery management practices for the heavily fished waters of Yellowstone National Park. Work is closely coordinated with the policies and plans of the National Park Service.

Grebe Lake: The greyling and rainbow trout of Grebe Lake were studied as in former years by counts and statistical estimates of fish in the lake and its spawning tributaries to determine trends in abundance of adults and survival of immatures. A record number of greyling

spawners ascending the principal tributary shows the reproductive potential to be relatively stable. Spawners were recorded as 5,416 in 1953 and 6,207 in 1956.

Fishing pressure and harvest have increased since 1953, but the harvest has not yet exceeded seven percent of the population in the years of measurement, so there appears to be little immediate danger from excessive exploitation.

Relationships between rainbow and greyling were examined in 1955-56 with no evidence that the rainbow are seriously reducing greyling numbers at present population levels.

Experiments in planting eyed greyling eggs in a Grebe Lake tributary revealed that production of fry was approximately the same as from plants in Grebe Lake itself.

The conclusion reached as a result of 1956 studies is that Grebe Lake is safely managed and that a greater harvest appears feasible and desirable.

Madison River System: Salmonoid fishes in the Madison, Firehole and Gibbon Rivers were studied as part of a long-term program testing planting practices. Rainbow and brown trout of various sizes were marked and planted in these streams in connection with regularly scheduled plants, and fishery workers patrolled the stream to determine the numbers of marked fish caught by fishermen. Thus far there is good agreement with former years, showing that fingerling rainbow and brown trout planted in the streams do not contribute to the creel in any measurable numbers. Yearling rainbows contribute about 45 percent of the Madison River rainbow catch the year they are planted, but very few survive the river to enter the creel the following season. Marked fish work also established that only about 15 percent of the 25,000 yearling rainbows planted in the Madison River were caught in 1954 and 1955. This indicates that heavier fishing pressure may by advisable.

Electric shocking of these streams in the spring of 1956 showed a great abundance of fingerling brown and rainbow trout, but no marked fish were recovered. Evidently natural reproduction was responsible for practically all of the fish, since those planted in 1955 were not found in the streams in 1956 in significant numbers.

Squaw Lake: Advanced fry have been planted in Squaw Lake for several years without measurement of the success of the stocking. In the spring of 1956 studies began to measure the harvest and the characteristics of the catch from the lake. Materials for aging the fish have been collected, and some measure of the population and size will be undertaken later.

Yellowstone Lake: The measurements that indicate to us the relative condition of the cutthroat trout population in Yellowstone Lake have been encouraging this year. The numbers of spawners entering tributaries to the lake seem high. Fishing success in the 1955 season was the highest measured since 1949, with a catch-per-hour figure of 0.671. Fishing pressure was high, with 520,898 hours of fishing, and the catch, 349,757 fish, was the largest yet counted. The outlook for future years is good, judging by summer, 1955, stream conditions and by the relatively large concentrations of yearling trout observed on the shoreline in 1955. These indications suggest that the management regulations inaugurated in 1953 are beginning to have desirable results.

Yellowstone Lake limnological work in 1955 yielded clues as to the most productive parts of the lake. Temperature and food studies showed differences from place to place and revealed that the central and northern portions of the lake contain the most abundant supplies of fish food. Mapping of the bottom of Yellowstone Lake is being continued as an aid in relating physical and chemical features of the lake to the distribution of fish foods and fish.

Insecticide Studies: Aerial spraying for spruce budworm was done in the Yellowstone drainage area in July 1955, and dead fish were found in the Yellowstone River in great numbers in October of the same year. The conclusion reached was that DDT was probably responsible for the fish kill, but the mechanism of the toxicity was not understood. The Forest Service undertook a mortality study in connection with 1956 spray operations, and the Rocky Mountain Investigations and the Montana Fish and Game Department offered cooperation. Results of this study will be closely watched in many areas where spraying is done.

TROUT NUTRITION INVESTIGATIONS

The Trout Nutrition Investigations, at Cortland, New York, seeks countermeasures for increasing hatchery food costs and the unavailability of many food products utilized in the past. Fat, protein, carbohydrate metabilism and the vitamin and mineral requirements of trout are studied to provide data that may be applied in the preparation of diets for hatchery trout. An understanding of nutritional requirements permit development of new feeding techniques which reduce food storage costs as well as preparation time and the labor of feeding fish. Many hatchery trout mortalities are of nutritional origin and the application of the findings of the investigations may prevent the appearance of these disorders.

Vitamin Requirements: Vitamin omission studies with a synthetic diet have established the need of brown trout for inositol, pyridoxine, niacin, choline, riboflavin, folic acid, biotin and B_{12}.

Since the vitamin B requirements are now known for brook, brown and rainbow trout, the completion of studies underway on lake trout and Atlantic salmon will provide data on the vitamin B complex requirement for all of the species of cold water fishes cultured on the east coast.

Minerals: Radio-active tracers have been used to study the uptake of minerals by brook trout from [illegible] and water.

The absorption of radio-active cobalt from the water has been correlated with metabolic activity and it has been found that the greater the metabolic activity, the greater the degree of absorption. The cobalt is deposited in the gastro-intestinal tract and absorption is at the gills.

Starving brook trout absorb less calcium from the water than feeding trout, indicating a conservation metabolism during starvation. After one week of starvation the metabolic activity of the fish (measured by calcium absorption) is greater than after three weeks of starvation. Brook trout absorb more calcium from low level than from high level calcium diets.

Experiments are underway to continue study of the influence of dissolved minerals on the osmoregulation and metabolism of the trout's body. These studies are extremely important in hatchery and stream management improvement. Previous studies have shown that calcium does have as osmoregulatory function in trout and that through this function, the survival and growth of the fish may be effected by its metabolic activity.

Chemistry: Chemical comparison of hatchery and wild brook trout indicate that wild trout have more protein and ash and less fat in their bodies than hatchery trout, indicating more true flesh production in wild trout. A speculative comparison of the protein conversions shows natural food to be more efficient than hatchery food. The protein conversion of hatchery food is approximately twice that of natural food.

Feeding trials with live brine shrimp have produced excellent total conversions of food into fish flesh. Analyses are underway to determine the chemical content of trout-fed shrimp and those fed the regular hatchery diet. These studies will help to confirm or reject the observations made upon the efficiency of natural as compared to hatchery foods.

A chemical embryological study of developing brown trout eggs has shown

changes in protein, fat and water content during incubation. Ash content and iodine number of the fat of the egg remain unchanged. The wet weight of the egg decreases during incubation. Increased fat content and decreased protein storage are utilized for the formation of fat within the embryo. A definite shift in metabolic activity within the egg during development is indicated. Eggs used in these analyses were spawned from adults under light control and it is possible that some of these observations are caused by induced early spawning.

Feeding Trials: Food pellets for hatchery trout are a recent development and have led to reduced conversions, (of food to fish flesh) reduced labor cost for feeding and food preparation and growth rates and mortalities equal to standard diets. Fresh meat must be fed with the present pellet available for hatchery use.

Preliminary experiments have indicated good promise for a heavily fortified pellet designed to provide high levels of all members of the vitamin B complex and minerals.

The usual protein content of hatchery diets is between 28 and 35 percent. This is high in comparison with the protein needs of other animals. A newly designed pellet has a low (18%) protein content and, if tests prove successful, may reduce the diet cost for hatchery trout.

The preservation of meat by radioactive sterilization is being studied to determine if meat so sterilized is nutritionally adequate for trout. Success of this method would eliminate hatchery freezing facilities, and its potential is of importance for, even if fortified pellets are successful, meat will be necessary for small trout for the first few months of their lives.

Service School: The 11th session of a seven and one-half month In-Service Training School for fish culturists was completed during the year. Four Service fish culturists and one each representing Connecticut and New York completed the course, which covered most of the procedures involved in hatchery and fish-culture operations.

SALMON NUTRITION LABORATORY

Some of the work of the Salmon Nutrition Laboratory is being conducted in temporary experimental facilities at the Federal hatchery at Hagerman, Idaho, because of the favorable water temperatures (58° F.) which are ideal for vitamin and amino acid studies.

Vitamin Requirements: Tentative conclusions from a study of the qualitative fat-soluble vitamin requirements of chinook salmon indicate vitamins A and K are required. This study has produced the first evidence of vitamin D deficiency syndromes.

Experiments have been initiated with chinook salmon to determine quantative levels for 10 required water-soluble vitamins. Indication to date are that levels for at least five of the 10 vitamins will be determined from this set of experiments. Chemical and histological analysis of samples periodically removed from each subgroup will be assayed during the next research year and will be used to corroborate feeding trials. Levels of vitamins stored in the liver and body tissue will be assayed microbiologically. Histological analysis of serially sectioned tissues will be surveyed for deficiency syndromes and proximate analysis will be added to the information on general body chemistry.

Amino Acid Requirements: An amino acid test diet was developed which maintained fish for a period sufficient for the detection of any amino acid deficiency syndrome. Cooperative research with Purdue University has qualitated the amino acid requirements and shown that of 18 common amino acids, 10 (arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tyrosine and valine) are required for life and growth in chinook salmon.

Salmon Chromatography: Techniques have been developed for routine paper chromatography for free amino acids in muscle tissue. Soon surveys of the free

amino acid content of salmon tissue will be available for use as a tool for racial identification. Introductory work has been initiated on ultra violet sensitive materials in the tissues and paper chromatography investigations will be expanded to include pigments and tissue proteins.

Inorganic Requirements: A flame photometer has been used with those elements with characteristic emission spectra excitable by the oxy-hydrogen flame to determine metal ion concentration in food, water, tissues and body fluids of experimental fish.

Standard curves for sodium and calcium have been completed as well as the interference of calcium, potassium and magnesium on sodium emission and the interference of sodium, potassium and magnesium on calcium emission.

Histology: To utilize histological techniques in disease, nutritional or physiological studies with fish, it was first necessary to examine tissues from normal fish. An extensive collection was made of wild and hatchery salmonids representing all species of importance of the Pacific Coast. This material was sectioned and stained, and now forms a complete collection of normal fish tissues from salmon and trout. The collection is available on loan to other investigators.

The effects of specific amino acid deficiencies on tissues in general and wound healing in particular are under study. The techniques of this work, which is nearing completion, may be applied to all nutritional experiments contemplated in the future.

A histological and chemical study of hatchery reared and wild fish, based on 150 samples from the normal tissue collection, showed that, in general, hatchery fish were much fatter and had markedly lower protein and mineral values than did the wild fish. This phenomenon was further investigated by observing the changes which took place in a group of hatchery-reared silver salmon after planting and by comparing them with wild fish from the parent stock. After three months of hatchery life, the fish were over three times as fat as wild fish of the same age. If planted at this time, the hatchery fish transformed fairly rapidly and resembled the wild fish three months later. However, if retained in the hatchery for six months, it took at least six months to complete the transformation. Fish reared for periods of nine and 12 months failed to make the complete transformation by the time of ocean migration at 14 months. These latter groups had a markedly lower survival in the ocean than did either wild fish or the apparently completely transformed hatchery fish. There is definite indication that hatchery fish are physiologically handicapped by their environment.

Histophysiology and Histochemistry: An example of acute sulfonamide toxicity related to a single sulfamethazine treatment was recently observed. Since sulfonamides are used with increasing frequency in the treatment of fish diseases, a short investigation of acute toxicity was conducted. The results indicate that an ever-present possibility of mortality and tissue damage from overdosage exists.

Studies are being made on a group of fall chinook salmon now completing their fourth year in fresh water to determine what factors would be instrumental in their survival and sexual maturation in fresh water. The fish now have an average weight of 300 grams, a maximum weight of 600 grams and the males are beginning to mature. The potential value of methods for supplying fall chinook eggs independent of a natural run are apparent.

Neoplasms: Abnormal cellular growths, called neoplasms, are important as a clue to fish mortalities of unknown etiology. Malignant cancers have been observed, for example, in ocean-caught salmon. Neoplastic studies of fish are also valuable as they may offer a unique experimental animal for studies with human cancers. For example, any water soluble carcinogen can be placed in an aquarium in constant contact with the surface, respiratory and oral epithelium--a condition difficult to attain with mammalian screening tests.

In view of the recent information on the carcinogenic effects of urethane, an experiment was designed to test its possible effect on fish. After 50 successive anesthetizations over a 10-week period, a group of guppies have not shown any adverse effects. The period is as yet insufficient to record the experiment as negative.

Histopathology: More than 50 diagnostic studies were made on experimental material from the Eastern and Western Fish Disease Investigations. Pathological examinations were made of mortalities from nutritional and physiological experiments and several autopsies were performed to determine the cause of death of salmon in the vicinity of dams. An investigation of the age of net mark scars was conducted for the North Pacific International Fisheries Commission.

WESTERN FISH DISEASE LABORATORY

The Western Fish Disease Laboratory, with headquarters at the University of Washington, at Seattle, deals with fish disease problems in States west of the Mississippi River. In recent years it has been engaged in an extensive study of the problems of the Columbia River System.

Sockeye Virus: The 1955-56 season marks the second straight year without a single known outbreak of sockeye "virus" disease, which in past years brought severe mortalities to many western hatcheries. The Coleman, Calif., and Carson, Wash., hatcheries are currently experiencing severe losses from an infectious disease of unknown etiology which, to date, seems to bear only a partial resemblence to the explosive "virus" epizootics experienced from 1951-53.

Experiments on the sockeye "virus" set up with cooperating laboratories, have been halted by the absence of the sockeye agent in both laboratory and nature. They will be revived should a recurrence be noted.

A survey of returning 1951 year class sockeyes for indications of the causative agent of that year's epizootic was negative. Examination of a large number of returnees at Lake Wenatchee, Wash., where the original hatchery plant had been 100 percent marked, failed to produce a single marked fish, confirming suspicions that the fish were a wild population and indicating that the 1951 outbreak was confined to hatchery-reared fish. In view of these findings, it appears that the taboo against planting diseased fish should be reconsidered. Speedy planting would save many fish with no more contamination of the water supply than would result from holding entire stocks through the epizootic period.

Parasite Check List: A parasite check-list was developed as part of an International North Pacific Fisheries Commission (INPFC) project for the identification of salmon by parasitological methods. Collections made in the development of this list constitute the most impressive survey of to date of wild populations. Although intended primarily as a tool for racial separation, the check-list will be of great value in the field of fish diseases.

Kidney Disease: Kidney smears from the fish examined in the INPFC project were used in a pilot survey of kidney disease incidence. After nearly 1,000 negative reports from tests for the diseased organism and/or acid fast bacteria, the tests were terminated with the conclusion that incidence of diseased organisms is not a reliable method for racial identification.

A survey of chinook salmon captured in the lower reaches of the Columbia River provided scattered evidence that acid-fast bacteria is primarily endogenous to fresh water. Other information from this continuing study suggests that kidney disease is contracted early and remains throughout the life of a fish.

A common soil organism, genus Nocardia, has been tentatively identified from two recent isolates of a gram positive, acid fast, pathogen. This identification completes a mycobacterial spectrum ranging from the frank Streptomycete to true mycobacteria. Because the organism responsible for "fish handler's

disease", a painful skin eruption striking employees of fishery plants, has, at times, been included in this group, more exact classification is considered desirable. The degrees of specificity and overlapping are unknown, and a serological approach is considered the most promising key to their definition. Preparation of purified protein antigens is underway, but are notoriously tricky, and no real progress is expected for some time.

Kidney disease reports have been steadily mounting, possibly reflecting an increase in incidence, possibly an increase in recognition. With the development of a suitable culture media, sufficient numbers of pure cells have been made available for use as antigens in a serological approach to the study of the kidney disease organism.

In order to learn if the various pathogens involved in this disease are the same or different, cultures from two sources in Washington, one in Idaho and one in California are under study. Comparisons are in progress of their morphology, biochemical reactions, drug sensitivity and pathogenicity.

Long-Range Studies: Almost all fish diseases are caused by endogenous waterborne organisms, and long-range considerations are of possible prevention of these diseases. Toward this end, and to obtain disease-free fish for immediate research, several thousand sockeyes were reared on a beef liver diet in troughs supplied with well water. These fish have remained disease free for a six-month period and all seem vigorous and of uniform size. While a wide gap remains between laboratory and hatchery conditions, these results encourage consideration of large scale semifiltration of water for hatchery use.

MICROBIOLOGICAL LABORATORY

The Microbiological Laboratory located at the Fisheries Experimental Station at Leetown, W. Va., serves the eastern United States as a center for research on the nature, treatment and prevention of infectious fish diseases. Courses in fish diseases, including diagnosis, methods of treatment and general control, are conducted for Federal, State and privately employed fishery biologists and fish culturists. Within the limits of time, facilities and personnel, the role of micro-organisms in the turnover of organic and mineral materials in water is being studied. This knowledge should provide a better understanding of microbiological processes as a basis for development of more efficient production of fishes in warm water ponds.

Blue-sac Disease: A three-year series of experiments dealing with blue-sac disease have been completed. Tissue culture tests have not shown evidence of viral agents in blue-sac fluid. Previous work had indicated that bacteria were not the cause of the disease. The experiments provided additional confirmation of this. Blue-sac disease was routinely induced among trout under closed system incubation in which products of egg and sac fry metabolism accumulated. Filtration of the water through charcoal in a closed system reduced the incidence of the disease. Blue-sac disease incidence increased significantly when ammonium hydroxide alone or in combination with urea was added to the water in which eggs were incubated.

The conclusion is that products of metabolism excreted by hatching eggs should be considered as a casual factor in the incidence of blue-sac disease. The results of the tests with ammonia and urea indicate that they may be identical or similar with some of the products of egg metabolism. Attempts will be made to qualitatively determine this similarity.

Infectious Pancreatic Necrosis: Infectious pancreatic necrosis is a disease of very young salmonid fishes. Losses caused by it may reach 80 percent. Results of studies to date indicate that it is probably a virus disease. Histopathological examinations have revealed necrotic areas in the pancreas and in the voluntary muscles. Lesions are of the same type as those found in suckling mice infected with viruses belonging to the Coxsackie group.

The need for research on fish diseases caused by viruses led to development of techniques for tissue culture studies, a

basic approach to virus studies. In the course of this work a piece of a goldfish heart was kept alive and beating for almost a year.

Kidney Disease: Kidney disease in salmonid fishes is of considerable economic importance. It has caused heavy mortalities at most of the northwestern salmon hatcheries and seriously interferes with brook trout production in the northeast. Goals of kidney disease studies have been a better understanding of the pathogen and a determination of geographical distribution of the disease.

At Leetown kidney disease can be maintained only by parenteral introduction of the infectious material into the salmonid fishes. At hatcheries further north it spreads spontaneously. Some non-salmonid fishes such as bluegill, goldfish and the only channel catfish tested were found to be refractory even to parenteral inoculation.

The spread of reports of the disease to inland stations at South Dakota and Michigan raised doubt that the original reservoir of the disease was the oceans and made imperative a survey of the disease in the central States. In April 1956, a survey encompassed seven Federal and five State hatcheries in an area roughly bounded by West Virginia, Iowa, Utah, South Dakota, Minnesota and Michigan. Kidney disease was presumptively identified at seven hatcheries in Iowa, Nebraska, Wyoming, South Dakota, Minnesota, Michigan and Wisconsin. Five of these were new records of occurrence.

Cultures of the kidney disease organism were furnished by Dr. E. J. Ordal of the Department of Microbiology, University of Washington. Dr. Ordal also provided his formula for a medium upon which the organism can be cultivated. Cultures have since been carried with difficulty through four transfers at Leetown, and preliminary trials are now in progress wherein the in vitro antibiotic sensitivity of the organism is being determined.

Fish Furunculosis: Furunculosis experiments conducted by the late Dr. Louis Wolf established that in the Eastern United States there are strains of brook trout which are susceptible and other strains which are resistant to furunculosis and ulcer disease. In general, inheritable resistance to one infectious disease is independent of the resistance to other diseases. If a certain strain of animal or plant is resistant at the same time to more than one disease, it is purely coincidental, unless the pathogens are serologically related.

Three strains of fingerling brook trout were tested for resistance to ulcer disease and furunculosis. Test sites were the Federal hatcheries at Erwin, Tenn., and Berlin, N. H., and a State hatchery at Bellefonte, Pa. Six weeks after challenging with pure cultures of the pathogens the percentage losses at each site were: Erwin, 94; Berlin, 86; and Bellefonte, 12. Aeromonas salmonicida, which causes furunculosis, was present at Bellefonte without causing trout mortalities attributable to that disease.

Fig. 3--Taking blood from an adult rainbow trout by means of heart puncture.

On the basis of these tests, crosses were made at another hatchery between brook trout from Bellefonte and Berlin hatcheries. The fertilized eggs were sent to Leetown for tests. When the resulting fingerlings were challenged with pathogens, losses due to furunculosis were very high, showing that there was little inherited resistance to the disease among the tested trout.

Drug Resistance: The drug resistance of A. salmonicida has been subject of another series of experiments, now nearing completion. It is a well-established fact

that most pathogenic bacteria are likely to develop drug resistance, particularly if the treatment is carried out for a prolonged period of time, at frequent intervals, or with gradually increasing drug dosages. From outbreaks at Leetown and other hatcheries, about 80 cultures of A. salmonicida were isolated and tested. A method was developed for testing A. salmonicida's sulfonamide sensitivity which can be used with little experience in the hatchery. When applied to the collection of cultures, this method provided information that most of the cultures isolated from outbreaks of furunculosis which were refractory to treatment with sulfonamides were sulfa resistant in vitro. Cultures isolated during outbreaks of furunculosis which responded to sulfa therapy generally proved to be inhibited by sulfonamides in vitro. Impregnated filter paper disks for most commercially available antibiotics are available from several sources. They permit testing of a wide variety of antibiotics for effectiveness against a bacteria pathogenic for fish.

Consulting Service: During the research year a survey of the fish disease problems in warm-water fish culture in the south was completed. A report on visits with some of the largest private pond-fish producers was prepared in January 1956, under the title "Report on the Problem of Diseases in Warm-Water Fish Ponds, Minnow Hatcheries in Particular". The report contains recommendations that facilities should be expanded to include research and consulting services on diseases of warm-water and aquarium fishes.

SALMON-CULTURAL LABORATORY

The Salmon-Cultural Laboratory at Entiat, Washington, seeks improvement of fish-cultural procedures. Investigations pertinent to this field are conducted in nutrition, physiology and hatchery techniques.

Feeding Trials: Experimental feeding trials indicate that the addition of five percent of distiller's solubles to the coldwater diet of chinook salmon fingerling is effective in the elimination of the anemia normally encountered in this species in May and June.

The loss of water-soluble diet components before they are consumed by fish is a serious problem in all nutrition experiments. In a side-study seeking adequate means for binding diets ten commercial binding agents are being subjected to preliminary tests.

Salmon Maturation: Two methods of accelerating sexual maturation of adult salmon are under test. The first employs injected hormones derived from the salmon pituitary, and the second relies on physical stimulation as represented by the seasonal variation in the amount of daylight.

The use of injected gonadotrophins derived from the fractionated salmon pituitary proved ineffective and harmful in 1955 experiments. Premature aging and death of the injected fish is thought to have resulted from an excess of ACTH contained in the fraction of the salmon pituitaries used in the injections. Removal of the ACTH from the gonadotrophic fraction of the pituitary is now under investigation.

Fig. 4--Injecting hormones into a salmon.

More promise is shown by salmon response to the effect of light. Blueback salmon exposed to continuous light for a two-month period prior to the normal spawning time were retarded in their sexual maturation, spawning one month later than the control group. The assumption that if abnormally long light exposure will retard maturation, then

abnormally short exposure should accelerate maturation will be explored in future experiments.

Diversion and Retention: The use of an electrical field for the diversion of adult salmon and trout on an upstream migration has wide applicability. Because it is easy to install, economical to operate and a positive fish barrier under all conditions, it is superior to any other type weir developed to dated.

Several applications of the Entiat electrical diversion weir are now in use or contemplated. Two, one at the Service's Quilcene, Washington, station and the other at an Alaska Fish Commission station near Ketchikan, have proved successful. Additional weirs are proposed at Service and State installations.

Rearing Pond Design: A new type rearing pond, retangular in form and employing turning vanes to direct the recirculating water path, has been developed. Hydraulic evaluations of a scale model indicated that, hydraulically, the pond is superior to any of the type ponds now in common useage. Biological and physical efficiency tests are now in progress on a prototype pond.

Methods for improving hydraulic patterns in existing pond types are being developed. Length, width, depth and volume of inflow are all factors which affect the efficiency of the raceway pond. Improvements in the Foster-Lucas pond may be made by concentrating the inflow and redesigning the center wall.

The self-cleaning action of the pond is one important criteria used in pond type comparisons. Pond screens in common use are made of either hardware cloth or plate preforated with round holes. Both these types are inefficient in that they plug readily. Tests were conducted on 30 variations of two main types of preforated plate - the oblong hole or slot, and the round hole. Efficiency was judged on the basis of water passage, fish retention and self-cleaning ability.

As a result of these evaluations a screen was developed which is virtually self-cleaning. Incidental to the testing, a single trough screen was developed which is more efficient than the two sizes of preforated plate heretofore necessary to accommodate all sizes of fish in trough rearing.

Algicide Development: The control of green algae is a serious problem in fish rearing ponds which necessitates excessive scrubbing of ponds and even the transfer of fish from pond to pond. Algal growth, if unchecked, may become so luxuriant as to alter the flow pattern and retard the current creating an unfavorable environment for the fish. In order to control algal growth by periodic chemical applications without removing fish the toxic concentration of the chemical for control must be less than the toxic level for fish. Several chemicals are now being tested and two show promise of meeting the requirements.

Salmon Eggs: Most salmon hatcheries have little or no control over the water temperatures at which the eggs are incubated. Unfavorable temperatures, either high or low, may result in excessive mortalities.

The first phase of an experiment to determine threshold temperatures for normal salmon egg development was confined to chinook eggs and extended over three years. The eggs were incubated at constant temperatures ranging from 35.0°F to 60°F. The thresholds of normal development as measured by significant differences in mortality were found to be between 40° and 42.5°F at the lower limit and between 57.5° and 60°F at the upper limit. Eggs spawned and incubated at constant temperatures of 40° and below incur progressively higher mortalities until at 35°F the mortality is in excess of 99 percent. Because water temperatures rarely remain above 57.5°F throughout the egg incubation period, the effect of high water temperatures on chinook salmon eggs is difficult to define, but the inference from the experiments is that natural chinook spawning at stream

temperatures below 40°F are not suitable for the incubation of the eggs.

Time and Temperature: The hatching time of eggs is of importance in fish cultural operations in that the change from an immobile to a mobile form requires different methods of handling. Various methods for calculating the time of the hatch on the basis of the theory of thermal summation have all used 32°F as the threshold temperature for the measurement of development. These methods all show considerable variability between incubation time at different water temperatures.

Time records of the hatch of 30 lots of chinook salmon eggs incubated at constant temperatures of from 35.5° to 60°F were analyzed. The least variation in time of hatch occurred at a threshold temperature of 31.5°F. Under the conditions of the experimental data no significant difference existed between the accumulated thermal units required to hatch chinook eggs incubated at water temperatures ranging from 37.5° to 60°F. The theory of thermal summation, therefore, is applicable to the hatching time of chinook eggs providing a threshold temperature of 31°F is used. The application for fish-culturists is that chinook eggs incubated within the defined temperature range may be expected to start hatching after being exposed to 850 thermal units.

Squawfish Incubation: The recognition of juvenile squawfish is necessary in life history studies of this hatchery products predator. To provide positive identification squawfish eggs were incubated and the resulting fish reared. Samples were withdrawn at various stages of development and furnished to the Lower Columbia River Investigations for the formation of an identification key.

Squawfish eggs were incubated at constant water temperatures ranging from 55°F to 65°F at 2.5° intervals. A temperature of 55°F is very close to the lower threshold of normal development. The comparatively high incubating temperature required for squawfish eggs may be a significant factor in limiting the range of the species.

EASTERN FEDERAL WATERS INVESTIGATIONS

The Eastern Federal Waters Investigations, at Kearneysville, West Virginia, is concerned with the 700 miles of trout streams in the Shenandoah National Park and the Great Smoky Mountains National Park.

A program was established in 1953 for the study of native eastern brook trout, rainbow trout, and the factors which influence the fishery and productivity of park streams. Among the initial problems encountered were: increased fishing pressure coupled with declines in wild trout populations; severe reductions of fish in some streams due to flashflood and droughts; deficiencies in the National Park Service regulations governing fishing, and a lack of suitable methods and equipment for the survey of streams and the collection of fish in extremely soft waters.

Great Smoky Mountains National Park: The collection of creel information was resumed on the Little Pigeon River in 1955 and a new station was opened on Big Creek. These stations were reopened in 1956 with additional reports of fishing pressure and creel returns gathered from Little River, Oconaluftee River, and from Bradley Fork and the West Prong Little Pigeon, the two experimental streams restricted to "fishing for fun".

Little Pigeon River: The 1955 Little Pigeon creel coverage was estimated to be 79 percent complete and calculated total returns numbered 1,841 fishermen and 3,718 trout. One angler in five caught the daily limit of five fish, whereas two in five caught no fish of legal size. Tourist fishermen from 21 States and the District of Columbia were outnumbered seven to one by local Tennesseans on the stream and caught but 2.4 percent of the fish.

Fishing quality was not noticeably affected by the 1955-56 discontinuation of annual plants of from 1,000 to 1,700 fish. Successful fishermen made an average catch

of .09 fish per hour in 1954 and .08 per hour in 1955. Less than two percent difference existed between those who caught their limit and those who caught nothing in both years. Incomplete 1956 figures indicate an increase in fishing pressure and a greater yield of trout.

Heaviest fishing pressure on the Little Pigeon was along the five miles of river easily accessible by car. In 1955 this area was favored by 80 percent of the fishermen, leaving the remaining 43 miles of fishable waters to those hardy individuals who took to the trails.

Big Creek: Big Creek, an unstocked stream in North Carolina on the northeast side of Great Smoky, provided 43 percent of the fishermen who sought trout in its steep, rough, mainstream their limit. In all, 1,011 fishermen took 3,358 trout at an average catch per hour of effort rate of 0.9 fish. The 42 miles of fishable water in this excellent stream average 30.3 feet in width.

Big Creek is the only stream encountered so far in which rainbow trout outnumber and outweigh all other species combined. A trout population survey following the close of the 1954 fishing season showed 82.3 pounds per acre, a figure which, in 1955, jumped to 83.9 pounds per acre, including 37.3 pounds of legal size trout. The fish removed by anglers prior to the survey amounted to 15.9 pounds per acre.

Hazzard Plan: The Hazzard "Fish for Fun" plan calls for the release of all fish after capture and was offered as a remedy for declining populations of native or wild trout in waters where basic productivity is low or where fishing pressures are increasing beyond the capacity of the streams to support them.

First test of this plan has been in the Great Smoky Mountains National Park where two streams, Bradley Fork, a good trout stream, and the West Prong Little Pigeon, which needed protection to afford reasonable quality wild trout fishing, were selected. Since 1954 fishing has been permitted from May 16 to August 31 each year. Artificial lures are required and all fish caught must be returned to the stream unharmed. Early results show increased survival of larger fish. Length-frequency distribution of collected trout from Bradley Fork showed fish seven inches or longer increased from 10.2 percent in 1953 to 23.1 percent in 1955. The plan will be continued.

Age and Growth Studies: Age determinations made from the scales of 335 rainbow trout indicated that the great majority of fish of a given year class will achieve the minimum legal length (7") in their third year. Fish surviving their fourth summer average 10 inches. The oldest specimen observed thus far was an 18.2 inch female taken from Big Creek which was in its seventh year.

Population Estimates: Collections made in a 17 stream survey totaled 10,151 rainbow trout of from 2.5 to 18.4 inches long, and 751 brook trout 2.5 to 12.5 inches long. Estimates of standing populations ranged from 5.6 to 83.9 pounds per acre, with most waters showing a small gain over 1954 figures. The 1955 rainbow trout year class was generally small, however, in comparison with that of 1954.

Shenandoah National Park Stream Surveys: Drought conditions in Shenandoah National Park, while persistent, were less severe in 1955 than in previous years. The generally abundant young-of-the-year trout showed an increase in survival attributable to improved water conditions. Fall surveys of seven streams indicated trout populations ranging from 3.8 to 133.1 pounds per acre. Many fry, resulting from water levels favorable for spawning in November, were observed in April.

Creel Observations: Shenandoah streams were opened in May for fishing, marking the first time in two years they have been available to anglers. Regulations permit the use of artificial lures only, but are otherwise similar to those in effect in Virginia waters.

Creel census checks were made on several streams in May. Returns indicated that anglers were enjoying fairly good success with nine to 12-inch native brook trout. Regulations and management

procedures to foster restoration and preservation of wild trout have been endorsed by many fishermen.

Electrode Systems: Modifications of the Petty-type alternate polarity electrode system has improved its performance in very soft waters by as much as 69 percent. The best of the modified systems have been employed in making fish collections in both parks where conventional electro-fishing gear proved completely ineffective.

In working with these systems considerable data has been accumulated on the resistivities of stream waters in the parks which have contributed to the more efficient use of electro-fishing equipment. Specific resistance readings can be interpreted in terms of total electrolytes present in the water and thus provide a rough indication of the relative fertility of the streams. Information on the soft-water modifications in equipment has been made available to cooperating agencies.

NORTH ATLANTIC FISHERY INVESTIGATIONS

The North Atlantic Fishery Investigations is headquartered at the Service's Woods Hole, Mass., research center. From this base a continuing program of planned research and cooperative activities is carried out in collaboration with the Atlantic States Marine Fisheries Commission and the International Commission for the Northwest Atlantic Fisheries (ICNAF).

ICNAF does not maintain a research staff of its own, but draws on the cooperating agencies of its 10 member nations. Through its coordination a program has been formulated for long-range research in the Convention Area. Under study are four principal species; cod, haddock, redfish and halibut. United States research deals with those areas most heavily fished by vessels of the American fleet and includes Georges Bank, the Gulf of Maine, the Nova Scotian Banks, the Gulf of St. Lawrence and the Grand Banks.

Other activities of the North Atlantic Investigations are concentrated in the area of interest to the Atlantic States Marine Fisheries Commission, representing the compact of the 15 Atlantic Coastal States. Reports on the progress of these activities are made regularly to the Commission.

Research Projects

Mesh Regulation: In June 1953, an ICNAF regulation requiring a minimum mesh of 4½ inches in otter trawl cod-ends used for haddock fishing on the New England banks was placed in effect. A continuing study on the effect of this regulation is a part of ICNAF participation.

The large size of the 1952 year class, first to come fully under the regulation, showed an average increase of 16 percent in the weight per fish taken. This increase was not due to a change in the growth rate of this year class, but to the selective effect of the large mesh.

Redfishing tests using manila cod-ends of three different mesh sizes demonstrated that "gilling" would not be a serious problem in the utilization of large mesh nets.

Haddock escapement through cotton and nylon cod-ends was studied through simultaneous towing of various gear combinations by the research vessels Delaware and Albatross III. Valid fish selection results were obtained and the practicability of this method of fishing was shown.

Based on data gathered from a few vessels licensed to fish with preregulation small mesh and a comparison of the catch and effort data on 1948 and 1950 year classes, 1953-55 landings from the 1952 year class appeared about 30 percent greater than would have been produced by the same effort applied with the small mesh. This increase, amounting to 12.5 million pounds, checks well with a calculated increase of 6.2 million pounds, based on average weight, and a calculated benefit of about 7.4 million pounds, based on the saving of fish which would have been discarded had the small mesh been used.

Haddock Fishery: The Georges Bank haddock fishery featured an abundance of large "scrod" and small "large haddock" from the successful 1952 year class. Fishing was good, prices were low and the discard very light. The discard of a study boat using small mesh consisted almost equally of one and two year olds with a sprinkling of threes.

Since 1947 the fishery has been supported largely by two and three year old fish. The 1953 year class was of average strength and at the time of this report the 1954-55 year classes has not appeared in abundance.

Comparisons of haddock age as shown by scale and otolith (ear stone) readings were made by Canadian and United States biologists from 1952 to 1954. Scale and otolith readings agreed in 476 of 764 comparisons, or about 60 percent. Differences, indicating that otoliths tend to give a higher age estimation than scales, were generally found among the older fish.

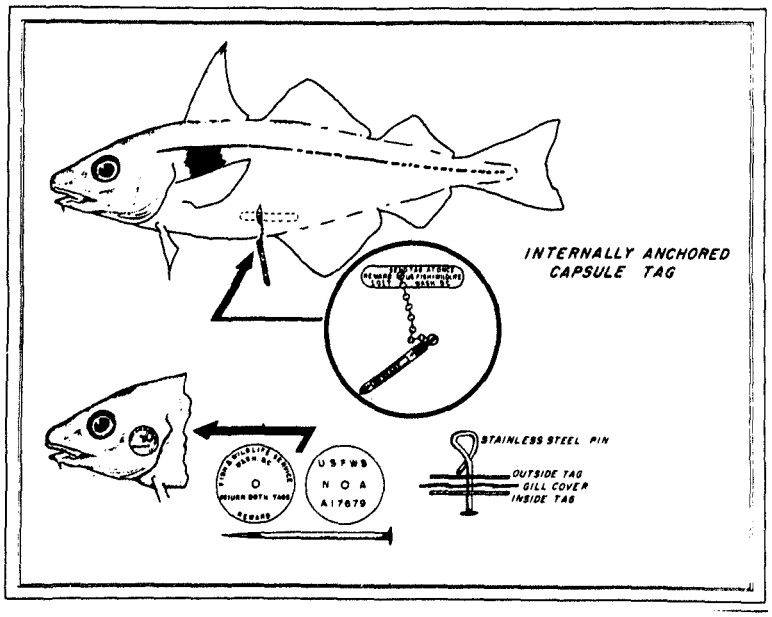
Scales from 2,338 haddock taken from 1950-54 (to include years of varying brood strength and growth characteristics) were studied to determine if the periodic markings established as annuli are actually formed at the rate of one per year.

Special emphasis was placed on "summer" and "winter" marginal growth.

The age of each fish was determined and the type of circuli at the margin of the scale recorded. Summer circuli were more widely spaced than winter circuli and were easily recognized. In winter circuli the cell-like structures of each circulus are heavy-walled and characterized by a partially occluded lumen.

Annuli are sharply defined in the scales of two, three and four year old fish. Rapidly growing haddock produce numerous circuli in which the difference between summer and winter growth is very marked. In older fish the seasonal change is not as obvious. Winter-type growth circuli were found during every month of the year for each age, but the summer-type circuli predominated at the scale edge during a period from May to July and then nearly disappeared during the winter months. This development confirmed the belief that these zones are annual in formation and that their use in age interpretation is valid.

Other haddock research activities included a study of migrations in the Gulf of Maine. Petersen disk and external hydrostatic tags were used to mark a total of 1,870 fish. The hydrostatic tags were attached to 1,235 haddock and the disk tags to 617. To the time of this report 174 fish (9.3%) had been recaptured. These early returns indicate that the hydrostatic tag, despite higher apparent initial mortality, produces good long-term results. Indications are that the disk may be grown over and not seen when tagged fish are taken.



Redfish: Study of the slow-growing redfish, which attain an age of eight to ten years before reaching commercial size, is aimed at determining population size and degree of stability or migration. In important fishing areas this study has shown that high abundance at the outset of the fishery gradually decreases to a level of equilibrium at about 25-50 percent of the high value.

Our statistics show that stocks of redfish in the North Atlantic are being sought out and exploited by those countries best situated to do so. A comparison of United States redfish landings with those of all nations fishing the Atlantic indicates that since 1949 the center of the fishery has shifted from America to Iceland and Germany. During this period landings from the New England - Newfoundland

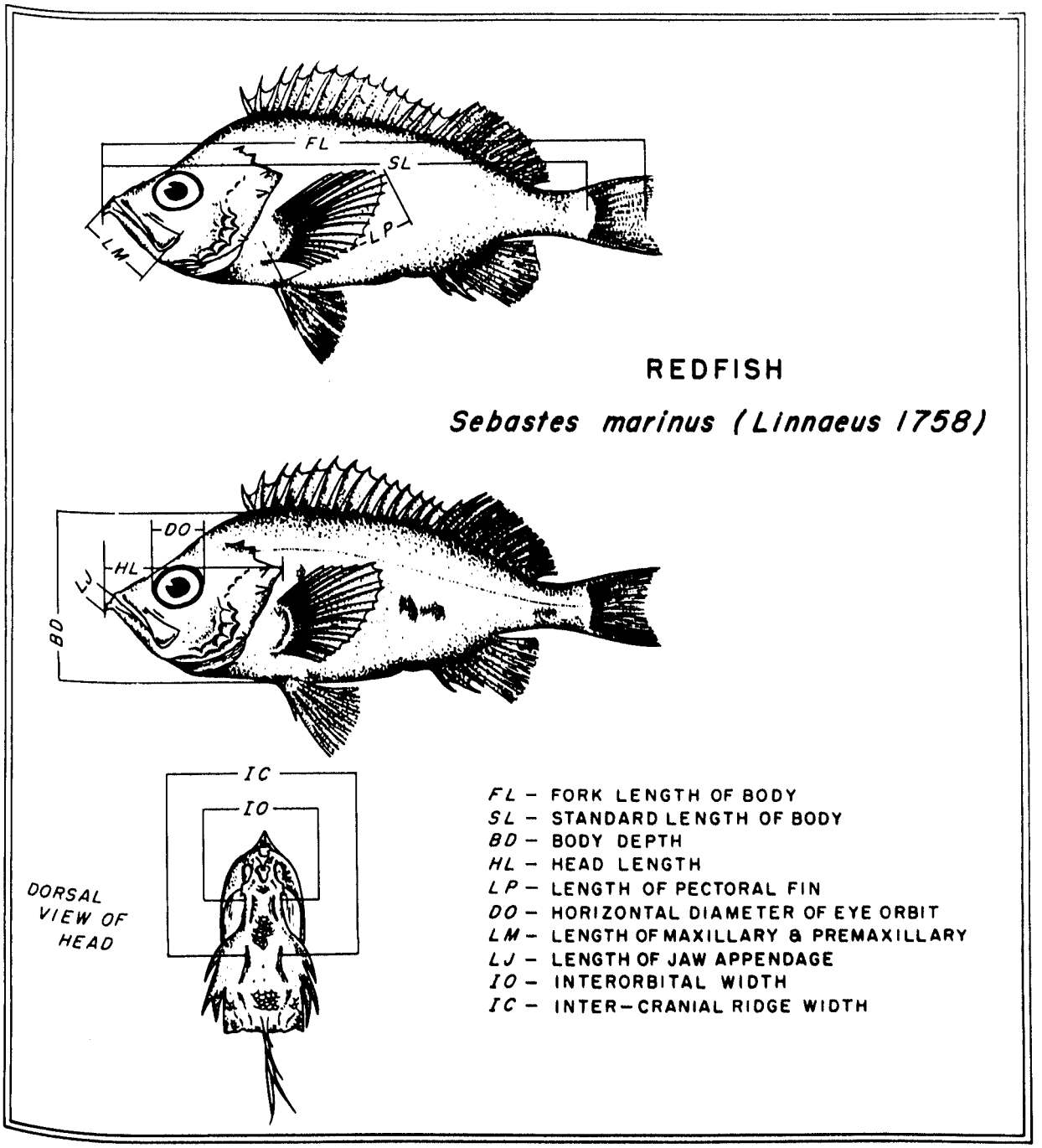


Fig. 6--Measurements used in racial comparisons of Redfish

area have fluctuated between 200 and 300 million pounds annually. Using the American fishery as a guide, we can expect an eventual reduction in the catch-per-day in all of the newly exploited areas.

Preliminary studies of the growth of redfish from the Grand Banks area show growth to be less than that noted in previous studies in the Gulf of Maine and show a greater number of older fish in the population, indicating that Grand Banks fish enter the fishery at a greater age than those in the Gulf of Maine.

A study of more than 1,000 otoliths taken from redfish in the Gulf of Maine revealed that otolith size is more closely related to size than to age of the fish. In fish of the same length, the older fish have slightly larger otoliths, but within the same age-class the larger fish have otoliths much larger than those of smaller specimens.

Early results from a study of racial differences of redfish show that fish from the Grand Banks, Nova Scotian Banks and the Gulf of Maine appear homogenous in all respects. There is evidence of large-eyed and small-eyed groups in the Gulf of St. Lawrence. Continuation of these studies may lead to the eventual separation of stocks into subspecies or races.

Whiting: Whiting, or silver hake, constitute an increasingly important fishery. Research funds were made available under the Saltonstall-Kennedy Act, to commence studies on how to maintain a maximum sustained yield.

Meristic counts, analysis of body proportions and tagging were utilized in a study whose early results indicate the existence of a whiting population off southern New England and New Jersey and a separate one in the Gulf of Maine.

Otoliths have been established as a satisfactory age indicator. Rings counted as year marks appear on the otolith as dark bands.

Whiting were found to spawn from May to September in two offshore areas in depths exceeding 40 fathoms. Both areas are on the seaward slope of the continental shelf.

A young-of-the-year census and study of the commercial fishery have been initiated as a start toward the possible prediction of year class strength. Data collected thus far indicate that the female of the species grows faster, is larger and lives longer than the male.

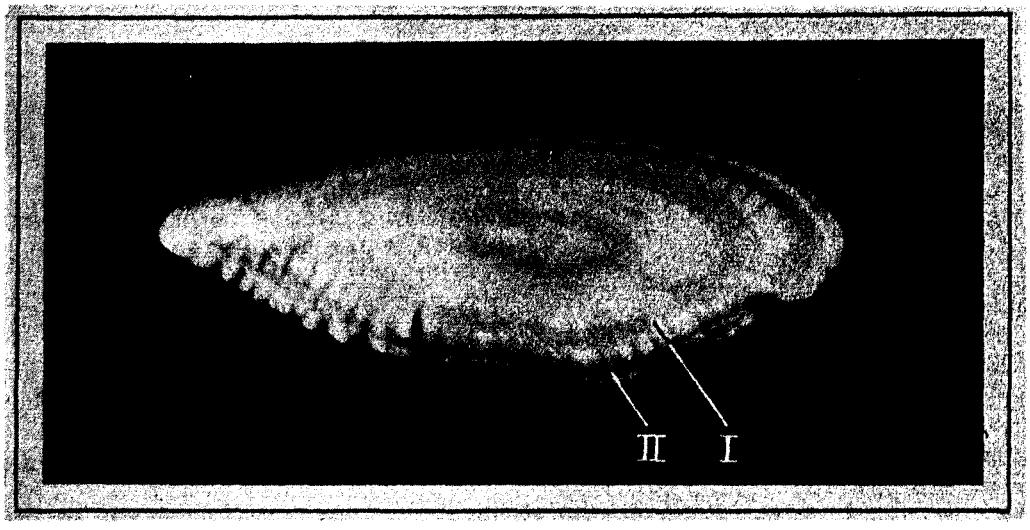


Fig. 7--Photograph of a silver hake otolith immersed in glycerin, showing seasonal growth rings believed to be year marks.

Flounder: The yellowtail, blackback (including lemon sole) and fluke members of the flounder family supplement industrial fishing operations of small draggers and often contribute the difference between annual profit and loss. A study of these commercially important flounders was reactivated in 1955 with Saltonstall-Kennedy funds.

Otolith readings have been found to provide a good association between size and age of the fish, and in the case of yellowtails, are easier to read than scales. Early tagging attempts have produced returns thus far which are inadequate for use in determining movement patterns. Blackback and fluke were found to spawn from spring to early summer, and in all cases the females were found to grow faster and larger than the males.

Cod: In the late 1920's, W. C. Schroeder of the United States Bureau of Fisheries, tagged many thousands of cod on the Nantucket Shoals. He found a large percentage of returns from his summer tagging came from the winter line-trawl fishery off New Jersey.

To complement this work 451 cod were tagged off the New Jersey coast in February 1956. Returns from this program and further tagging at strategically located points should lead to a good knowledge of the identity of cod stocks and the southern limits of their range.

Sea Scallop: North Atlantic sea scallop landings jumped from six million pounds to over 20 million pounds in the period 1945-56, bringing the fishery recognition as a major resource. Under provisions of the Saltonstall-Kennedy Act, the Service joined biologists of the Canadian Fisheries Research Board and the States of Maine and Massachusetts in a study aimed toward recommendations for the most advantageous exploitation of the fishery.

Interviews with scallop boat captains have been conducted since 1943 on boats returning to port at New Bedford, Mass., our major sea scallop landing place. These catch and effort records were expanded in 1955 by the extension of interviewing to Rockland and Portland, Maine, and Glouster, Mass. Information is now obtained from roughly 70 percent of the landings.

Fishermen have cooperated in this study by supplying shells from dredge hauls. A recording and measuring board was designed to facilitate estimation of the population structure of each of these hauls. Size-frequency is given directly in 5 millimeter groups on a row of 24 counters.

Tagging studies for age and growth determinations were begun during the year. A new underwater camera capable of photographing 40 square feet of bottom at the rate of a picture a minute was perfected to assist in the study of the affect of environmental factors on distribution and density of sea scallops.

Trash Fish: Many fish once cast aside from commercial catches as "trash" have gained new stature as ingredients of animal food and as the raw material for a fish oil and meal industry. Vessels in ever increasing numbers rely on the markets of this "Industrial Fishery" to add to their regular activities in the various New England food fisheries. A few, with capacities of up to 90,000 pounds, range farther offshore and profitably specialize in industrial fish.

Red hake is the backbone of this fishery, accounting for more than 60 percent of the industrial landings. Those species represented in the food fish portion of the catch are the blackback and yellowtail flounders. Silver hake is used as pet food when prices on the food fish market are unfavorable.

The red hake is a relatively short-lived, fast growing fish. The male and female of the species maintain equal growth until the onset of sexual maturity at the end of the second year. By May of the third year the male growth rate has distinctly fallen behind that of the female, a condition which continues through the fifth year, the maximum age for most of the fish. The bulk of the catch is composed of three year old fish, as is most of the breeding population.

Delaware Bay Survey: Delaware Bay sport and commercial fishery surveys related to possible waste disposal in the area were reduced in 1956 to routine collection of statistics on catch and effort. Reports for 1954 and 1955 are in preparation to supplement a completed report for the period 1952-53 and historical data to 1946.

Ecology: A detailed study of the relationship of offshore groundfishes to their environment has broadened our understanding of the fluctuations in availability of commercial species of marine fishes.

To know the physical and biological factors which control the spawning of haddock and survival of their eggs and larvae requires knowledge of the centers of abundance and their movements in relation to the time and ecological conditions. A continuing program which includes plankton sampling over a large area, water current studies and fall otter trawl surveys in major fishing areas, is providing this information.

Primary objective of the sea bottom ecology investigation is to determine how the kinds and amounts of food available affect the abundance and distribution of the fishes of an area. Interest is centered on the five major groups of animals shown by stomach analysis to supply the bulk of food for groundfishes. These are: crustaceans, mollusks, annelid worms, echinoderms and fish.

Two cruises were made late in 1955 to investigate the relationship of fish distribution to food supply. Samples of burrowing animals as well as those living up to four feet above the bottom were taken from 68 stations bracketing Georges Bank. A direct correlation between the abundance of groundfish and the abundance and variety of suitable foods was shown by preliminary analysis of these samples.

Atlantic Herring: The Atlantic Herring Investigation is designed to gather biological information beneficial to the fishing industry in its harvesting of herring. Sardine packers, who are the principal

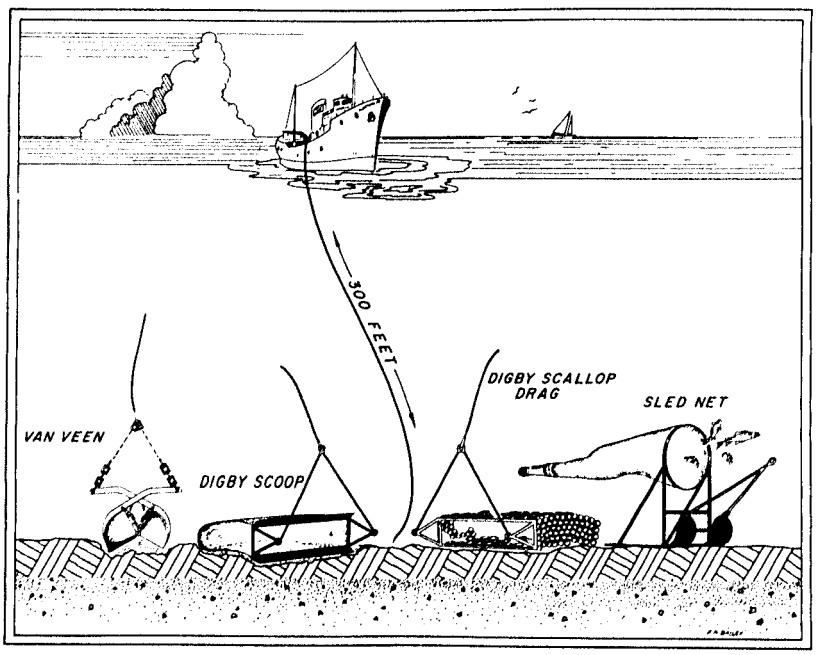


Fig. 8--Apparatus used in collecting samples of bottom organisms

herring users, are faced with marked fluctuations in supplies of small herring and the resulting uncertainties of quality and availability of the fish for commercial production. To understand these fluctuations, requires a comprehensive knowledge of the biology of the species throughout its entire life span.

In 1955 spawning herring were collected from the western shore of Nova Scotia and from Georges Bank, Stellwagon Bank and Nantucket Shoals for racial studies. An attempt will be made to follow immature herring of the 1954 year class to maturity using the racial characteristics noted in fish collected in these areas.

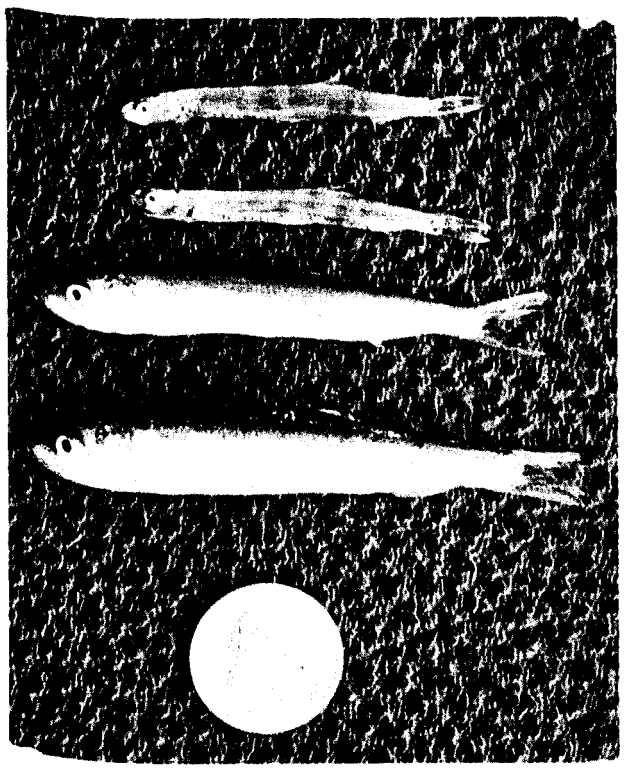


Fig. 9--Development of Atlantic Herring before and after metamorphosis

The possibility of herring parasites as a means of racial identification has been raised by the clear difference shown between Gulf of St. Lawrence and Gulf of Maine herring on the basis of fungus infection. This infection (Ichthyosporidium hoferi) is frequently found in fish from the Gulf of St. Lawrence, but seldom in those taken from the Gulf of Maine. A myxosporidian infection (Kudoa clupeidae) hints at partial separation of immature herring in the Gulf of Maine. The incidence of larval cestodes, probably Grillotia erinaceus, in mature herring is high in the southern part of the Gulf of Maine, declines to neglible proportions in the eastern part, and is absent from samples from the Gulf of St. Lawrence.

The unusual distribution of myxosporidian, Kudoa clupeidae, is of special interest as a biological tag. The disease, myxosporidiosis, has never reached serious proportions. Detailed study of its incidence along the Maine coast indicates no eastward movement of herring during the first and second years of life when they are sought by the commercial fishery.

Electrophoretic study of herring serum has indicated marked changes in serum proteins in fish infected by the fungus Ichthyosporidium hoferi. Fluctuations in the incidence of this fungus in the Gulf Maine and the Gulf of St. Lawrence suggest that immunizing infections occur, epidemics breaking out whenever the proportion of susceptible fish in the populations exceeds a certain critical density. Studies of the proportion of immunes to susceptibles during various phases of the epidemic wave offer the possibility of prediction of epidemics in the future.

These studies, coupled with intensive inquiries into the fluctuations of year class strength, will be continued.

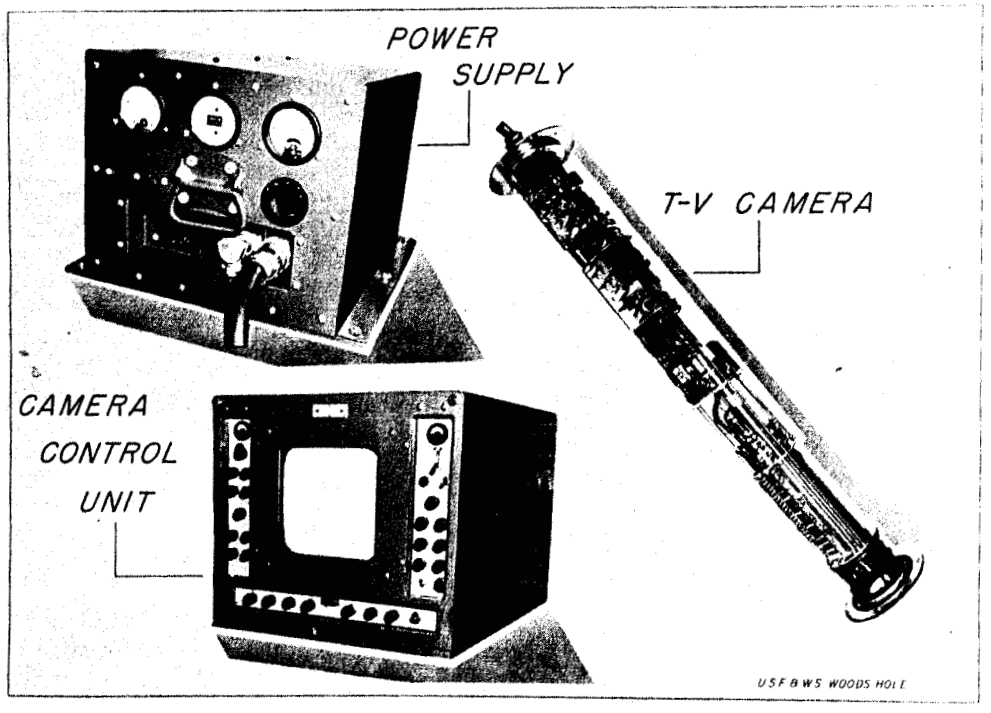


Fig. 10--Underwater television and photography have become valued tools of marine scientists. The marine television unit, pictured above, has been placed in use at the Woods Hole Laboratory.

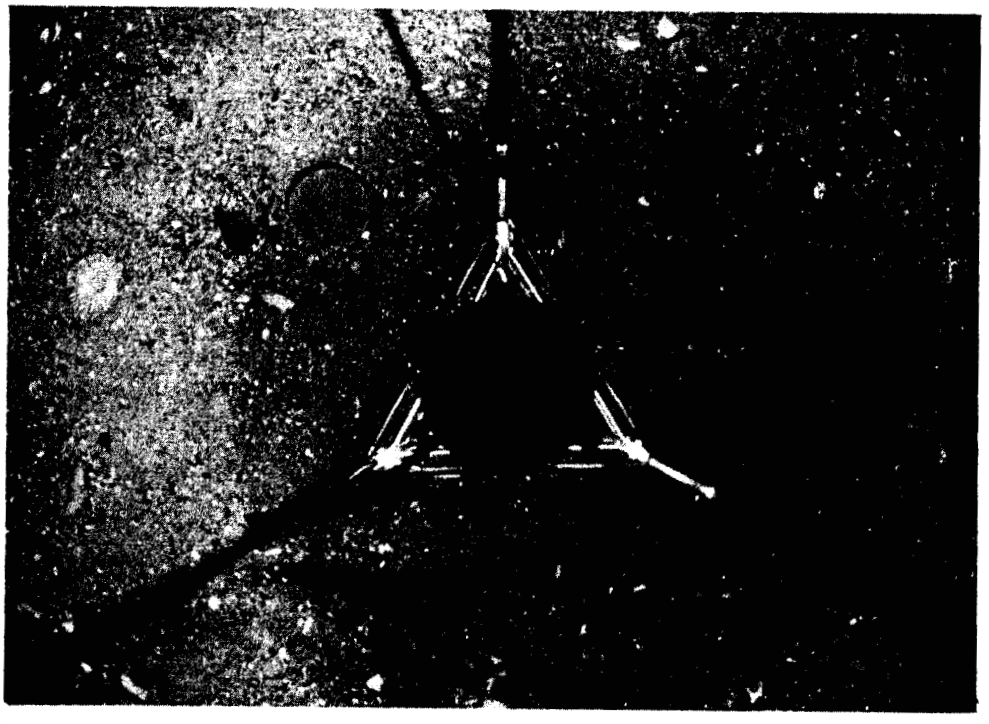


Fig. 11--An underwater camera for bottom survey use provides photos such as this, which encompasses an area of some 40 square feet. Continued usage will lead to more effective utilization of these seagoing "eyes".

SOUTH ATLANTIC FISHERY INVESTIGATIONS

From a base laboratory at Brunswick, Ga., the staff of the South Atlantic Fishery Investigations is making an initial step toward a better understanding of the potential productivity of the waters adjacent to the South Atlantic coast. In form, this step consists of a general biological and oceanographic survey of the area from Cape Hatteras to lower Florida. Cooperating are the Office of Naval Research, Navy Hydrographic Office, the Georgia Game and Fish Commission and the Florida State Board of Conservation.

Nine exploratory cruises were made in 1953-54 by the research vessel T. N. Gill and 1955-56 efforts have been directed toward processing and interpreting the data and material collected.

For discussion purposes the study area from Cape Hatteras to the Florida Straits was considered in northern, central and southern sections. Each section was split into three theoretical parts: inner shelf (water less than 10 fathoms); outer shelf (10 to 100 fathoms), and offshore (100 fathoms to beyond the axis of the Gulf Stream).

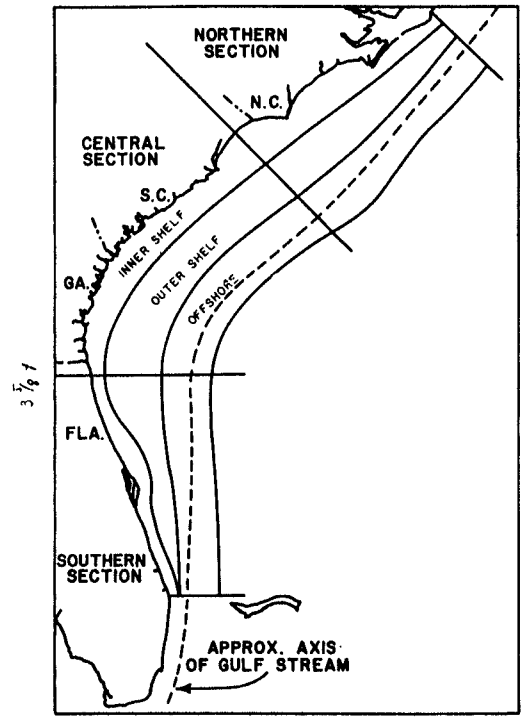


Fig. 12--Division of the area of interest to the South Atlantic Fishery Investigations.

Water Temperatures: On the inner shelf water temperatures increased sharply from north to south. On the outer shelf relative stability was found at a depth slightly less than that noted in the southern section of the inner shelf. Offshore temperatures were relatively uniform from north to south and higher than those shoreward of the 100 fathom line.

Salinities: A uniformity of 36 parts per thousand was found for salinities in all parts of the area except the central and northern inner shelf where they were a little lower.

Inorganic Phosphate: A slight north to south increase in inorganic phosphate was noted on both inner and outer shelves.

Offshore the highest value was in the central section and the lowest in the northern.

Plankton Volumes: Wet plankton volumes showed a south to north increase on the outer shelf and offshore. On the inner shelf the lowest volumes were in the center section and the highest in the northern. Waters shoreward of the 100 fathom line had two to three times the plankton volumes found offshore.

Fish Eggs: Fish eggs were most abundant in the southern section of shelf waters, where high numbers were found at a few stations. Outer shelf waters in all sections proved more productive of fish eggs than the other area divisions.

Fish Larvae: Fish larvae were most abundant on the southern outer shelf. In the central and northern sections numbers of larvae in offshore waters exceeded those of the inner shelf. Inside the 100 fathom line eggs outnumbered larvae, but the opposite was found in offshore areas.

Eighteen families, two suborders and leptocephali are represented in the tentatively identified fish larvae from plankton samples thus far studied.

Plankton Organisms: Copepods were the most numerous organism collected and led the second most numerous groups, tunicates and ostracods, 10 to 1. Others, in order of abundance, were protozoans, chaetognaths, miscellaneous crustaceans, shrimp and crabs.

Fig. 13--A much enlarged photo of a typical haul of assorted plankton. Shrimp and fish larvae are the largest and most easily identified forms.

Dip Net Samples: Dip net samples (obtained by netting larvae and small fish from over the ships side) furnished specimens from 15 families, 21 genera and leptocephali. Eight families and leptocephali comprised over 90 percent of the occurrences.

Trolling: Trolling led to the capture of 21 tunas, 19 little tunas, one yellowfin, and one oceanic bonito. The little tuna were taken from south Florida to North Carolina over the continental shelf, and the oceanic bonito was taken off the south Florida coast. The yellowfin was captured just north of Little Bahama Bank.

Atlantic Sailfish: It was possible to separate Atlantic sailfish above 10 mm from a collection of istiophorids (spearfish) ranging from 3.4 to 625 mm. A growth and development study of the various body parts of the samples was done in preparation of a developmental series.

Stomach analysis of 32 specimens revealed that copepods comprised the food of specimens of less than 6 mm, but were not present in those exceeding 13 mm. Fish larvae was the bulk of food noted in the larger specimens.

Spawning of the Atlantic sailfish in the western North Atlantic appears to be from April to September beyond the 100 fathom line from the Carolinas to south of Cuba. In the eastern Gulf of Mexico the season is from April to August, and in the western Gulf, from June to August.

Silver Mullet: Running ripe males and females were taken from a school of spawning silver mullet near the 20-fathom line off the Florida coast in April 1954. The eggs were fertilized and hatching occurred in about 40 hours. Larvae were maintained for 32 hours after hatching.

Through these and other collections, a developmental series from egg to juvenile has been prepared.

Spawning in the South Atlantic coastal area appears associated with the outer continental shelf from North Carolina to Florida and apparently occurs from late March until September.

In Georgia waters, young silver mullet grow rapidly from April to November--at a rate of roughly 17 mm per month. During late fall and early winter the fish left rapidly cooling inshore waters.

Jack Crevalle: The genus Caranx is represented by five species present in Atlantic coastal waters. There are indications that a majority of the young of these species are spawned in the Bahamas and southward, with limited spawning off the South Atlantic coast. The season for spawning apparently extends from April to October.

Larval and juvenile C. ruber, C. crysos and C. bartholomaei were found primarily in association with the axis of the Gulf Stream. Less numerous specimens of juvenile C. latus and C. hippos were obtained offshore.

Ten Pounder: The ten pounder undergoes a regression of growth and metamorphosis during its development to the juvenile stage. "Shrinking" which takes place in the leptocephalid larvae (40 mm to 20 mm) before metamorphosis has been recognized and described in some detail, for the fish is present in estuarine and coastal waters of the South Atlantic and Gulf. However, no information has been available on the growth of this species before the largest leptocephalid size.

Offshore plankton tows yielded specimens of the earlier stages. Description and illustration of a series ranging from 6 mm through initial growth to 40 mm, the shrinkage to 20 mm and subsequent growth through juvenile stages is in preparation.

Seine Collections: Offshore collections are supplemented by biweekly seining of young fish from an ocean beach, a salt marsh and the tidewaters of a fresh-water river in coastal Georgia. The value of simultaneous collections from these areas becomes apparent in attempts to piece together the early life history of various species. Part of the life of some fish is spent in each of these environments, as is the case with the ten pounder, the silver mullet and some of the carangid fishes.

MENHADEN INVESTIGATIONS

The Atlantic menhaden, Brevoortia tyrannus, is caught from the Gulf of Maine southward to mid-Florida. This species accounts for virtually the entire Atlantic coast catch and for an estimated 70 percent of the annual all-species menhaden production. Although the supply shows no apparent decline, violent fluctuations in catch occur in certain areas. To determine the cause and predictability of these fluctuations a menhaden investigation was established in 1955 with headquarters at the Beaufort, N. C., research center.

Analysis of middle Atlantic menhaden catch data from 1939 through 1955 is in process. Over the 16-year period total annual catch for the area has fluctuated about a mean yield of 200,000 tons. Log-book data gathered during the 1955 fishing season has been transferred to charts showing the geographical distribution of fishing effort.

Sampling of pound net and purse seine catches over the range of the fishery disclosed that all age groups are caught, including young-of-the-year fish. During the summer months the younger, sexually immature fish occur in the southern and central parts of the range, while older, mature fish occur in northern waters. A north to south migration occurs in the fall and early winter. Among the younger age groups, the 1955 year class was large and contributed substantially to the fall and winter fishing in North Carolina waters. The 1954 year class, on the other hand, appears to be one of the smallest in recent years.

Examination of the gonads of several thousand fish and results of plankton surveys for eggs and larva indicate that a major spawning occurs off the coast of the Carolinas from November through March. In waters north of Long Island spawning appears to be confined to a relatively short period in early summer.

The plankton survey indicates that hatching of menhaden eggs occurs at sea and that larva are transported by ocean and tidal currents into the estaurine nursery areas. Larval recruitment in the area between New Jersey and North Carolina was was found to be continuous from November through March.

Positive identification of menhaden larvae and previously unidentified eggs and larvae of several other species has been achieved by rearing under simulated natural conditions. Rearing pens lined with plankton netting or plastic screen were placed in the same localities where the eggs and larva were obtained. Mortalities were slight.

Estimates of menhaden early growth and the validity of scale marks as age indicators have been confirmed from several hundred fish placed in an outdoor rearing pond as juveniles and one-year olds held a full year.

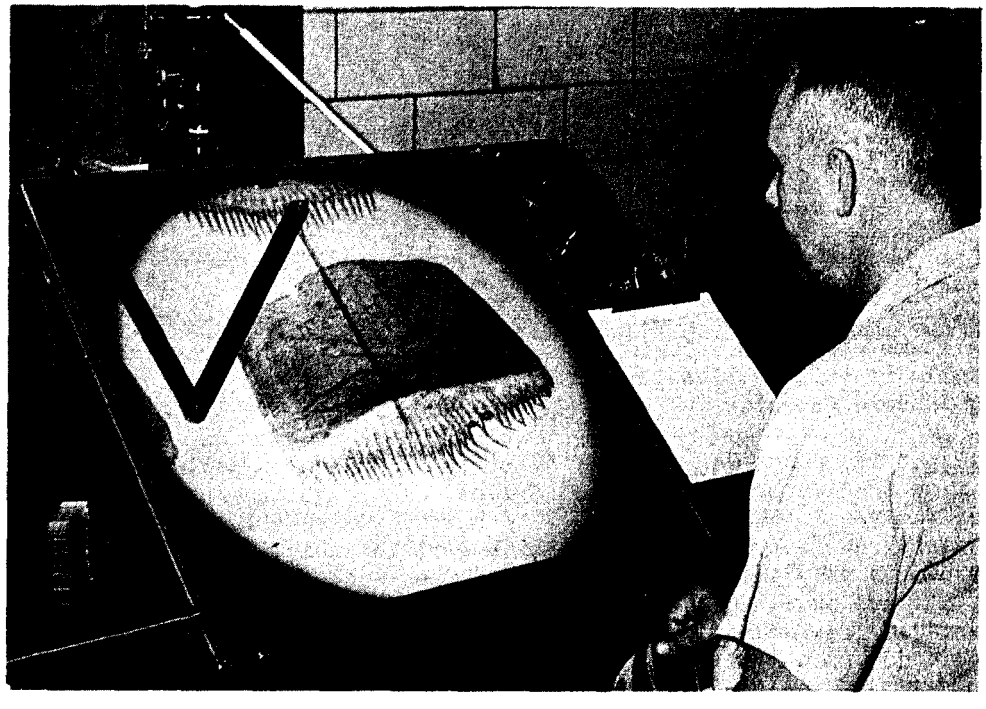


Fig. 14--A projection machine enables detailed study of menhaden scales for age determinations.

A study of meristic character variations in juveniles of the 1955 year class demonstrated the existence of more than one population in the various nursery areas between Cape Cod and southern Georgia. Consistent differences in mean numbers of vertebrae, ventral scutes and dorsal fin rays indicate separate populations north and south of Long Island.

North of Long Island a distinct decrease in mean counts of all characters was noted. The difference in mean water temperatures during the time of spawning and early larval development may be sufficient to induce the observed differences in mean meristic counts between the two areas. Development of this, and other, information will continue.

GULF FISHERY INVESTIGATIONS

From the Galveston, Texas, laboratory and Naples, Florida, field station Gulf Fishery Investigations (GFI) staff members are seeking an answer to biological questions on how much can be drawn from our marine food stocks without affecting the generation of new crops.

The GFI approach begins with an understanding of the individual organism and proceeds through a study of the environment in terms of the individual. Unless the peculiarities, physiological or behavioristic, of the species are known, the real meaning of environmental fluctuations may never be fully revealed. After we know a given organism and have evaluated the environment in terms of its requirements, we are ready to turn to a study of populations.

Fishery Microbiology: Diatoms and dinoflagellates are the principal photosynthic agents of the sea. They produce metabolites which may be self-limiting and which may have important influences on other organisms. A case in point is the mass of fish mortalities known as Florida Red Tide, caused by the dinoflagellate Gymnodinium brevis Davis, which is the subject of intensive study by the GFI.

G. brevis is extremely sensitive to environmental factors and yet, when conditions are favorable it can quickly explode into a community dominant. This sensitivity is the reason for the infrequent and erratic occurrences of Florida Red Tide.

Organic compounds, perhaps produced by bacteria, stimulate rapid multiplication of G. brevis when all other factors, such as light and temperature, are suitable. The organism has shown great sensitivity to certain metals, notably copper.

To get absolute values for the physical limits imposed by these factors is difficult. The organism must be grown in bacteria free culture so the unknowns created by the presence of many kinds of bacteria can be eliminated. Mass cultures of bacteria-free G. brevis have been grown in quantities sufficient to permit free use in fish killing experiments, and provide a chemically defined growth medium for the study of what factors are the keys to the beginning of a red tide outbreak.

Unialgal and bacteria-free cultures differ in that the former will subculture indefinitely whereas the latter thus far will not. This is evidence that bacteria are producing one or more substances in addition to those contained in the experimental media that are necessary for the growth of the dinoflagellate. Such interreactions are probably common in the sea.

The principal of ecological succession--that of one organism preparing the way for another--was demonstrated during the course of G. brevis experiments. A medium of sea water with added vitamin B_{12} produced cultures of G. brevis only after another dinoflagellate, Prorocentrum sp., had been cultured and then filtered out of the medium. G. brevis would not grow in the original medium or the living culture of Prorocentrum.

The development of a completely defined medium for unialgal cultures of G. brevis is noteworthy for only analytical grade chemicals containing some impurities were used. It contained no soil extract, vitamins, trace metals, carbohydrates, amino acids or sea water. An implication is that normal sea water contains elements which are antagonistic to blooms of G. brevis, but which are occasionally inactivated by other natural factors.

Fig. 15--Many bacterial cultures have been developed and maintained for experimental usage.

Work with unialgal cultures has always indicated that vitamin B_{12} is a required growth promoter in culture media with natural sea water as a base. Produced by bacteria, this vitamin is vital for many organisms, man included. It is probably one of the many organic compounds swept into the Gulf during Florida's rainy season. At least one bacterium which is dominant in all unialgal cultures of G. brevis has been found to produce B_{12}. A reliable assay for the vitamin has been developed and put into routine use in field studies to discover the mechanism of its production and distribution.

The use of bacteria free cultures of G. brevis to kill fish was necessary to remove doubt from earlier experiments with unialgal cultures which, while they killed fish, might have included the toxic effects of other substances in the culture. In pure culture experiments fish were killed as quickly and with the same response to toxic concentrations of the organisms as has been observed in nature.

Research to prove or disprove the feasibility of control of Florida Red Tide outbreaks is still in the experimental stages. Present knowledge indicates that control lies in the elimination of active patches of G. brevis before they reach fish-killing proportions.

Land drainage plays an important part in supplying the Gulf with nutrients and marks rainfall as one of the important climatic considerations in the study of Florida Red Tides. All available temperature and precipitation data for the drainage basins affecting the red tide area have been accumulated. Development of a method of correlating rainfall data with hydrographic information may aid in the early prediction of circumstances leading to red tide outbreaks.

Hydrographic Observations: Special floats are followed in inshore Florida waters by radar tracking and their courses are plotted for direct observation of the movement of coastal water masses. With continuous sampling from the vessel within the area covered by the floats it is possible to establish a reasonably reliable distribution of a given plankton organism within a given mass of water. This method has been found more satisfactory than the sampling of a network of stations over a great area.

Fig. 16--Tinsel-topped floats are used to track Florida coastal currents. The Christmas tree tinsel reflects back beams of the radar set aboard a research vessel.

G. brevis was associated during the 1955-56 period with fish kills in south Texas and Mexican waters, it has been consistently found in the Florida coastal area although no red tide fish kills have occurred there since the first few days of 1955. G. brevis has also been isolated from waters at Galveston, establishing its presence at three widely separated points in the Gulf and supporting the conclusion that it is to be found in low concentrations throughout the Gulf.

During the year over 3,000 water samples were taken in the red tide area extending from Clearwater to the Florida Keys and encompassing the range of known fishkills from the inshore bays to the 10 fathom line. All samples were examined for the presence of G. brevis and counts were made when the organism occurred. It appeared in less than five percent of the samples, and in most cases counts ran less than 40 per liter. In three separate periods, September 1955, December to January 1955-56, and March and April 1956, no organisms were found. As G. brevis samples were collected, other samples were taken for chemical analysis.

In Florida waters affected by red tides, copper has been found to range from 0.00 to 2.80 microgram atoms per liter (ug at/L) and is usually found in concentrations less than 1.0 ug at/L. High values have been recorded inshore and in late summer. Considerable fluctuation in copper concentrations has been noted and could account for the extreme variability in the occurrence of G. brevis. The high copper values reported from inshore waters and in late summer were associated with deficient rainfall. This condition was reflected in salinities reaching 37% near river mouths. Copper, like other salts, is concentrated by evaporation.

Copepods: Copepods are universally present in the Gulf of Mexico, as in other oceans, and serve as an important link in the flow of energy from plant to fish. The GFI program represents the first organized, sustained effort to study Gulf copepod distribution.

A completed study of earlier collections brought forth a list of 97 species in a group designated as the calanoid copepods. This is three times the number formerly reported and includes seven new species, four of which are deep water forms which may be peculiar to the Gulf. The distribution of some of the inshore species suggests they may be associated with certain types of river discharges.

The copepod Labidocera aestiva Wheeler is noteworthy since its distribution appears to be confined to coastal waters between northwestern Florida and eastern Texas. The species occurs in considerable abundance within this range with numbers noticeably dropping in the eastern and western peripheries. A closely related species, L. scotti Giesbrecht, overlaps the eastern and western extremes of L. aestiva's range and extends southward into Mexico and to the southern tip of Florida. There is considerable evidence that the overlap regions represent transitional zones between different types of coastal waters.

Distinct morphological differences have been found between Gulf representatives of L. aestiva and those occurring in Atlantic coastal waters from central Florida to the Gulf of St. Lawrence. A geographic variation was noted in the Gulf population of L. aestiva with the greatest numbers found in the central portion off the Mississippi Delta.

Confirmation of these initial findings will provide an additional tool for tracing the movement of coastal water in the Gulf and a new biological attribute for differentiating environments.

Menhaden: Establishment of a system for sampling Gulf menhaden catches has been the first step in a new program. The samples will be used for relating scale readings to size and year classes, and experimental work with young fish will round out the first phases of this program.

Shrimp: Histology, anatomy, physiology, field observations and catch statistics are all involved in the study of the shrimp.

Histology, the study of the cellular makeup of tissues and their functions, is fundamental to understanding the life processes and behavior of an animal. The histological study of shrimp was assigned under a Saltonstall-Kennedy contract to Texas A. and M. College.

From the point of view of the histologist, the shrimp is a large bundle of muscle tissue wrapped in a comparatively thin shell of chitin. Chitin, in simple terms, is a complicated form of sugar molecules. This shell is a prison to the young, growing, shrimp and unless it can be shed at the proper time there will be no growth. For

a shrimp to shed its shell and grow a new one, a number of chemical processes must occur.

First is the moulting process, a period of great danger when the shrimp sheds its armature which, until replaced by a new shell, leaves it easy prey for many predators.

The shell is not a dead thing, but a living complex of membranes, pigments, glands and pores. There are four layers: a thin outside layer; a pigmented layer of similar thickness; a calcified layer which gives the entire structure stiffness, and beneath this a membranous layer. Beneath these four layers is the epidermis, which contains, among other things, the cells which secrete chitin.

The shrimp's major energy storage depot appears to be in the big digestive gland which is the conspicuous brownish organ in the thorax. Preceding the moulting process a supply of glycogen (animal starch) accumulates in the hepatopancreas, an organ which also serves as a depot for fat.

Volume is a more sensitive indicator of size and one by which size can be more easily ascertained without damage to the animal than by other available methods. A series of length and volume measurements were made and subjected to mathematical analysis. The results were consistent with similar studies on other animals.

Operating on another Saltonstall-Kennedy contract, the Tulane University Department of Zoology is completing an anatomical atlas of the white shrimp, Penaeus setiferus.

Eye structures scrutinized in the anatomical study have been related to the moulting process. Several possible growth regulating components of the eye structure have been detailed and a hitherto unreported structure, the anter, or eyestalk pore, has been described. All of this information will be put to use as studies on the effects of light conditions on the growth and survival of shrimp progress.

The effect of temperature on growth of shrimp of the Panaeus aztecus-duoraum complex was studied during the retention of post larval shrimp for 56 days at three temperatures. At room temperature the shrimp developed at almost twice the rate of those held at an average of eight degrees centigrade less. Salinity tolerance limits at three temperature ranges studied have been tentatively determined for post larval shrimp of this complex.

Marking animals is an established technique for tracing movements and changes in populations. The difficulty of application of this technique to crustaceans has long been recognized. Any tag or mark imposed upon any of the hard body portions without connection to the central body will be lost in moulting within a short time if the animal is actively growing. The commercially important shrimp experience rapid growth throughout their natural life span of approximately one year. The only tag previously used with any degree of success utilizes a pin piercing the abdomen and affixing a celluloid button on each side of the shell. This tag cannot be used to mark very young shrimp.

Under a Saltonstall-Kennedy contract the University of Texas Institute of Marine Science is investigating methods of marking shrimp populations for study. The object is the development of a generalized mark without reference to individuals, as opposed to tagging, by the mechanical attachment of an identifying object.

Over 30 different dye substances have been used in 101 experiments. A most promising technique has been developed in which dyed food is fed the shrimp. The dye transfers from the food to the tissues of the shrimp on ingestion and becomes fixed in the gills. All sizes of shrimp can be marked in this way with the mark lasting in experiments at least 215 days and through two moults.

Statistics: In cooperation with the Branch of Commercial Fisheries, shrimp production records are analyzed by GFI biologists and will be used as a basis for measuring population fluctuations and

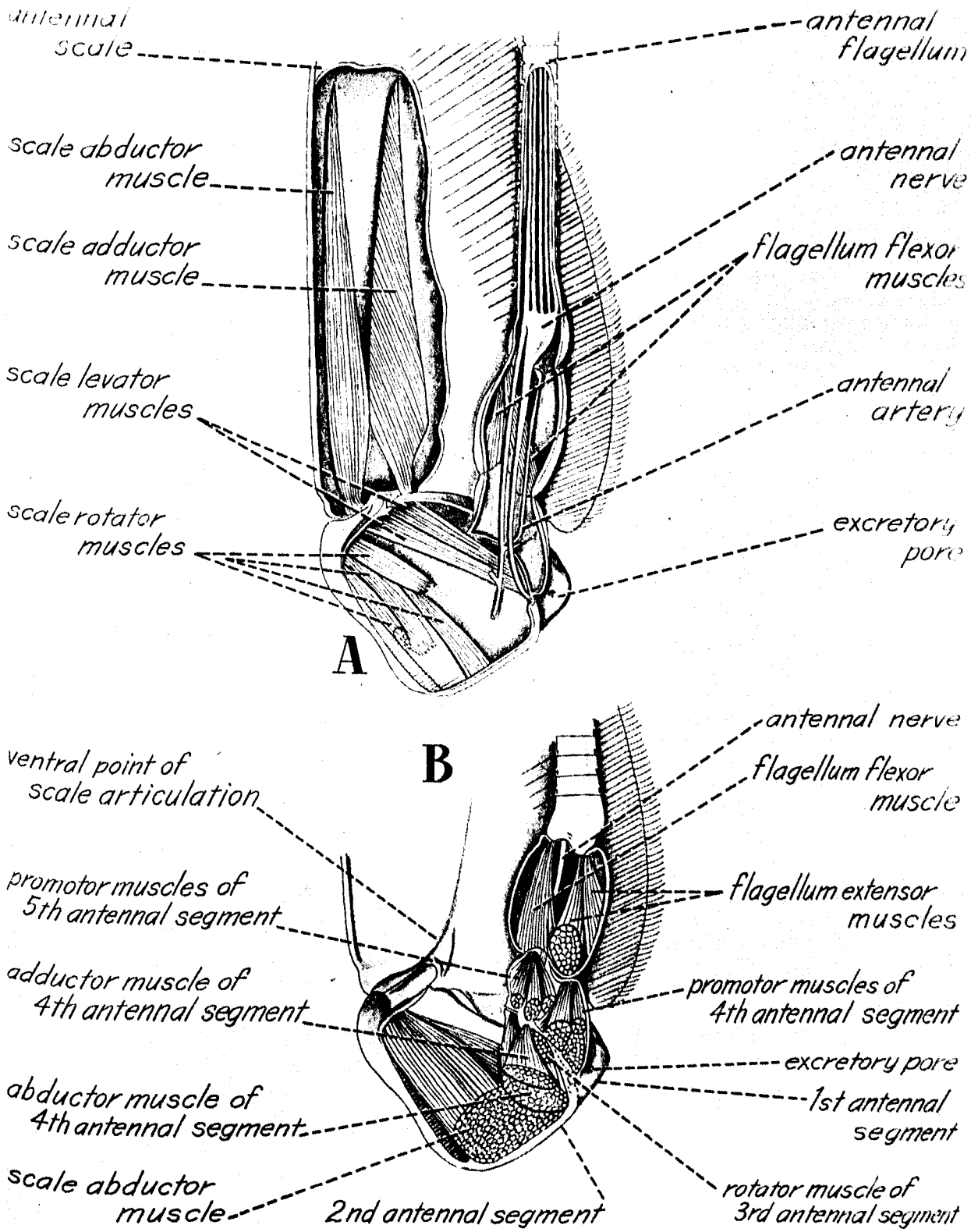


Fig. 17--Careful dissection and observation lead to results such as this detailed drawing of the antennal scale of the white shrimp.

movements. The availability of reliable statistical data will provide a means of keeping a watchful eye on the shrimp fishery, which is undergoing a gradual but definite change from a predominance of white shrimp to a dependence on brown shrimp. From this combination of statistical coverage and biological inquiry may well come the answers to many voids in present knowledge.

Alaska Data: Data collected during past cruises of the research vessel Alaska indicate that the Gulf can be divided into three sections according to both organic and inorganic constituents. These sections are the western Gulf, central Gulf and southeastern Gulf. The areas have been differentiated with temperature, salinity, density, nitrates, nitrogen, phosphate, phosphorous, carbohydrates and proteins serving as criteria.

Chemistry: Two chemical studies important to interpretation of the Alaska data have been completed. They supply supplementary data on the phosphorous content of representative fish and shrimp, and provide some new information useful for interpretation of salinity data.

Efforts to improve reliability of routine analytical techniques have continued. Refinements in the analysis for the tyrosine content of sea water, and the attainment of better temperature control in N-ethyl carbazole tests for carbohydrates improved precision and made these tests more versatile for the study of sea water.

Florida Red Tide studies have led to development of improved methods of study for many planktonic organisms. Use of these methods showed that the dinoflagellate Prorocentrum, after attaining maximum growth, produces a supply of energy-building carbohydrates. Measurement of this production gives information on the part this organism plays in the transmission of energy through the food chain of the sea, and provides important naturally produced nutrients for use in experimental work with shrimp, copepods and menhaden.

At the close of the fiscal year GFI personnel were moving into expanded quarters next to the present laboratory building at Fort Crockett, a Gulf front installation on Galveston Island. Acquisition of additional buildings at the deactivated fort will nearly double laboratory space and accommodate the expanded program.

SOUTH PACIFIC FISHERY INVESTIGATIONS

The main objective of the South Pacific Fishery Investigations, centered at La Jolla, Calif., is to describe and increase understanding of the variations in distribution and abundance of the sardine (Sardinops caeculea). Ecologically associated species, such as anchovy, jack mackerel and Pacific mackerel are also of interest.

The Investigations form a part of the California Cooperative Oceanic Fisheries Investigations (CCOFI), whose other members are the California Academy of Sciences, California Department of Fish and Game, Hopkins Marine Station of Stanford University and Scripps Institution of Oceanography of the University of California. Joint studies are coordinated by the California Marine Research Committee and activities are supported in part by a special State tax on sardine, anchovy, herring, jack mackerel, Pacific mackerel and squid landings.

The research vessel Black Douglas made 11 cruises during the fiscal year in cooperation with Scripps Institution vessels. Most were regular CCOFI cruises off California and Baja, California. Egg and larval collections were made on all cruises and detailed physical and chemical hydrographic observations were taken on alternate cruises.

One cruise was part of NORPAC, a synoptic coverage of the North Pacific Ocean. Reports on this cruise form a part of the full NORPAC report.

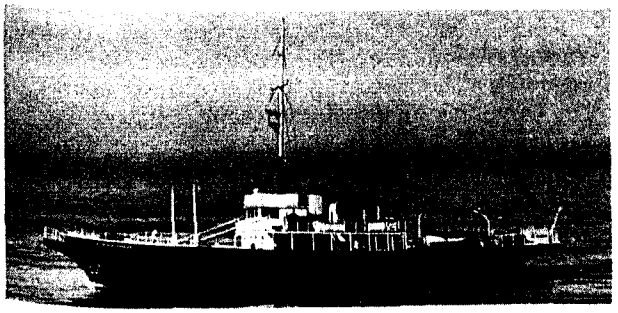


Fig. 18--The Black Douglas

Populations: Sardine subpopulations are considered to have a genetic foundation and, based on distribution of spawning in time and space, there appear to be four isolated spawning groups.

Comparison of length-frequency distributions of the 1940 year class landings at San Pedro and British Columbia in the 1944-45 season showed that the maximum mixing possible between the two areas was 17 percent. Similar comparisons will be made between other year-classes, seasons and ports.

Spawning Studies: Distribution of sardine spawning is the best known of any pelagic fish. Surveys since 1949 serve several purposes: (1) When used in conjunction with fecundity data they make possible estimates of the size of the spawning population; (2) They provide estimates of egg abundance needed in studies of egg and larval stage survival, and (3) the surveys are useful in showing the relative abundance of spawning populations in different areas.

Most recent sardine spawning has occurred in two major centers. The northern center is off southern California and adjacent Baja California and the southern off central Baja California.

A northward shift in the distribution of spawning populations was observed in 1954, coincident with a marked increase in sardine availability in the California fishery. Spawning distribution in 1956 is following the pattern of the last two years with heavy spawning off southern California. The only portion of the sardine spawning range not covered by survey cruises was in the Gulf of California, but during the year both biological and hydrographical observations were taken at carefully planned grid stations in this area.

Sardine spawning takes place across the full width of the Gulf and from data collected it is obvious that the spawning population is large. Coverage through the spawning season will be obtained to estimate the size of the spawning population.

Sardine Fecundity: A fecundity study was made on 13 samples of sardines from the commercial fishery at San Pedro, Calif. Taken from November to February, the samples included 587 females and 638 males. Assuming the presence of yolked ova in the ovary as an indication of maturity, 28 percent of the year old females and all of the two-year and older fish were maturing in February. Fecundity-weight showed the best correlation in a study of fecundity-age, fecundity-weight, and fecundity-length. Pending completion of other studies, no conclusions have been drawn from these samples as to the number of times an individual fish will spawn per season.

Age Analysis: Age determinations from sardine scales have been made continuously since the 1941-42 season. Through the work of Mosher and Eckles, age determinations based on otolith samples extended age data for the ports of San Pedro and Monterey in California, and British Columbia back to an earlier period.

Age compositions have been derived for San Pedro and Monterey for the 1938-39 season, for which no age samples were available. Length data for all seasons was used in conjunction with age composition records of the two adjacent seasons to formulate an approximate age composition and thus bridge the only gap in a 24-year continuous series of age determinations for the two ports.

Larval Studies: A basic reason for sardine larval studies is to test the widely held hypothesis that the early post-embryonic period is the most critical in the life of a pelagic fish and that year class strength is determined during this period. Survival rates for the 1952 and

1953 spawnings showed higher survival rates in the 1952 year-class which is the strongest to appear in the fishery since the start of the expanded research program.

Early survival of the sardine will continue to be measured and the relation between distribution and abundance of the types of "food" utilized by sardine larva will be investigated.

Mortality Rates: Total mortality rates of sardines of spawning age are estimated from year-class catch curves, from the size of population based on the egg census and from the catch.

Natural mortality rates are derived from estimates of the difference between total and fishing mortality. Mortality estimates for year classes not yet in the fishery are made from data collected by the California Department of Fish and Game on their young fish scouting surveys.

Total mortality rates for the 1954-55 and 1955-56 seasons, as estimated from year-class catch curves are:

Year-class	Total mortality rate	Year-class	Total mortality rate
1947	90%	1950	58%
1948	65%	1951	32%
1949	71%	1952	-33%

The 1952 class showed a "negative" mortality rate because more of this year-class were caught in the 1955-56 season than in the 1954-55 season. The average total mortality rate (omitting the 1952-class) weighed by numbers of fish caught from each year-class is about 45%. The total 1955 sardine population, based on egg censuses, was about 3×10^9 fish. The total 1955-56 catch was slightly more than 5×10^8 fish. Fishing mortality, then, was about 17%, and natural mortality about 34%.

Anatomical Studies: Examination of the eyes of the Pacific sardine, northern anchovy, jack mackerel and the Pacific mackerel has shown differences in musculature and circulation, in visual cell distribution and in type and nuclear organization of the retina.

The distribution and type of visual cells exemplified the functional differences in the eyes of these four species. The sardine and anchovy have regions of high cone (bright light receptors) density in a portion of the retina. The increased number of cones per unit area in part of the eye means that an object in the forward part of the visual field can be most sharply resolved.

Rods (dim light receptors), though abundantly present elsewhere in the sardine retina, are absent from the specialized area. This situation is typical in vertebrate eyes. In the anchovy, however, rods are not only present, but are elongated and more densely packed in the specialized area. There is a layer of reflecting pigment associated with the rods over the whole anchovy retina, indicating that the anchovy has a greater capacity for seeing in dim light than the sardine.

Pacific and jack mackerel do not have such well developed areas of acute vision. A variable distribution of two types of cones is the most noticeable difference between them. Cones in the jack mackerel eye are in constant ratio over the entire retina, while in the Pacific mackerel one type shows increased density in one quadrant of the retina, and the other type shows only a slight increase in the same quadrant. Since the functional differences between these cones, both of which occur commonly in fishes, are not yet fully understood, it is difficult to draw conclusions concerning their distribution within a particular eye. An objective comparison of acuity will be made when data on lenses of these species are completed.

Behavior Studies: The adaptability of sardines as experimental animals was evaluated through a behavior experiment. After a school of 400 sardines was responding well to prepared food pellets, 21 of them were isolated and subjected to a conditioned response technique, with food as the unconditioned stimulus and light as the conditioned stimulus. Within 11 days the group responded well to the light signal.

The test group response showed it possible to replace an occasional mortality with an untrained specimen without altering

group responses. Though not conditioned at the onset, such an individual follows the actions of others promptly and becomes conditioned in a short time.

Climatology: Available evidence indicates that anomalies in the distribution of pelagic fishes are associated with anomalies in temperature distribution. To examine this possibility, we are examining temperature data from 10 degree squares of the North Pacific Basin adjacent to Oregon, Washington, northern California, southern California and Baja California for the years 1935-53. So far, no temperature trend off Oregon and Washington has been found. Southward, however, the annual means tended to rise to a high in 1942-43, then enter a decline.

Comparison of temperature data for shore stations with offshore information shows, in general, rather good agreement. It may be possible to utilize shore station data in expanding knowledge of offshore temperatures.

Plankton: Since 1949 basic data on wet plankton volumes have been published in the Special Scientific Reports: Fisheries series. Plankton volumes for 1955 were above the average of the last five years and only one year in the series, 1953, had a larger average volume.

Large plankton volumes were contributed principally by two areas. Off central California, between San Francisco and Point Conception, and off Baja California, between Point San Eugenio and Point Abreojos. In both areas volumes exceeded those of any previous year of the series. The most marked increase in plankton volumes was in the area off central California, where average volumes in 1955 were between 3 and $4\frac{1}{2}$ times as large as in the preceding four years.

The nonrandom time and spacial distribution of organisms is termed contagious distribution and applies in varying degrees to all of the planktonic organisms encompassed during recent studies. A primary problem has been to find a reliable method of estimating the abundance of contagiously distributed organisms. For the collections analyzed, a negative binomial sampling distribution has been found to apply satisfactorily to plankton counts and a formula for the transformation of these data to a variable, whose distribution is known and tabulated, has been developed.

Anchovy: Abundant anchovy spawning has occurred in recent years only between Point Conception and Point San Junaico, Baja California. In the 1951-55 period there has been a steady increase of anchovy larvae in this area. Census estimates of the number of anchovy larvae taken in 1954-55 were double the 1951 estimate, indicating either a doubling of the spawning population or an increase in survival.

The 1955 commercial anchovy catch was 21,220 tons. Anchovies landed at Monterey and San Pedro have, since 1952, been sampled routinely for size and age determinations in a cooperative effort of the Service and the California Department of Fish and Game.

Pacific Mackerel: A striking similarity has been noted between distribution and season of occurrence of Pacific mackerel and sardine larvae. Neither species has been taken north of Point Conception in recent years and the distribution of larva of both species off southern California and northern Baja California is similar and seasonal occurrence is identical.

Pacific mackerel, like the sardine, spawn throughout the year off central Baja California. Pacific mackerel larvae taken off central Baja California have been four to six times more numerous than those taken off southern California and northern Baja California in most recent years. The ratio was nearly 20 to 1 in 1953, a season of unusually low water temperatures. On a February 1956 Gulf of California cruise Pacific mackerel larva abundance was much greater than on the outer coast.

Pacific mackerel eggs were found to require incubation of four and one-half days at 14.3°C. This value is close to that reported by Worley for development of Atlantic mackerel eggs at 14°C.

Jack Mackerel: Survey cruise information places the area of heaviest jack

mackerel spawning off southern California. To estimate the number of eggs spawned it was necessary to determine the rate of development of the eggs in relation to water temperature. To accomplish this a special fish egg incubator was designed which showed that jack mackerel eggs require about 96 hours to hatch at 14.3°C. Over 80 percent of spawning in nature occurs at temperatures between 14° and 16°C.

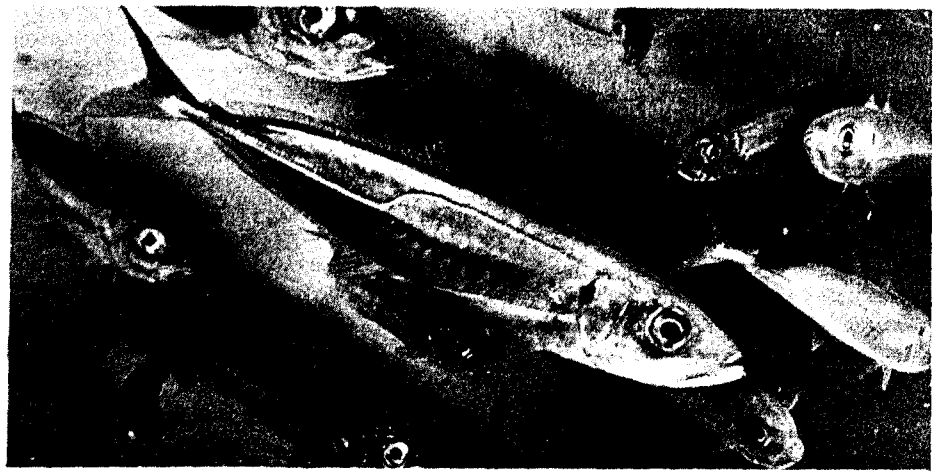


Fig. 19--Jack Mackerel

Saury: Basic information on the number of saury eggs taken in plankton hauls have been summarized for the seasons 1950 through 1955. Saury eggs are taken throughout the area routinely surveyed on CCOFI cruises. On the NORPAC cruise saury eggs were taken in hauls offshore from Oregon and Washington. It is likely that spawning takes place across the Pacific. In the area routinely surveyed, the center of abundance of saury spawning is off southern California. The bulk of the spawning takes place from January through July.

A visual saury survey was initiated in September 1951, and made a part of all CCOFI cruises. Sauries are attracted to working lights at night and records are kept of the abundance by size. Distribution and abundance of juveniles and adults as determined from the visual surveys are similar to that indicated by egg surveys.

Sauries have been observed throughout the survey area, with highest concentrations observed off southern California. A sharp drop in abundance was noted below Point Abreojos and only occasional sauries were observed off southern Baja California.

Ovary examinations show groups of eggs in two or three different stages of development indicating multiple spawning. The number of ova spawned per hatch is low compared to other pelagic fishes--1,300-2,200 in individuals thus far examined.

Hake: The hake constitutes one of the largest latent fishery resources in the eastern Pacific. Larval abundance is determined yearly. Hake larvae are taken in abundance off southern California and adjacent Baja California.

Gray Whale: California gray whales are annually censused by a count of migrating whales made from shore vantage points and by aerial reconnaissance of the calving and mating grounds along the coast and lagoons of Baja California. The 1956 land census, which was hampered by fog, gave a total count of 903 whales. The aerial census gave estimates of 826 adults and

138 calves. Both counts were below those of the preceding year.

Fur Seal: A small herd of fur seals was discovered in 1954 on Guadalupe Island, marking the return of an animal once so zealously exploited that it was believed extinct. A recent check indicated the Guadalupe herd now numbers 91.

PACIFIC OCEANIC FISHERY INVESTIGATIONS

Since 1948 the Pacific Oceanic Fishery Investigations (POFI) at Honolulu, Hawaii, has worked toward the exploration, investigation, development and maintenance of fishery resources of the Central Pacific which are available to the residents of the Hawaiian Islands and other United States island possessions in the Pacific.

Oceanography: POFI participated this year in EASTROPIC, a cooperative survey of the eastern tropical Pacific designed to fill a major gap in the descriptive knowledge of the oceanography of the central Pacific. Currents were measured indirectly by geostrophic methods and directly by drags and current meters. In concept the POFI cruise was part of a program for firming up the apparent relationship between the age of upwelled water and yellowfin tuna abundance and to explain major features of zooplankton distribution in the equatorial area. The information gathered was combined and compared with data from previous cruises and with that of a monitoring station at Christmas Island.

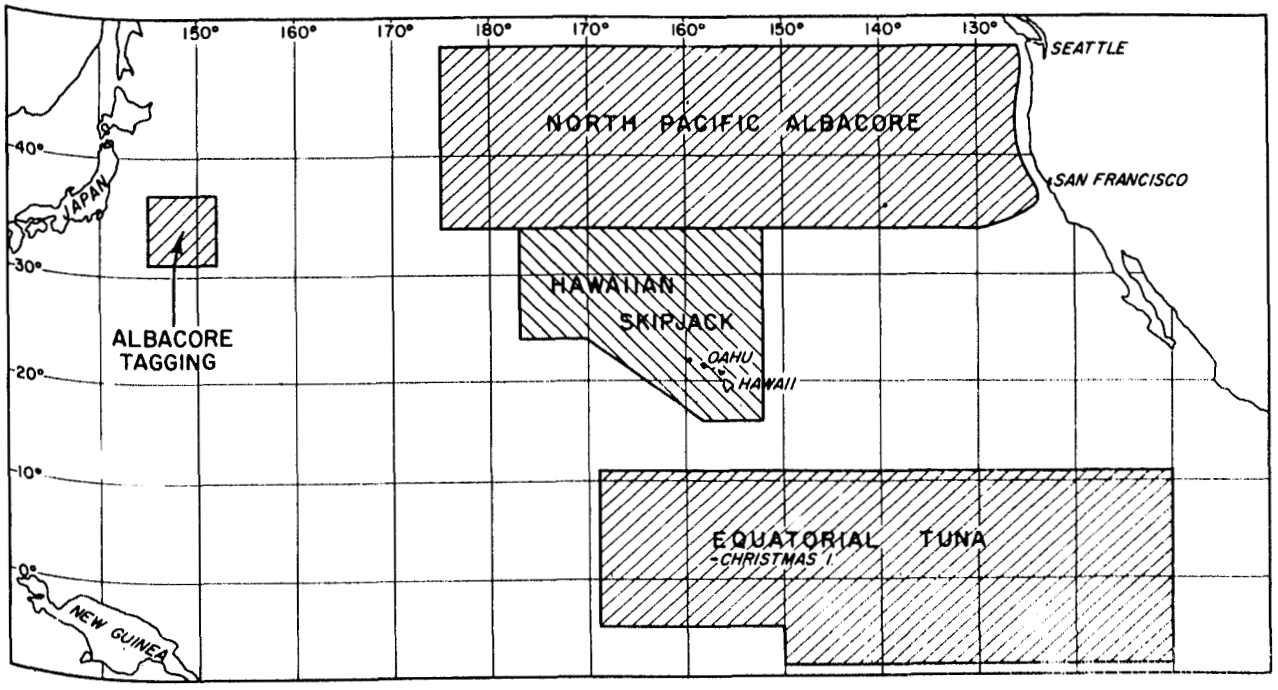


Fig. 20--Areas of the Pacific in which POFI conducted scientific research during the research year.

Biological indices show that the standing crop of yellowfin and zooplankton reach a peak between the equator and 5°N and between 145° and 155°W longitude, suggesting a region of well defined optimum conditions for biological productivity. Analyses of the available physical and chemical data have partially explained the factors underlying the existence of this area of high productivity.

First upwelling is associated with the equatorial divergence; a replacement or "mixing" of the deeper, cooler, nutrient-rich waters with those at the surface. Considering the energy source of this upwelling--winds from the eastern South Pacific anticyclonic high--the maximum divergence of the surface waters should be, and apparently is, between 140° and 160°W longitude.

Also related is advection. The cooler waters of the thermocline generally reach the surface between 100° and 120°W longitude. These cooler, enriched surface waters are transported west by the south equatorial current. Being more dense, the "new" surface water sinks and accelerates vertical mixing along the equator, decreasing in effectiveness as westward movement continues.

Probably the most important factor is the equatorial undercurrent. This pressure driven current, centered beneath the equator, flows to the east beneath the westerly flowing, wind-driven, south equatorial current. At the interface of these two opposing currents is a pronounced shear and vertical zone of intensive mixing. The thermocline and equatorial undercurrent slope upward between 160° and roughly 100° W longitude. Thus, this zone of physical mixing is decreasing in depth from west to east and waters of high nutrient content become more readily available with the thermocline "entering" the euphotic zone in the region of 145°-150°W.

To the east of this area of optimum productivity, at about 100°W, the thermocline again deepens, and winds on the equator have a more southerly component, and thus are not as effective in producing divergence of the surface layers. Westward, the thermocline deepens and the frequency of westerly winds (convergent in terms of surface flow in the ocean) increases. The equatorial undercurrent apparently has its origin between 160°W and 160°E longitude, and within this region the interface between the two opposing currents is relatively deep. Little or no upwelling occurs west of approximately the 180th meridian.

Productivity: A major portion of the EASTROPIC cruise was devoted to comprehensive surveys of the biota of the eastern central Pacific. Measurements were made of forage fish, zooplankton, plant pigment and carbon-14, the latter two being made in collaboration with the University of Hawaii. Zooplankton sampling included an extended series of 3-level closing net hauls to provide a basis for better understanding of the relations between vertical and horizontal distribution of plankton and between plankton and environment.

Preliminary analyses have revealed an interesting relation between surface water values for temperature, inorganic phosphate and the rate of carbon fixation, particularly at or near the equator. Lower temperatures were associated with the highest phosphate values and carbon fixation rates in regions where deeper waters are being mixed with those of the surface. In addition, and probably of great significance, these carbon-14 measurements revealed a marked, consistent, dinuaral variation in the ability of phytoplankton to fix carbon.

Yellowfin Tuna: A year-round program of yellowfin population sampling initiated in the Line Islands area in January 1955, has been completed. Results show that longline, or deep swimming, tuna were generally scarce. Catches fluctuated from one per 100 hooks to three per 100 hooks with little indication of seasonal variation as noted in earlier years. Troll-caught surface tuna paralleled the low availability of deep-swimming tuna. Troll catches were highest during March and April, and catch rates were highest in the northern Line Islands, which lie in or near the countercurrent, an area previously shown to support larger numbers of surface fish than the waters to the north and south.

Coincident with low yellowfin abundance at Christmas Island water temperatures were unusually low in comparison with the 1950-53 period. This provided additional evidence in support of the theory that near the equator cooler water indicates newly enriched water in which the biota to support a large yellowfin population has not yet developed. Conversely, warmer water near the equator is thought to be upwelled water that has been in the euphotic zone long enough to develop a food supply for tuna. Ocean water temperatures recorded at the Christmas Island station took an upward turn during the spring of 1956, suggesting that the environmental conditions associated with high abundance during 1950-53 may assert themselves during the period starting in 1956.

Approximately 1,000 yellowfin tuna were tagged during a one-year program, and the only recovery at the time of this report was a yellowfin tagged and recovered at Fanning Island. This fish had been at liberty for six months when recovered. This recovery tends to support the contention that there are small localized populations of yellowfin tuna associated with each of the small islands in the central Pacific.

Wahoo: A byproduct of the tuna investigations has been collection of information on the biology of the wahoo, a little-known scombroid. These data suggest that the wahoo is extremely prolific and that it engages in extensive migrations among the islands within the study area. The food of the wahoo is roughly the same as that of tuna and it appears they compete to some extent with tuna in the vicinity of smaller islands. This competition cannot be considered as serious since the wahoo appear to be restricted to inshore areas.

Central Pacific Oceanography: The results of past oceanographic surveys indicate that the Hawaiian Islands are located in a region of small net transport of water. During winter months the net flow decreases to a minimum and large eddy systems extend to the north and south of the islands. During summer and autumn months the number of systems appears to decrease. The nature of these eddies also seems to change from scattered, weak vortices in winter and spring to pronounced vortices in the lee of the islands which extend to depths of more than 600 meters during summer and autumn.

During the year a new program of oceanographic field work was designed to focus directly on the general problem of fluctuations in the availability of skipjack. Included are weekly temperature and salinity observations; biweekly observations by the University of Hawaii and the Territory Division of Fish and Game; monthly observations by POFI and fairly elaborate investigations on a quarterly basis. The program differs from a traditional oceanographic survey in that it involves pertinent reconnaissance-type observations focused on problems of skipjack distribution.

Skipjack distribution and Abundance: The study of skipjack has led to initiation of a detailed program designed to ascertain the ecological requirements of the fish and the factors in the ocean responsible for their presence and absence, both seasonally and geographically. This involves measurement and analysis of hydrographic factors, measurement and analysis of plankton in terms of levels of abundance and distribution in the ocean. The Hawaiian commercial fishery supplies information on the distribution and abundance of skipjack in space and time. Analyses have been initiated on local catch statistics, utilizing small areas and short periods of time as sampling units. Brochures have been prepared and distributed to skipjack fishermen, introducing them to the general program and soliciting their support.

A preliminary hypothesis based on the relation between wind flow over the island area and skipjack catch holds that there is a positive correlation between the catch during summer or "season" months and the direction and strength of winds during the late spring. It appears that winds may affect the environment of the skipjack through their control of oceanic circulation. This hypothesis serves as a starting point for exploring the equestion of annual fluctuations in abundance.

Tagging: California-type spaghetti tags were used on 945 skipjack in Hawaiian waters. To date 12 recoveries, nine by live bait fishing and three from the stomachs of long line caught yellowfin and bigeye tuna, have been reported by commercial fishermen around Hawaii. The recoveries have indicated limited movement, with the maximum distance traveled about 40 miles. All but one of the fish were out less than three months. The exception was at liberty just over eight months and had gained seven pounds. This growth rate agrees with past studies on Hawaiian skipjack growth based on size-frequency analysis.

North Pacific Albacore: Exploration for albacore fishing grounds north and east of the Hawaiian Islands and the collection of basic chemical and physical data for use in analysis of fishing results have been the major objectives of this program. Another objective has been to work "upstream" of the American coastal albacore fishery to investigate the biological and physical causes of the violent fluctuations in the catches of the fishery. Supporting these studies, investigations are being made of the ocean-wide distribution of albacore, albacore growth rate and spawning, races of albacore, North Pacific weather and the distribution of plankton in the North Pacific.

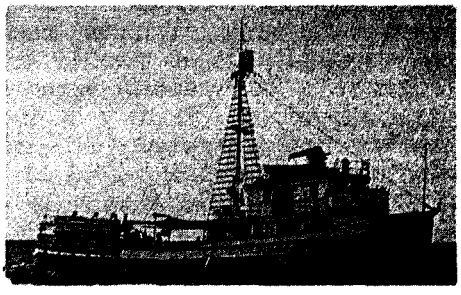


Fig. 21--The John R. Manning rigged for long line fishing.

Oceanography and Meteorology: Oceanographic field work consisted of one formal cruise and incidental observations such as BT and collections of surface salinities and phosphates during fishing cruises. Informal cooperation through the Eastern Pacific Oceanic Council resulted in Norpac, a quasi-synoptic physical, chemical and biological survey of the North Pacific during July and August 1955, by vessels of the United States, Canada and Japan. POFI's participation consisted of 114 oceanographic and biological stations in the area from the Hawaiian Islands to 49°30'N between 157°30'W and the 180th meridian. At a meeting of the NORPAC agencies in February 1956, the data were exchanged and plans drawn for an oceanographic atlas of the North Pacific. POFI's task in this work is preparation of dynamic topography profiles and geostrophic current charts.

The summer of 1955 was the first time that a POFI vessel completely crossed the Polar Front into the subarctic waters of the Aleutian Current, the most significant feature of the North Pacific as far as albacore occurrence is concerned. The front extended from a west-southwest to east-northeast direction. According to temperature and salinity conditions the southern boundary is about 32°N on 180°W and 34°N on 157°30'W, and the northern boundary is about 43°N on 180° and 45°N on 157°30'N. The Central Pacific stocks of albacore are found in this zone, which may also serve as a migratory path for albacore approaching the west coast of America.

Preparation of a wind atlas of the North Pacific for use in evaluating areas in terms of operation of small vessels, such as POFI's, has been started. Preliminary analysis of United States Weather Bureau raw wind data is complete and monthly charts of the average percentage of occurrence of winds of less than 20, 25, 30 and 35 knots and maximum observed winds are in preparation. Next, an attempt will be made to correlate deviations from normal in wind strength and direction, as indicated by atmospheric pressure, with fluctuations of the west coast albacore catches.

Plankton: The zooplankton collections obtained on the NORPAC expedition were processed and data were published. Other sampling, on fishing cruises, has been planned to provide information on the amount and kinds of plankton organisms associated with favorable albacore environment. Based on plankton fauna, the North Pacific may be divided into three zones: subtropical (North Pacific Current) containing an abundance of warm water species but a low biomass; subarctic (Aleutian Current) which is an area of few species but high biomass, and a transition zone (Polar Front) characterized by mixed fauna and variable biomass. The dividing line between the tropical and boreal species of copepods appears to be the 58°F isotherm. A literature survey indicates that the major cold and warm water currents of the

world are separated during winter periods by the 58°F isotherm.

Albacore Distribution: Three exploratory fishing cruises were made during the year to determine distribution and abundance of albacore north and east of the Hawaiian Islands.

The area northeast of the Hawaiian Islands between 152°30'W longitude and the United States Pacific Coast was covered during a summer cruise of the John R. Manning. Results of this cruise, coupled with trolling results from the NORPAC cruise and gill-netting results made available by the North Pacific Salmon Investigations, suggested a discontinuous distribution between the surface-swimming albacore of the central and eastern North Pacific. In the Central Pacific albacore occurred in a band between 45° and 48°N latitude west to an unknown point beyond the 175°E limit of the survey area, but not significantly east of 160°W. This band was along and slightly to the north of the upper limit of the Polar Front. In the eastern Pacific the band of fish was encountered at 135°W longitude and at about the same latitudes as in the central Pacific, and extended roughly south-southeasterly toward the coast of southern California.

A fall cruise to the area bounded by 30° and 50°N latitude and 145° and 165°W longitude suggested that the break in albacore distribution, then between 148° and 165°W, was either transient or had diminished.

The area northwest of the Hawaiian Islands from 28°N to 42°N latitude between 163°W longitude and the 180th meridian was investigated by a spring cruise to observe the spring distribution following the breakup of the Japanese winter fishery to the west. Only a few surface swimming albacore were taken in the area between 32°N and 34°N latitude and between 180° and 170°W longitude. Four small pink salmon were taken in the gill nets at 41°28'N, 165°18'W and 41°30'N, 164°33'W.

As data have been accumulated and analyzed, emphasis has changed from that of past surveys which have been directed toward determining the limits of albacore distribution and associated environmental factors. Interest has shifted from subsurface to surface fishing and the principal gear used in the future will be gill nets, supplemented by trolling.

Albacore catch rate and length frequency data were compiled from all available literature to form the basis of a working hypothesis for their distribution and abundance in the North Pacific. While not extensive, the data seem to indicate a single albacore population which has its primary nucleus and source in the waters of the islands of the west central Pacific.

Tagging: Through the Albacore Steering Committee of United States west coast research agencies, POFI has encouraged a Pacific-wide albacore tagging program to define migratory routes and to clarify the relation between albacore taken on both sides of the Pacific and within the central Pacific. During 1956 the California Department of Fish and Game, with the assistance of the Oregon Fish Commission, tagged some 2,000 albacore off the United States west coast. POFI agreed to tag as many fish as possible in mid-ocean, and to provide tags for albacore which might be caught during salmon research cruises of vessels of the United States, Canada and the University of Washington. In May, two POFI biologists were sent to Japan to tag albacore and to instruct Japanese technicians in tagging methods. With the excellent cooperation of the Japanese, 270 albacore were tagged by the POFI biologists off the coast of Japan. The Japanese technicians will follow through by tagging 2,000 albacore during the spring of 1957.

Since the inception of the albacore program POFI has tagged 201 albacore and 82 bigeye tuna in the central and North Pacific. Four recoveries were reported during this year. two albacore and two bigeye. One albacore was recovered 2,670 miles from the release point after 471 days. It was 40 pounds heavier than when released. The other was taken 2,055 miles from point of release after 420 days. The first of the bigeye was taken 297 days from release at a point 800 miles from the tagging site. The other, taken after 367 days, was 640

miles from the release point. Weight gains of 10 and 35 pounds respectively were noted for these fish.

Albacore Biology: Albacore age determinations were attempted through study of growth rings in the vertebrae and on the scales. Agreements between successive readings and length frequency data were so poor that the work had to be set aside. Polarized light and colored filters were used in an attempt to accentuate vertebrae growth rings. The colored filters seemed to accentuate the rings but did not improve the agreement between successive readings. Scales were read while dry mounted or from cellulose acetate impressions. Preliminary plots of fish length against number of supposed annuli showed little consistency between size and "age" of fish.

Spawning and maturation studies have been started using gonads from albacore taken during summer months in the long line fishery of the Hawaiian waters. Gonads have been found to have all degrees of maturity from those having ova no larger than 0.30 mm to those having ova diameters up to 1 mm or well above 0.84 mm to 0.94 mm at which eggs are considered mature. No correlation between time or size of the fish and the state of maturity has been found.

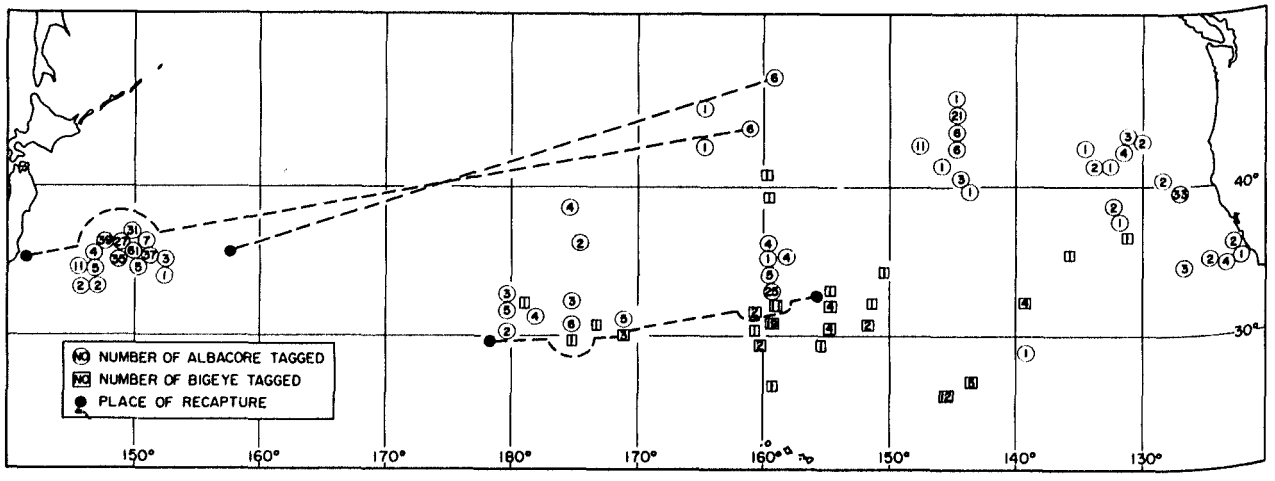


Fig. 22--Positions of release and recapture of albacore and bigeye tagged by POFI in the North Pacific.

Tuna Life History: Larval and juvenile stages of tunas are a potential means of assessing abundance independent of adult availability to fishing gear. It is exceedingly important, too, to locate spawning and nursery areas of the several species of tuna in the Pacific. This can most efficiently be accomplished through studies of larval abundance.

In the past positive identification of the several tuna larvae necessary for such application was made of the very early stages of yellowfin (Neothunnus) and skipjack (Katsuwonus). This year positive delineation of the early stages of little tunny (Euthynnus) and frigate mackerel (Auxis) was accomplished, bringing to four the total identifiable with reasonable certainty in the very small sizes taken by plankton nets. Preliminary experiments suggest the possible development of a special larval fish tow which will supply large enough catches to afford a reasonable basis for judging relative abundance among areas. During one such series of tows near the equator, catches ranged up to 45 per haul as contrasted with maximum catches on routine plankton tows of less than 10 and generally of only one or two larvae.

Early larval identification of Auxis and Euthynnus was made possible through material obtained by exchange with other institutions. A collection of some 20,000 larval scombroids was acquired from the Danish government. Additional material was received from the East and West Indies, western North Atlantic, Gulf of Mexico, Pacific Central America, Italy, Japan and Pakistan. POFI has reciprocated by furnishing series of material from the central Pacific. Analysis of new collections should permit early positive identification of the larvae of other important species of tuna such as the albacore.

Tuna larvae taken in the North Pacific during the NORPAC expedition show the northern limit of identified tuna larvae as about 34°N. Larvae taken in abundance between 25° and 29°N appear to be almost entirely yellowfin and skipjack. The absence of albacore larvae is not surprising in view of the apparent lack of individuals in spawning condition in the north central Pacific.

Sharks: A study of the distribution, abundance and food habits of pelagic sharks is nearing completion, and will add considerably to the knowledge of these predators and competitors of tuna. Three abundant pelagic sharks are the great blue (Prionace glauca), the brown (Carcharhinus floridanus) and the white tip (Pterolamiops longimanus). Bonito (Isurus glaucus), mackerel (Lamna sp.), thresher (Alopias vulpinus) and hammerhead sharks (Sphyrna sp.) are common to uncommon, but are, in order, generally less abundant.

The great blue is a wide-ranging species with its center of abundance to the north, the white tip and the brown are equatorial species, the bonito is wide-ranging, the mackerel is subarctic and distribution of the other species is not well known. All are broadly carnivorous on fish and cephalopods, and pronounced sexual sequestering is indicated for some species.

Gear Development: A new method for handling cotton long line gear developed during the year involves flaking down a continuous mainline into a large tub rather than breaking the gear into individual baskets. Using this method enables fishing of up to 1,100 hooks a day. In test usage the gear was fished by 11 men, but it appeared that it could have easily been fished by six men. This is indicative of more efficient operation than that of Japanese commercial fishermen who fish around 2,000 hooks with crews of 25-30 men. Further tests are needed to establish the commercial potential of this method, however, all indications thus far are favorable.

Continued testing of steel gear established it as inefficient when used in tuna long line fisheries. Steel is expensive and does not last long in the field because of excessive kinking under the strain of holding heavy fish. More important, the steel gear does not appear to capture tuna as efficiently as cotton gear. There are indications that this is due to its lack of resilience and failure to provide a drag on the fish struggling to escape.

Sonic Ranging: A new and potentially promising sonic scanning device was received from the Minneapolis-Honewell Regulator Company in December. To date most of the work with this equipment has been devoted to ironing out bugs in design and construction.

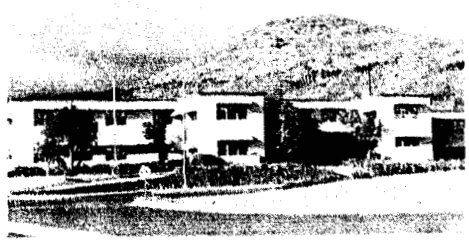


Fig. 23--POFI Headquarters

Contract Research: Three projects have been contracted to the University of Hawaii. A tuna vision project, initiated in June 1955, stemmed from the observation that vision was the predominant sense in tuna feeding and the belief that fundamental vision research might suggest a new solution to the tuna bait problem.

First year objectives were to determine if anatomical or morphological differences exist in the eyes of different sizes and species of tuna which might be associated with different habits and habitats, and to determine the optical potentials of the tuna eye. Comparison of eyes of small and large skipjack (surface fish) with large yellowfin (deep-swimming) so far has revealed no basic differences in shape, structure, musculature or retinal mosaic pattern, despite the differences in habit and habitat. Fresh whole eyes, with an artificial opaque viewing screen covering an aperture in the retinal-chorioid layer and a movable pin-point light source were immersed in a long trough of sea water to determine the distance of acute vision. Problems arose because of the variation in the position of the lens at rest and the difficulty of devising an apparatus to move the lens and thus to simulate accommodation. These problems have not been solved as yet. A new contract for a comparative histological study of the retina of different tuna species, with special emphasis on the distribution and ratio of the rods and cones was initiated June 1, 1955.

A second contract project continues the investigation of the possibility of utilizing electrotaxis as a means of harvesting tuna. An apparatus constructed during earlier phases of the contract was tested on tuna and other fish during the year. The apparatus employed pulsed DC current generated by intermittent charging and discharging of a bank of condensers powered by ten, 6-volt storage batteries. Theoretically this equipment was capable of creating an electric field sufficient to control the movements of tuna in a concrete tank 35x11x14 feet.

In testing, 8-10 pound yellowfin were controlled over a distance of 16 feet at a frequency of 18-20 cycles per second. This was the first demonstration that tuna respond electrostatically. Because of the relatively low power source, and because of the probability that the dissipation of energy in the well grounded tank was comparable in magnitude to that which would be encountered in the open sea, the results were considered particularly significant. The contract for this work has been extended to complete this phase of the study.

A third contract is aimed at providing basic information useful to the commercial tuna fishery in combating the numerous cannery rejections of yellowfin tuna from the central equatorial Pacific because of a "green" or "off color" condition which develops during processing.

It was found that in raw fish the pigment associated with incipient "greening" was a peroxidase-like or myoglobin-like heme-protein; that oxidation of the pigment is involved in the formation of the condition; that substances, such as ascorbic acid, which may act as reducing agents, tend to inhibit the condition and, most important, that the "green" appearance following precooking is not due to the production of green pigment, but to an abnormal lack of reddish pigmentation. This study will continue under additional contracts and is being followed closely by technologists in Hawaii, the continental United States and in Japan, for it offers promise of a solution to an industry-wide problem.

OCEAN RESEARCH

Thinking regarding the conservation of fishery resources has passed through several stages. In the 19th century the resources of the sea were generally thought to be inexhaustible. Toward the close of that century the outlook changed and there ensued two or three decades of effort to augment the natural stocks through artificial propagation. In the decade from 1910 to 1920 it became increasingly apparent that this remedy was not effective for sea fish and there began serious efforts to conserve the fishery resources by controlling the kind and amount of fishing.

Fishery research has passed through corresponding stages. In the 19th century most study was by naturalists who, working in universities and museums, classified our fishes, noted interesting features of their habits and produced faunal treatises describing the fishes and their distribution in the sea.

During the popularity of the sea fish hatcheries scientists in government service as well as those in universities turned toward studying the life history and habits of fishes, especially their spawning, embryological development and the various biological phenomena germane to the art of artificial culture.

With the realization that sea fish hatching was ineffective, scientists turned toward the study of fish as populations, defining the limits of stocks which act as population units, investigating birth and death rates and the resilience of the stocks to the additional mortality imposed by fishing. They erected theories on population dynamics by which to guide formulation of sound conservation measures. Fishery science is today in the midst of this phase of research which produces information fundamental for intelligent control of fishing.

At the same time it is becoming increasingly evident that it is not sufficient to learn inherent capacities of fish populations to renew themselves through reproduction, but also to understand the effects on population numbers of environmental changes. In many ocean fisheries there are large fluctuations in population size and therefore of fishery yield which cannot be attributed to the pressures of fishing. These, then, must be caused by changes in the ocean climate either directly, as by swings in sea temperatures which may shrink, expand or shift the habitable area, or indirectly, as by alterations of ocean circulation which may diminish or enhance the fundamental productivity of given sea areas and so affect the food supply.

Oceanographic advances have demonstrated that the circulation of the ocean and the distribution of its properties, such as temperature, salinity and fertility, are dependent on the radiation received from the sun and on the energy received from the winds. Oceanography has also taught that there is unity in the ocean--a change cannot occur in one place without adjustment in other places. Similarly, in meteorology it has been found that the atmospheric circulation acts with global unity. Thus to investigate the fluctuations in the environment affecting a certain fish stock we are led to consider oceanography on an oceanwide basis, and since the ocean is the slave of the sun and the winds, to connect its changes with global-scale weather oscillations.

The Service has supplemented local research on specific fish stocks by formation of a new research unit to bring together data on ocean circulation and related meteorological conditions to make available to the more localized and specific research units the background of information needed to explain the fluctuations observed in particular fish stocks. In the long run this service should lead to earlier and more firm results from individual investigations on the effects of fishing.

The field of oceanwide research is a complex one and this pioneer effort in it will inevitably require long-term application to achieve success. If achieved, it could lead to future prediction of spectacular fishery events such as the disappearance of the albacore from the waters off the United States west coast in 1928 and its reappearance again in 1937, or the failure of the pink salmon run in southeastern Alaska in 1953.

Ocean Research, as the new unit is called, is located at Stanford University and will work on the oceanography and meteorology of particular application to Pacific Ocean Fisheries.

The opening phase of research is a study of oscillations in the semipermanent North Pacific high pressure cell which dominates the wind system over the Pacific. It has been found that this important weather feature performs oscillations of seemingly sufficient amplitude and duration to cause substantial changes in major features of the North Pacific Ocean current system.

From this point plans call for a study of the concomitant changes in certain major wind fields over parts of the Pacific which appear to be critical for major oceanic features of significance to

fisheries. Some of these are the divergence of westerlies on their approach to the North American coast, whose swings in latitude may affect the relative amounts of cold subarctic and warm subtropical water fed into the Gulf of Alaska gyre; the field of northwesterlies off the United States west coast which governs the upwelling and hence fertility along our Pacific Coast, and the field of northwesterlies in western Bering Sea--Kamchatka-Okhost Sea area which may materially affect the amount of subarctic water fed into the North Pacific drift and carried by it across the ocean to the areas of the United States west coast and Alaska fisheries.

SECTION OF ANADROMOUS FISHERIES

ATLANTIC SALMON INVESTIGATIONS

The Atlantic Salmon Investigations were reorganized in 1954 to obtain basic biological information on the Atlantic salmon and its environment. The Sheepscot River, near investigation headquarters at Boothbay, Maine, is annually stocked with 20 to 30 thousand young salmon and was selected as study site. All segments of the environment of the migrating salmon are subject to scrutiny, including the river, its estuary and the inshore coastal waters.

Salmon Tagging: Salmon tagging in 1954-55 did not produce sufficient results to justify continuance of the program. Salmon catches in coastal mackerel traps are small and sporadic, and since only five to seven salmon taken by this method have been tagged each of the two years, it was felt that such small numbers of the tagged fish were statistically useless and did not warrent the time and expense devoted to tagging operations. Quite remarkably, one tag out of five was returned in July 1955 from a salmon captured at St. John, New Brunswick, about one month after tagging at Small Point, Maine.

As a partial substitute for the tagging program, weekly visits are now made to a Bath, Maine, fish dealer who markets all the salmon taken in the Small Point trap. He has been alerted to watch for and report all marked, tagged or unusual salmon, and has agreed to report the numbers of salmon taken each week. Measurements and scale samples are taken from specimens on hand at the time he is visited.

Ecological Studies: An intensive survey of the upper estuary of the Sheepscot, within three miles of the river mouth, has been initiated. It is in this part of the estuary that adult salmon remain during the summer prior to ascending the river in the fall spawning run. The objectives of this phase of estuarine study are to determine the effect of freshets on the hydrography of the estuary, learn the zonation of estuarine fauna and flora with reference to seasonal and diurnal salinity fluctuations and to determine comparative abundance of bottom organisms available as food for young salmon in different parts of the river and estuary.

Two years of plankton and hydrographic studies made in the lower end of the Sheepscot estuary have been prepared for publication, and the studies have been reduced in scope.

Sheepscot Counting Weir: The base platform for an upstream and downstream counting weir was completed during the 1955 low water period. It is located about two miles above the mouth of the Sheepscot River, just below the tidal head, and replaces a temporary structure operated in 1954 about 1,000 feet downstream.

Seaward migrating young salmon were taken in the downstream trap almost immediately after completion of the weir. Two hundred forty-eight migrant young were counted in the downstream trap during a nine-day period. Of these, 173 were one year olds, most planted in the fall of 1955. The other 75 were two year olds, for the most part planted in 1954. There were 11 unmarked individuals, assumed to be naturally spawned. Average length of the one year old fish was 121 mm., while that of the two year olds was 160 mm. The greatest numbers of two year olds appeared somewhat earlier than the one year olds. Some migration may have occurred prior to the closure of the weir on May 18, 1956, and some after a washout on May 28.

Continued utilization of this or similar counting devices will provide cumulative information of value.

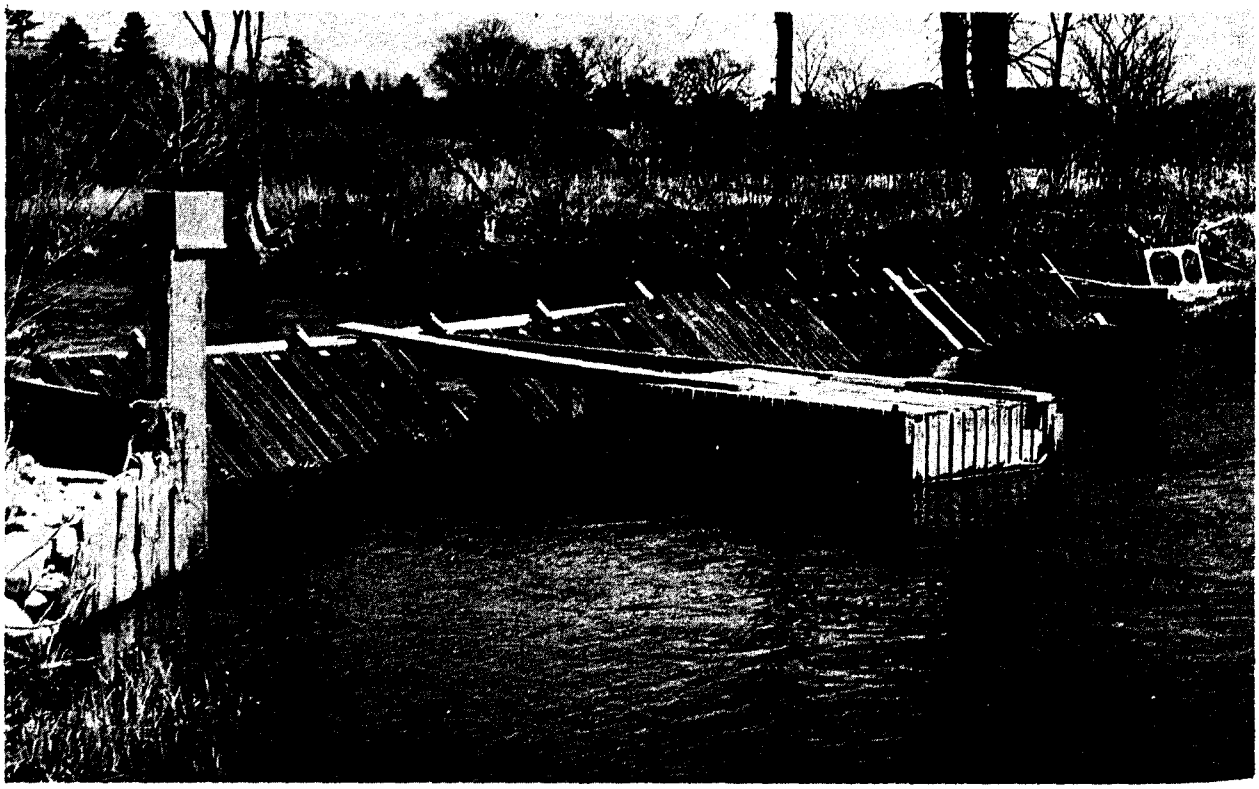


Fig. 24--Sheepscot River Counting Weir

MIDDLE ATLANTIC FISHERY INVESTIGATIONS

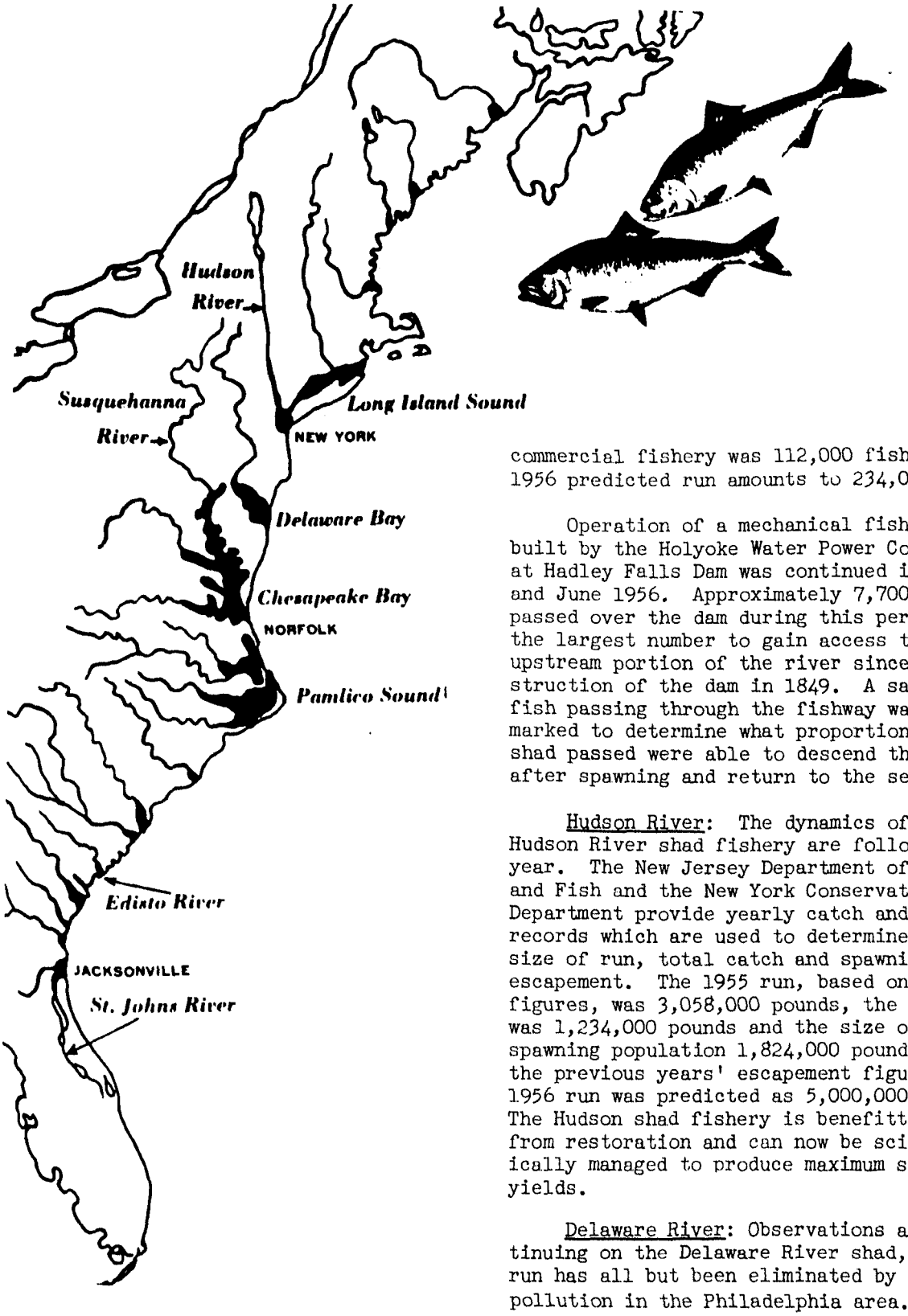
From its base at the Beaufort, N. C., laboratories, the Middle Atlantic Fishery Investigations seeks information from Maine to Florida on its two coastwide projects, the shad and striped bass investigations.

Shad: Atlantic coast shad production has declined since the turn of the century. The Service, as the primary research agency of the Atlantic States Marine Fisheries Commission, has undertaken a coastwide investigation of the shad fisheries to determine the underlying causes of the decline and to determine conditions favoring recovery of the runs and the proper management principles necessary to assure a sustained maximum yield. Because funds and personnel are not sufficient to study all shad fisheries simultaneously, research is carried out on the fisheries of limited areas each year. During 1956 the area of interest was the New Jersey coast.

Racial Studies: In the spring of 1956, 2,960 shad were tagged off the New Jersey coast to determine the racial composition of the catch and the fishing mortality exerted by the New Jersey coast pound net fishery on individual and river populations.

Meristic data were obtained from shad caught at three locations on the Jersey coast and from shad caught in the Hudson and Connecticut Rivers. These data, combined with results from the tagging program, should indicate what proportion of the New Jersey coast pound net catch consists of fish native to the Hudson and Connecticut Rivers. Data collected in this study are now being analyzed.

Connecticut River: Since the initial investigation of the Connecticut River shad fishery in 1951, the yearly size of run, total catch, spawning escapement and predicted size of the next year's shad run is determined from catch and effort data collected by the Connecticut State Board of Fish and Game. The 1955 shad run totaled 173,000 fish, the commercial catch was 60,500 fish and the escapement from the



commercial fishery was 112,000 fish. The 1956 predicted run amounts to 234,000 shad.

Operation of a mechanical fishway built by the Holyoke Water Power Company at Hadley Falls Dam was continued in May and June 1956. Approximately 7,700 shad passed over the dam during this period, the largest number to gain access to the upstream portion of the river since construction of the dam in 1849. A sample of fish passing through the fishway was marked to determine what proportion of the shad passed were able to descend the dam after spawning and return to the sea.

Hudson River: The dynamics of the Hudson River shad fishery are followed each year. The New Jersey Department of Game and Fish and the New York Conservation Department provide yearly catch and effort records which are used to determine the size of run, total catch and spawning escapement. The 1955 run, based on these figures, was 3,058,000 pounds, the catch was 1,234,000 pounds and the size of the spawning population 1,824,000 pounds. From the previous years' escapement figures the 1956 run was predicted as 5,000,000 pounds. The Hudson shad fishery is benefitting from restoration and can now be scientifically managed to produce maximum sustained yields.

Delaware River: Observations are continuing on the Delaware River shad, whose run has all but been eliminated by heavy pollution in the Philadelphia area. Under

the leadership of the Interstate Commission on the Delaware River Basin progress is being made in cleaning up the river. Restoration of this shad population is dependent on abatement of pollution, especially in October and November when young shad pass through the polluted area on their journey to the ocean.

Edisto River: The Edisto River, in southern South Carolina, was studied in the spring of 1955 to determine the size of shad run, the commercial and sport catch and the number of fish allowed to escape the fishery and spawn. Catch and effort data were combined with a tagging and recovery program to produce data indicating a run of 56,000 shad, a total catch (sport and commercial) of 11,000 shad and an estimated spawning population of 45,000 shad. The State of South Carolina has been urged to establish a system of collecting catch-and-effort records so that studies may be possible to determine what factors affect Edisto shad abundance.

St. Johns River: Catch and effort records have been collected on Florida's St. Johns River yearly since the first inquiry into the shad fishery began in 1953. The 1956 commercial catch was 293,000 pounds while the sport fishery caught 75,000 pounds. Analysis of data collected on this fishery is continuing.

Striped Bass: The Atlantic States Cooperative Striped Bass Program continues to progress with eight states actively participating (Mass., Conn., New York, New Jersey, Maryland, Virginia, North Carolina and South Carolina) and two States (Rhode Island and Delaware) participating to a limited extent. The program was initiated with Service coordination in 1953 to obtain facts necessary to settle the controversy between sport and commercial fishermen over exploitation. In addition, information was needed on size limits, spawning areas and racial origin of striped bass stocks.

Catch and monetary value inventories, tagging studies and racial studies of meristic and morphometric characters all form a part of the continuing program. Spawning areas have been delimited to a great extent in New York, New Jersey, Maryland, Virginia and South Carolina, and data have been obtained on fecundity, sex ratio, growth, age at maturity and length and weight of the striped bass of the various fisheries.

Roanoke River: The flow pattern and water quality of the Roanoke River has been altered in recent years by power and flood control dams, and striped bass runs have deteriorated. Conservation agencies have been faced with the problem of maintaining striped bass runs with diminished and irregular flows and the resulting concentration of domestic and industrial pollution. To resolve all of these problems a cooperative study whose goal is the intelligent development of the river basin was formed, and in September, 1955, funds were made available for a three-year striped bass research program in North Carolina waters. Particular emphasis is being placed on the populations of Albemarle Sound and its tributaries.

A tagging program began in lower Albemarle Sound in October 1955, at the beginning of the pound net fishing season for striped bass. From October through December 687 tags were applied, and 373, or 54 percent, were recovered. The tags were returned exclusively from the Albermarle Sound System, including four from the Roanoke River taken during the spring run. Nylon streamer tags proved more satisfactory for striped bass population estimates than the Petersen disk tags which were also used. Little or no evidence of selectivity was found in the recovery of the streamers in contrast to a high selectivity of the disk tags in the gill net fishery. Commercial catch and effort data were recorded and preliminary fishing rates and population estimates are being made from the results of the tagging study, which will be duplicated in the fall and winter 1956-57.

Beginning in April 1956, the Roanoke River spawning run was subjected to a tagging and recovery program and catch

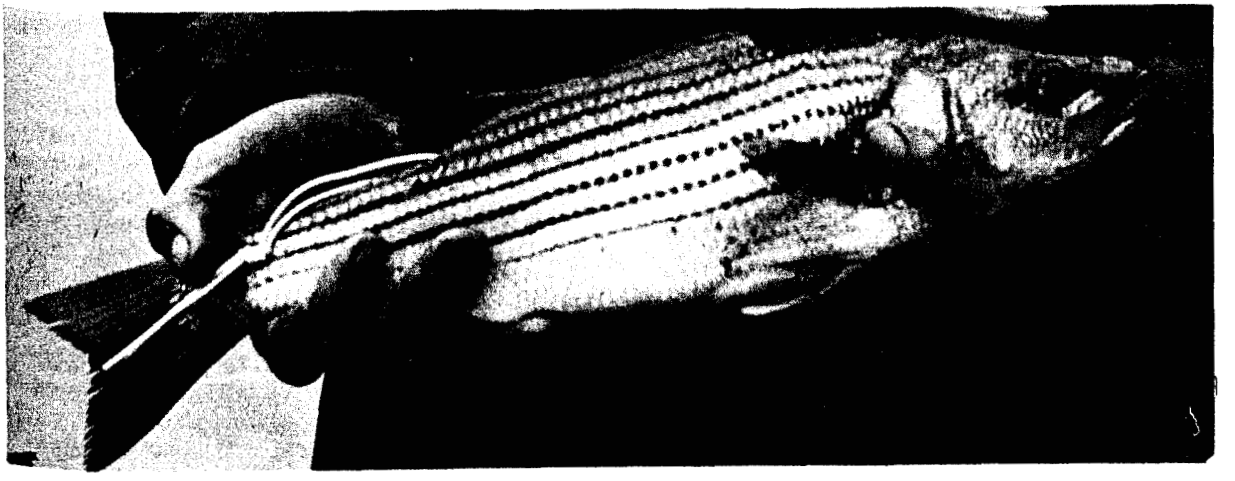


Fig. 26--Streamer-type tags have been used successfully on striped bass.

and effort statistics were recorded. Tags were placed on 117 striped bass taken randomly from a haul seine on the upstream run. Recovery of tags was continuing at the time of this report, most of them from the upstream sport fishery. A daily post card census was made of catches by boat in the sport fishing area of the river. A spawning survey was made in the Roanoke and in five other tributaries of the sound. Egg and larval collections are presently being sorted and identified. Scales collected during the study are being mounted and will be read for age determination. Over 200 striped bass were tagged on the downstream run in the Roanoke for the purpose of obtaining information concerning their fall and winter habitat.

Seining and trawling operations in the lower portion of the Roanoke and adjoining Chowan Rivers and in upper Albermarle Sound may locate areas inhabited by young striped bass and provide material for survival and growth rate studies.

As the program continues, population data will be integrated with those of water quality studies made by cooperating agencies to determine the influence which industry and power production exert upon production and survival of striped bass stocks. From criteria thus established, minimum requirements for the production and survival of striped bass can be determined.

PACIFIC SALMON INVESTIGATIONS

The Pacific Salmon Investigations, based at Seattle, Wash., is the coastal and high seas salmon research unit of the Service. Research activities are designed to understand fluctuations in the abundance of coastal stocks; to develop methods of getting fishes safely past increasing numbers of water-use projects, and to distinguish and determine the distribution of Asiatic and Alaskan salmon stocks of the North Pacific fisheries where fleets represent the U. S., Japan, Canada and Russia. The life history, distribution and abundance of king crabs is also under study.

Major research in all these broad fields is integrated with that of other organizations in the U. S., Canada, Alaska, Hawaii and Japan, through contract, cooperative agreement or international treaty.

Electrical Fish Guidance: In the Pacific Northwest, the most vexing fishery problem is how to get salmon past dams. Low dams have always been hazards to seaward migrants. High dams now proposed or under construction will destroy or delay adults as well as fingerlings. Of all the proposed methods of "steering" these fish through safe passages, electrical stimuli seem to hold the greatest promise of success.

Experiments were based on measuring the guiding effectiveness of segments of electrical arrays in flowing water. In tests with silver salmon fingerlings a direct relationship between fish size and guiding effectiveness was found, and an inverse relationship existed between water velocity and guiding effectiveness. In other tests, a significant decrease in guiding effectiveness occurred when water resistance was changed from 5,000 to 15,000 to 25,000 ohms/cm.^{3}. There was no difference between the effectiveness of two-inch pipe electrodes and those made of 12-inch strips of hardware cloth.

Field experiments continued at Icicle Creek with studies of the barrier-like electrical fields created by horizontally suspended electrodes. In one 13-day experiment 97 percent of the fingerling salmon studied were diverted into a bypass channel.

According to concurrent engineering and biological studies, duplicate electrical arrays in different streams may produce electrical fields differing in shape and energy gradient. In a separate engineering study scale models of proposed electrical arrays have shown ways of creating voltage gradients which have an effective electrical width of at least twice the physical width of the arrays. Methods of beaming or controlling the direction of the energy output of an array indicated by the tests may be of great value in guiding fish populations of mixed sizes and species.

Protection of upstream migrating adult salmon in the turbulent waters of the Snake River during construction of Brownlee Dam in Idaho led to the design of an array having great electrical flexibility. The power demand of each combination of electrodes was estimated, making possible the development of electronic devices capable of energizing the array with reasonable economy. Field tests with adult salmon were scheduled for the summer of 1956.

Expansion of the electrical fish guiding research to a large scale river installation created a need for power control devices capable of pulsing direct current under extremely heavy electrical loads. Where the control unit used in earlier experiments operated at a capacity of less than 100 amperes, the control unit designed for experiments at the the Brownlee Dam site will be able to pulse 1500 amperes of direct current at 500 volts with square wave pulses of 200-300 millisecond duration at rates from two to 30 pulses per second.

Other research results include development of a special type of voltage gradient probe for measuring electrical potentials in the water. An artificial load bank with a peak capacity of more than 600 kilowatts will allow electronic equipment to be tested prior to field installation and an analog plotter has been perfected for predicting and analyzing electrical patterns in water at field locations.

To answer the long-standing question about the effect of electric shock upon the reproductive ability of young salmonoids two age groups of young rainbow trout held over a three-year period were electrically shocked and held with unshocked fish of the same age. A comparison of the survival of eggs and fry from the spawn of the shocked and unshocked fish indicates shocking had no harmful effects upon reproductive ability.

A year-long study of the food habits of the predacious adult squawfish showed that salmon are found in squawfish stomachs in numbers only near hatcheries following release of fingerlings. In an effort to control this predation adult squawfish have been subjected to electric current. Two types of electrical devices may be used in the field: a barrier device for blocking the movement of squawfish into salmon release areas, and a trapping device for removing squawfish in the release areas. Inspection of release areas reveals that a barrier would have limited use, so present efforts are directed toward the development of a portable electrical device to trap squawfish in areas of heavy predation.

Light Systems: Various light systems have been considered as a means for guiding fish. Different intensities of steady and flashing lights, pulsing at moderate intensity, successfully diverted over 95 percent of a natural run of blueback salmon migrating seaward. The effectiveness of the diverting array increased as the number of fish passing within a given time interval increased.

Counting Devices: Two instruments to identify any count migrant fish have been developed and made available to commercial production. The first is a detector which records the passage of fish in underwater orifices. It measures the increased conductivity of a water path due to the presence of a fish and is unaffected by the turbidity of the water or by water-logged vegetable matter. While used on mature salmon, the device also tallies fish one inch in length.

The second instrument is a transistorized version of the first, considerably reduced in size and price. It is available as a dector or as a counter which indicates the direction of passage and ignores incompleted passages and smaller fish. Further experimentation will enable the use of these devices as triggers for a photographic counter which is being designed to record species, size, markings and tag numbers. Plans are also being developed for telemetering fish

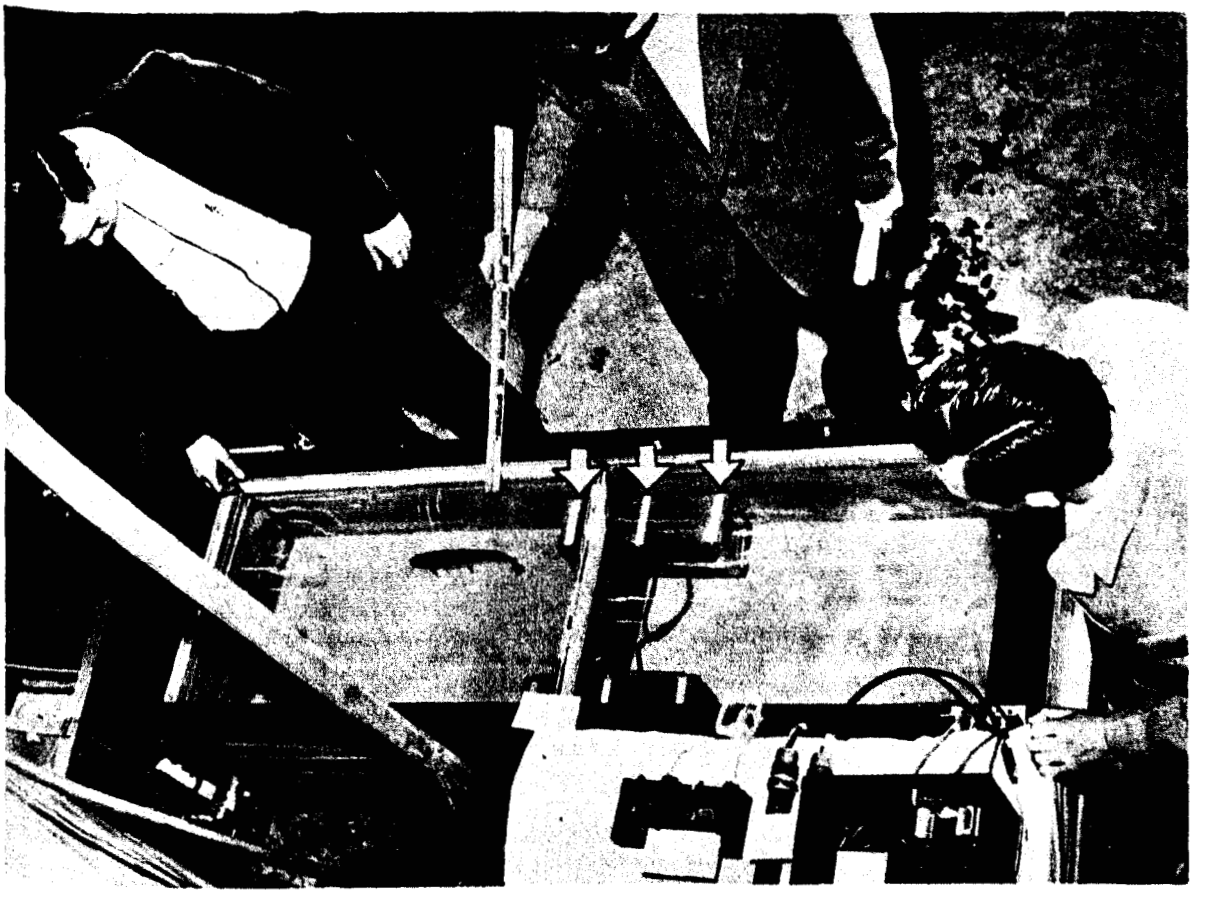


Fig. 27--The fish shown here has just passed through the tunnel indicated by arrows, activating by electro impulse the transistorized fish counter developed by the Pacific Salmon Investigations. This device can operate a camera which will enable identification of the fish and note the type tag attached, if any.

counts and various vital parameters of water quality from a stream location to a monitoring station in a remote central office.

An intriguing new piece of equipment is a tiny transistorized sound transmitter capsule which, when attached to salmon, enables observation of fish movements around dams through the use of receiving equipment which "homes" on the sound waves transmitted by the capsule. Fish can be "shadowed" as they move upstream, giving evidence of delay or rate of movement through a given section of river. The capsule tag is attached underwater with a minimum of handling. With some modifications, the tag can be used to accurately observe individual adult fish behavior in daylight or darkness under a variety of hydraulic conditions.

Fishway Studies: Fishways designed for the huge dams now being constructed in the salmon streams of the Pacific Northwest must not only pass the upstream migrants safely and without delay, but they must also be economically feasible. The cost of fish passage facilities is so great (fishways at six new Columbia River dams have been estimated in excess of $100,000,000) that a large scale research program was initiated to seek efficient and economical methods of passage for the adult migrants.

Construction of a laboratory financed by the U. S. Army Corps of Engineers made possible the measurement of the reactions of migrating fish under controlled experimental conditions. The structure, called the Fisheries-Engineering Research Facility, is located on a bypass into which fish can be diverted from one of the major fishways of the Bonneville Dam. The fish leave the fishway, are available for experiments, and can be released from the laboratory section into the fishway without disrupting the normal passage of fish in the main fishway. The construction of this laboratory makes possible the full scale study of fishway operation and fish behavior in the various fishway structures and opens an entirely new experimental approach to the problem of fish passage.

In 1952, modifications to the Rock Island Dam on the Columbia River provided increased operating head and additional power generating capacity. The dam's three fish ladders were altered and extended to link the tailwater with the new high forebay. Before the alterations, the left ladder was used by approximately 50 percent of the salmon and steelhead trout surmounting the dam. After the alterations, about 75 percent of all salmonoids passing over the dam used the left ladder. Conditions for attracting fish to the right ladder, which had always appeared poor, now seemed worse than ever.

Data obtained from a tagging experiment designed to disclose any delays involved for fish seeking passage at the dam indicate that the majorities of both tagged and untagged fish prefer the left ladder. Only 65 to 75 percent of the tagged fish released below the dam were later observed at the ladders, counting stations upriver and on the spawning grounds. Observations of fish tagged and released above the dam do not differ markedly from those released below. Additional tagging of chinook salmon is underway, to supplement information obtained on blueback in this way.

Above Rock Island Dam, the Chelan County Public Utility District has proposed power dams at two Wenatchee River locations and at Rocky Reach, on the Columbia River. The dams will obstruct migration routes of major runs of blueback and chinook salmon and steelhead trout. To facilitate planning of fish passage facilities information on the timing, size and composition of the runs are being checked at counting stations and on the spawning grounds. Downstream migrants are being sampled and identified to establish times and extent of their migrations. State Fishery and Game agencies and Service personnel are cooperating in the studies, which are financed by the Public Utilities District.

Water Quality Studies: The University of Washington, under a Service contract, is investigating the physical and chemical modifications of the water

quality in the Columbia River system resulting from hydroelectric and other water use developments. An attempt will be made to correlate the changes in quality with migration and survival of fishes. It is likely that this study will show some of the effects of existing dams on river ecology and lead to the prediction of water quality effects on migrations and survival of fishes of a given stream.

Blueback Salmon: The commercially valuable blueback salmon, whose runs extend beyond the Rock Island dam into the Wenatchee River and proceed up the Snake River in Idaho, has been made subject of fresh water survival research.

Production of the Columbia River Blueback salmon is limited to three of the previously numerous spawning areas: the Okanogan and Wenatchee Rivers in Washington, and Redfish Lake in Idaho. The productivity of these areas and the factors influencing freshwater blueback survival are studied by techniques including counts of adults, enumeration of downstream migrants, tagging, intensive observations on the spawning grounds and egg cartridge plants.

Tagging studies indicate that substantial losses occur in fresh water prior to spawning, due primarily to disease aggravated by high water temperatures. An upstream-downstream weir on Redfish Lake Creek will lead to the collection of information on productivity and the factors influencing survival and migration of the area. On the Okanogan River the effects of flood control channelization on blueback and the spawning grounds are being determined. The status of blueback runs in the Okanogan and Wenatchee Rivers prior to construction of the proposed dams is being documented and analyzed.

Bonneville Census Station: The last census point for seaward migrating salmon fingerlings on the Columbia River is at Bonneville Dam. To gain information concerning the time, extent, composition and origin of salmon and steelhead fingerlings migrating past the dam, the Service operates four fingerling traps there on a continuous basis. All downstream migrants intercepted are identified, counted, examined for tattoo excised fin marks and returned to the river. Daily random samples of fish are measured and scale samples are taken for determination of age. Marked fish data obtained at Bonneville is proving invaluable to fishery agencies conducting experiments involving marked fish released upriver. Some of the experiments have been designed to measure the effect of dams on downstream migrants, others have been helpful in planning hatchery releases. The recent capture of 2,549 fingerling salmon, 609 of which lacked single or both pectoral fins, indicating a marking experiment, led to the discovery that fin rot had actually caused the disfiguration. This emphasized the need for great care in planning and evaluating experiments dependent on fin marking techniques.

The influence of numerous variables on fingerling migrations is subject of a study which covers river flows, turbidity, water temperature, hatchery releases and operational schedules and procedures at the dams.

Scrapfish: A biological phenomenon associated with dams is the appearance of large numbers of scrapfish in the pools and tailwater, or migrating through the dam structure. The effect of scrapfishes on the survival growth of game and commercial fishes of the Columbia River Basin is unknown, and has been made subject of a study which, if necessary, may lead to control measures to curb undesirable populations and allow increased production of the desirable fishes.

Initial studies have centered on development of sites and methods of collection of scrapfish. Special collections were made during test releases of young chinook salmon at McNary Dam. These indicated that predation during and following the releases was negligible.

Artificial Spawning Grounds: Stream fluctuation in the Mill Creek tributary of the Sacramento River in California became an obvious factor in widely

fluctuating stocks of king salmon. At the Mill Creek research station incubation of salmon eggs in a man-made stream section was far superior to nature, and troughs had an even higher rate of survival. It appears that artificial channels and gravel boxes can be used to augment, or even replace, natural spawning areas. Investigations in this field include studies of sedimentation, dissolved oxygen threshold, dissolved salts, surface and sub-surface velocities, parasites and fungus as inhibitors of natural stream production.

North Pacific Studies: The most widespread collection of racial data in the annals of salmon research was completed in 1955, in accordance with an investigational program outlined by the International North Pacific Fisheries Commission. Chartered high seas fishing vessels and shore crews collected specimens and representative morphological and physiological data from all major red salmon, chum salmon and pink salmon populations throughout their geographic range in the North Pacific.

As principal research unit of the Commission, the Pacific Salmon Investigations was charged with these responsibilities:

1. To define the distribution of salmon in the North Pacific, trace seasonal movements and locate areas of concentration.

2. To measure oceanographic conditions related to the distributional pattern.

3. To collect and preserve samples of salmon and steelhead trout for racial analysis, with the objective of ultimately distinguishing between Asiatic and Alaskan stocks.

In the late summer and fall of 1955 three vessels fished 75 stations from Cape Blanco, Oregon, through the Gulf of Alaska, to the area south of the Aleutian Islands. In all, 3,274 salmon were taken north of 47°N latitude, where surface temperatures were 48 to 57°F., and 210 albacore were taken in temperatures from 54 to 64°F. between 45 and 48°N latitude.

All sets made in salmon waters yielded salmon or steelhead. Chums were the dominant species, accounting for 55 percent of the total. Others were pinks, 20%; reds, 17%; silvers, 7%, and kings, 1%. Two or more species were taken in a majority of the sets and most of the salmon were taken near the surface, in the upper half of the gill nets.

The charter vessels Mitkof and Tordenskjold left Seattle May 14, 1956, to obtain information on spring and early summer distributional patterns. The Mitkof's area is south of the Aleutians to 40°N on 175°E and 175°W, while Tordenskjold is fishing the Bering Sea south of 60°N and east of 170°W. Largest catch reported by the Mitkof at the time of this report was virtually in the center of the Japanese fishing operations at 50°N, 175°E. The catch included 90 reds, 41 chums, 3 pinks and one silver. Tordenskjold found few reds north of the Alaska Peninsula and north and east of the Pribilofs in mid-June, but encountered heavy concentrations of reds south of the Pribilofs. On June 20, at 56°N, 170°W, the catch included 917 reds, 62 chums, five pinks and three kings. The following night, at 55°N, 170°W, the catch was 679 reds, 67 chums, nine pinks and one king. These catches are in sharp contrast to one or two reds per set at a majority of the Bering Sea stations and may indicate that Bristol Bay reds school far out at sea prior to their migration into the fishery.

A total of 9,375 whole specimens of frozen salmon were obtained in 1955 for standardized methods of racial analysis, and an additional 43,765 salmon were sampled for both morphometric measurements and scales. The cooperation of fisheries agencies and industries in Japan, Canada and the U. S. contributed to a successful collection of data during the initial year of full scale operations.

In the laboratory, the salmon samples are subjected to an intensive study of form and structure of various anatomical

elements. These studies establish criteria and methods for obtaining accurate and documented counts and measurements. They determine differences in countable and measureable characters between populations of salmon from widely scattered areas, and examine the efficacy of applying these differences to morphological separation of Asian and North American salmon stocks.

Thirty-five characters (counts and measurements) were obtained from each of about 3,000 red salmon and 1,500 chum salmon. The reds were obtained from 10 general areas, including the major fisheries of the North American continent, the high seas adjacent to North America, the Japanese high seas mothership fishery and the Japanese fishery in the Sea of Okhotsk. Using techniques of multivariate analysis, red salmon data yielded coefficients of "likeness" obtained in the form of relative distances between areas with respect to morphological characters. Of noteworthy significance was the fact that the distance between samples from five Bristol Bay areas were minimal, as were the differences between the Japanese high seas samples and those obtained from the Okhotsk Sea, forming two clusters, separated by a relatively great distance.

Samples from other North American areas were more or less similar to those from the Asian fisheries. Dissimilarities, however, were sufficiently great to encourage further investigation with refinement of technique.

Age Data: The critical study of age data, a common tool in life history and management studies, may be important to the international high seas salmon research program. Red salmon have been more critically studied than any of the other salmon species. Increasing emphasis has been placed on features of the scale. Circuli (the conspicuous concentric rings on the scale) counts may be used to separate some races. Zones of growth also show promise. Intermediate growth, a transition zone between fresh water life and salt water life characteristic of some races of red salmon, is an example of this type of analysis. Further studies will find scale characteristics usable for separating or identifying stocks of salmon on the high seas.

Another phase of scale studies concerns the physiology of fishes. If elements normally missing or rare in the composition of the scales or tissue could be added to the diet and permanently deposited in the body of hatchery reared fish, then these elements would serve as a biological tag for later identification. Both bismuth and titanium were deposited in the scales and tissues of steelhead trout, but both disappeared after a few weeks of normal diet feeding. The effect of varying photoperiods on the endocrine glands and on scale development is being studied by the University of British Columbia under a Service contract. Results are not as yet available.

Parasitological Studies: Application of parasitological studies to the broad problem of identification of continental races if Pacific salmon was initiated in June 1955, to establish a knowledge of Pacific salmon parasites throughout the range of the North Pacific and to determine whether significant differences might be found in the parasite fauna which might reflect geographical origin and migration routes of the salmon hosts. Samples of chum, pink and red salmon collected in 1955 from coastal and ocean areas from the Okhotak Sea to the North American coast, have shown both qualitative and quantative differences in parasites. Many of the differences appear related to varying oceanographic features of the range sampled. Of 58 parasite species observed thus far, six appear applicable to the problem of racial identification. Completion of this study should allow final conclusions on the merit and applicability of the method.

Salmon Serology: The salmon serology projects seeks to discover genetically controlled serological properties which are characteristic of species and geographic races of salmon. In order to overcome the dependence of seasonal runs for samples, methods of preserving red blood cells by freezing in glycerol solutions have been used. So far, samples

have been preserved in excess of two months by this method. Utilizing immune sera prepared in rabbits and chickens, distinct antigenic differences have been demonstrated between most species of salmonoids studied. In addition, careful absorption coupled with specialized methods of detecting weak antibodies have resulted in the demonstration of individual antigenic differences in the red blood cells of chum, chinook and red salmon.

Analysis of immune sera prepared in rabbits against salmon sera has revealed the presence of as many as 13 antigenic components. Preliminary tests indicated that some of these components are missing in members of certain geographic races. Greater utilization of fish, especially other salmon, as the antibody producers, is expected to result in the preparation of distinct, type specific, sera with which genetic differences between the many stocks or runs may be demonstrated. Perfection of preservation techniques will allow typing of samples months or years after collection.

King Crab: The King Crab stocks of Bristol Bay and the Aleutian area are being investigated as part of the studies under the International North Pacific Commission. Knowledge of the life history of the large crabs is increasing. Years of data have been obtained from both the Japanese and American fishery. Based on catch-per-unit-of-effort values for the U. S. vessel Deep Sea, the relative abundance of crabs in the Eastern Bering Sea has remained fairly stable in the past five years and shows no signs of decline. Further study on life history and migration of the King Crab will round out this information.

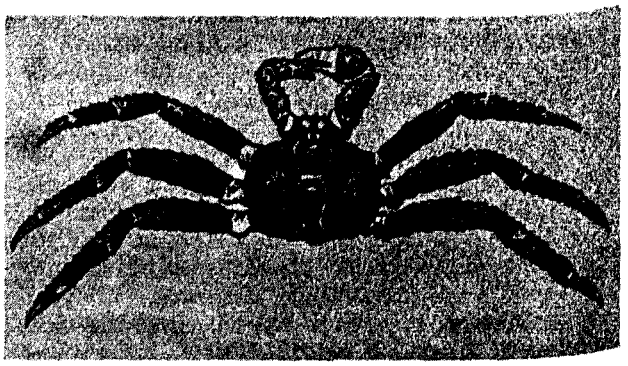


Fig. 28--King Crab

Literature Research: The first sections of two bibliographies requested by the International North Pacific Fisheries Commission were issued on cards. Included were 800 references on the biology of Pacific salmon and 600 on Pacific herring.

Translations of foreign fishery literature continued. Three translations were issued, and a volume of translations of Japanese North Pacific salmon fleet daily catches was distributed. A narrative review covering past and present knowledge of salmon systematics and differentiation of stocks is being prepared on contract by Stanford University.

WOODS HOLE SHELLFISH LABORATORY

Chief among the projects of the Shellfish Laboratory at Woods Hole, Mass., has been preparation of a manual on the biology and cultivation of American oysters. Its purpose is to present in a readable form detailed information on the structure and body functions of the American oyster, its development, ecology and cultivation. The manual is an attempt to tell the story of the oyster as the author (Dr. Paul S. Galtsoff) understands it, rather than to review existing literature. A large bibliography has been prepared covering, in addition to oysters, references to anatomy, biology and physiology of some other lamellibranches.

In writing the text, it became evident that certain problems of oyster anatomy and physiology required rechecking by further studies. A series of experiments on feeding, sorting out of food, nervous response to stimuli and on calcification were conducted during the past year in order to fill obvious gaps in the present knowledge.

Shell Formation: Published data on oyster growth usually refer to the growth of the shell in height and length. The shell, however, increases also in thickness. The measurement of only two linear dimensions does not take this in account and the weighing of specimens at regular intervals could not give an answer because weight changes may also be due to the accumulation or loss of glycogen and discharge of spawn.

The rate of shell deposition was studied by inserting small pieces of plastic of known weight and area between the mantle and the valve along the ventral margin of each valve. Ten 5-year-old oysters were maintained in running seawater for each experiment. Observations over 15 months indicate that the deposition of shell material continued from the second part of March until the end of November. Under normal conditions no shell formation occurred during winter months, although in several instances when the mantle was slightly damaged by insertion of the plastic, fairly heavy calcareous pockets were formed around the inserted pieces.

There were two well-pronounced periods of increased rate of calcification, one during May which ended at the first half of June, and the other extending from the second half of August until the end of October. Variation in the rate of deposition was quite large. The mean values expressed in the weight of shell substance deposited over an area of 1 cm.^{2} ranged from 0.1 to 1.5 milligrams per day. The medians ranged from 0.06 to 1.42. Decreased calcification during six weeks in July and August coincided with the spawning period of oysters at Woods Hole and indicated an inhibition of calcification during the reproductive season. From winter observations it became obvious that the biochemical mechanism for shell formation is suppressed by low temperatures but may become active in response to injury or irritation requiring new shell deposit.

Food Sorting: The fact that labial palps are the primary organs for the mechanical sorting of food was established more than 60 years ago. There is, however, a divergence of opinions regarding the operation of this highly complex organ.

Studies to date show that the mechanism for chemical discrimination is present in the organ, but have produced no evidence that the oyster uses it for selecting its food.

Oyster Anatomy: Anatomical studies disclosed an interesting abnormality in the position of the intestine in apparently healthy oysters. Normally the intestine forms a wide loop around the digestive gland. In some of the specimens the large loop was found missing, the intestine forming a sharp bend posterior to the digestive gland. The intestinal tract was studied by injecting latex preparation through mouth and anus and clarifying the body in methyl salicylate.

The promyal chamber, an asymmetrical space on the right side of the body adjacent to the right demibranch is an important part of oyster anatomy. The promyal chamber is present in oysters of the Crassostrea type but is absent in the group of flat oysters of the type of O. edulis. Consequently its presence is an important taxonomic characteristic. A

comparative study of the cloaca and promyal chamber was made by using casts of a rapidly setting material and revealed a number of anatomical details which otherwise could not be seen. Comparisons were made of the oyster species C. virginica, C. gigas and O. edulis. The anatomical and histological studies were supplemented by more than 50 detailed drawings made by Mrs. Ruth von Arx.

Ecology of Oyster Bottoms: Ecological description of oyster bottoms usually consists of a list of various organisms found in association with oysters, and of sketchy remarks concerning the character of the bottom, salinity of the water and other data that may have been observed. The inadequacy of this method lies in that it provides no means for evaluating oyster beds or comparing them with other productive areas. On the basis of lengthy studies, a method has been developed and proposed which consists of evaluating the effectiveness of five positive and five negative factors of the environment, which are:

Character of the bottom (B), temperature (T), water movements (WM), salinity (S) and food (F), are the principal positive factors which are essential for the rapid growth of the oyster community. The five negative factors, the presence of which impedes the growth of the community and may destroy it, are sedimentation (D), pollution (P), commensals and competitors (C), predators (E) and disease, including infestation by parasites (M). Effectiveness of each factor is evaluated from 0 to 100. For instance, optimal temperature or salinity conditions are scored 100, while the absence of any harmful pollution is scored zero. The highest maximum score under this system is 500 (each plus factor scored 100 and each minus factor scored 0). Zero for any positive factor and 100 for any adverse factor signifies that oyster population cannot permanently exist in a given locality. In all intermediate cases the total scored by negative factors is subtracted from the score of the positive factors. The final evaluation of oyster bottons is as follows: excellent - 400 to 500; good - 250 to 400; fair - 100 to 250; marginal - less than 100; unsuitable for permanent existance - 0. The system is highly flexible and permits easy analysis of principal ecological conditions affecting the oyster population of a given area.

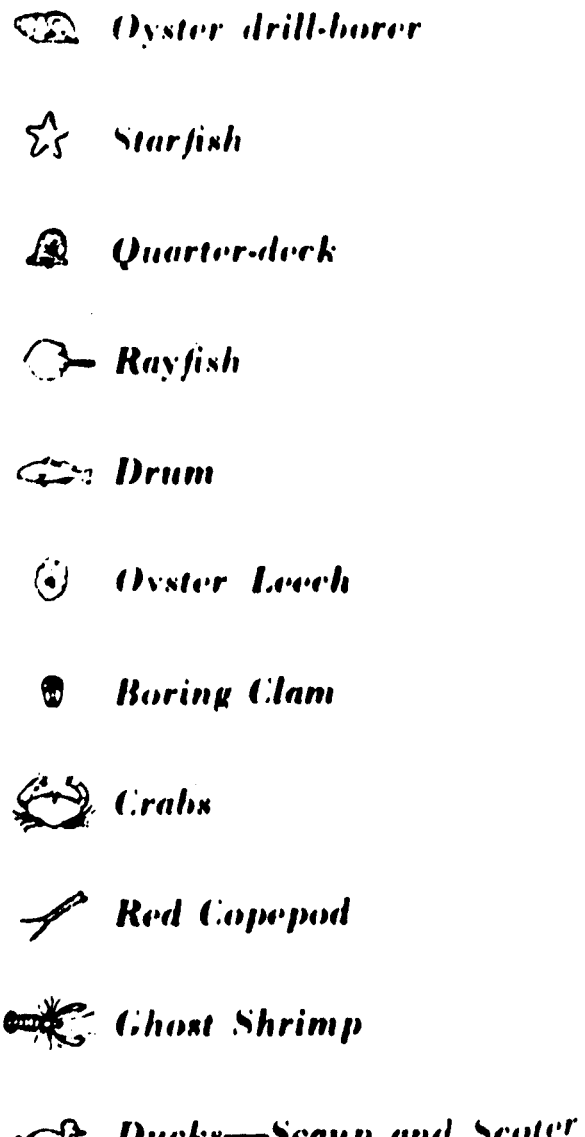


Fig. 29--Enemies of the Oyster.

Raft Culture: The oyster industry of the northern Atlantic States suffers from the lack of seed. In numerous small bays and tidal rivers of Cape Cod conditions are favorable and failures of setting are rare, occurring probably once in six or seven years, and oyster sets of commercial importance may be obtained almost every year. Despite this favorable situation Cape Code oyster farmers do not use the native set and are dependent on supplies from Connecticut, New York and New Jersey. This is due to the destruction of young oysters by drills and whelks which infest local waters. Since there are no large rivers on the Cape, salinity remains high over the entire oyster producing area and a natural barrier to carnivorous snails is lacking.

By raising the oysters above the bottom and keeping them suspended from rafts the inroads of drills and whelks can be materially reduced. Furthermore, it is known that oysters elevated from the bottom grow faster and become fatter.

A group of oystermen operating at West Chatham was persuaded to undertake an experiment with raft culture under scientific direction. Materials for the construction of rafts and spat collectors of different design were provided by the Service. The oystermen supplied the shells and oysters and permitted the Service use of their private grounds. Detailed experiments will start soon.

MILFORD SHELLFISH LABORATORY

From headquarters at Milford, Conn., the Milford Shellfish Laboratory conducts a continuing study on gonad development, spawning and setting of oysters and similar problems affecting clam and oyster populations in nearby Long Island Sound.

Oyster Forecasts: A series of bulletins is issued during the summer describing biological events occurring in waters of the Sound and containing advance predictions of oyster spawning and setting. In this way the oyster industry is informed of the intensity of setting of larvae and on the survival and growth of the set in different areas of the Sound.

Despite adverse weather conditions, larval survival was good and heavy sets of oysters were obtained during the summer of 1955. The best areas were west of New Haven, Conn. On the basis of knowledge developed in previous studies industry representatives were advised of the optimum time and locations for preparing oyster beds. Heavy sets resulted, a practical illustration of the effective utilization of the knowledge and experience of biologists in furthering the shellfish industry.

Similar cooperation was given the Connecticut Shellfish Commission in the form of a suggestion for a one month delay in the opening of public beds to enable oysters of the heavy late-season set to obtain better growth before being dredged and transplanted.

Ecological Requirements: The 1955-56 phase of a continuing of the ecological requirements of oyster and clam larvae centered on food requirements.

Naked flagellates, such as Monochrysis lutheri, Isochrysis galbana and Dunaliella euchlora appear to be readily utilized by oyster larva of all stages and are good foods. Organisms having cell walls, such as Platymonas sp., Cholrococcum sp., Phaeodactylum tricornutum and one species of Chlorella, are utilized only after the oyster larvae reach a size of about 125 microns in length. Other species, not utilized by the larvae may produce toxic external metabolites.

Detailed studies on the utilization of microorganisms for food by clam larvae have shown that, in general, clam larvae find naked flagellates the best food and are able to utilize certain forms more extensively than do oyster larvae, and to accept other forms which oyster larvae are unable to utilize.

Poor survival of clams and oysters from fertilized eggs to straight hinged larvae has been traced to the presence of dissolved toxic substances in the water. These conditions have been repeatedly associated with dense dinoflagellate blooms in Milford Harbor. Similar poor

survival has been experimentally induced by adding filtrate from a Chlorella culture to sea water in which molluscan eggs are developing, establishing that toxic external metabolites of certain organisms can significantly reduce the percentage of fertilized eggs reaching the early straight hinged larval stage. Tests have shown the possibility of removing these toxic metabolites by adsorption of activated charcoal, and studies will be expanded in this field.

Pond Studies: The new concept of shellfish farming in enclosed areas, such as salt water ponds, or of production of seed clams and oysters to be planted in open waters, necessitates new approaches to the biological problems concerned with the productivity of such ponds.

Treatment of food and water with ultraviolet light has led to success in the control of diseases and mortality of larval cultures. Work now centers on finding measures to prevent post-setting mortalities.

Emphasis in the past year has been on the feeding requirements of juvenile mollusks. In a continuing series of experiments foods are tested to determine their optimum and limiting concentrations, as well as their relative values. The effect of temperature and salinity on the development of growth data essential to salt pond hatchery methods are part of the laboratory program. A key to the larvae of several bivalves has been developed and will aid larval recognition in plankton samples.

Screening chemical compounds for attractors, repellants or poisons for a variety of oyster predators and their competitors, especially the destructive oyster drills Urosalpinx cinerea and Eupleura caudata continued during the year and turned up several promising compounds which are undergoing further tests. Observations on the life history of the polyclad worm Stylochus elliptious, and the gastropod Menestho bisuturalis, both established salt pond predators, was begun.

As a possible means of biological control, research is underway on a recently discovered fungus infecting oyster drill ova and larval veliger stages within their egg cases.

Other Activities: Close cooperation has been maintained with the Oyster Institute of North America on its contract studies on utilization of salt water ponds for shellfish propagation.

A large number of European oysters, O. lurida, were grown at Milford and will be used in some of the experiments planned on pond utilization.

Another study made during the year indicated that oysters from Sheepscot River, Maine, differ markedly from Long Island Sound oysters and may be incapable of developing gonads in response to high temperatures except during late spring when the normal spawning season approaches. Small populations of North Carolina and New Jersey oysters grown from eggs released by parents imported to Milford from the two states and maintained under the same conditions as Long Island Sound oysters have been maintained and will be used in future studies.

RADIOBIOLOGICAL LABORATORY

The Special Shellfish Investigations at the Beaufort, North Carolina, research center, has been renamed the Radiobiological Laboratory in recognition of its use of fission materials in cooperation with the Atomic Energy Commission.

Efforts of the Laboratory are aimed at attaining an understanding of the role of chemical elements, particularly the fission products, in the metabolism of marine organisms.

Increased consideration of the sea as a dumping ground for atomic wastes and the addition of fission products through radioactive fallout stresses the need for information on the mode of entry and the amounts of radioactivity accumulated in different tissues and organs of members of the marine community, and the passage of radioactive contaminants to other species through the food chain.

Radioactive materials in the marine environment are accumulated by marine organisms and may eventually reach man through his utilization of fish and shellfish. Consequently, the uptake and metabolism of fission products by marine plankton, fish and shellfish having different modes of life and feeding habits are investigated.

Radioactive tracers are especially suited to seeking those factors regulating growth and reproduction of plankton and the feeding processes of filter feeding fish and shellfish. Through these studies knowledge of the metabolism of trace elements in sea water is expanded.

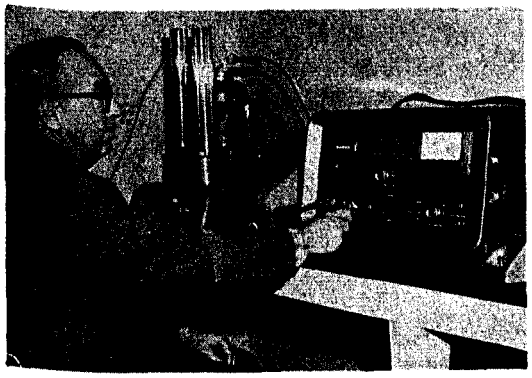


Fig. 30--Highly sensitive detection devices are used by the Radiobiological Laboratory to measure radioactivity present in fish and shellfish.

Radiostrontium: Strontium 90 (Sr 90) is probably the most widely known of all fission products, and the most feared as a hazard to living organisms. It is known to accumulate in calcareous structures where it remains for an extremely long time.

Recent tests on the accumulation and retention of radiostrontium by phytoplankton cells, clams, oysters, scallops, crabs and shrimp have demonstrated that the uptake of Sr 89 and 90 by scallops and blue crabs from sea water is extremely rapid, reaching an equilibrium situation within a few hours at concentrations below those of the surrounding waters. Accumulation is in the soft tissues of the shellfish.

Artemia nauplii (brine shrimp) used in the tests did not accumulate strontium. The calcareous shells of the other test animals accumulated large amounts of radiostrontium, as did other calcified structures, such as the gastric mills of the crabs. Distribution of Sr 89 and 90 in the soft tissues of the shellfish was uniform with the exception of lower amounts in the muscle tissues.

When the animals were returned to normal sea water, all but two to three percent of the radiostrontium left the tissues. The uptake of Sr 89 and 90, its distribution in the tissues and its loss with time after return to normal sea water were observed in a number of studies using marine fishes. Croakers, Micropogon undulatus, took up Sr 89 and 90 from sea water very rapidly with concentration of the radioactivity in the bones and scales. Young flounders, Pseudopleuronectes americanus, continued to accumulate radiostrontium throughout 14 days observation. Those held at warmer temperatures grew more rapidly and accumulated more strontium per gram of fish than those kept at cooler temperatures. The radioactivity of the entire fish was due primarily to concentration of the Sr 89 and 90 within the bones, autoradiographs of the entire fish showed.

From single doses of Sr 89 and 90 in the solution, solidified in gelatin and placed in the esophagus of each of several bluefish, Pomatomus saltatrix, the uptake by the various tissues and organs was followed. There was no accumulation in the soft tissues but considerable in structures and tissues known to have a high calcium content, bone, the base of the scales and the sclera of the eye. Very promptly after administration the radiostrontium left the blood and soft tissues, but continued to accumulate in the bone and scales.

Since radiostrontium is accumulated in bone and not the soft tissues of this and is retained for long periods, tests were made of the uptake of Sr 89 and 90 by king whiting, Menticirrhus sp., fed radioactive bones of croakers previously exposed to radiostrontium. The bones were

encased in capsules placed down the esophagus each day for 12 days. Analyses of the bones of the king whiting made three days after the last dose showed considerable accumulation of radiostrontium, indicating that radiostrontium in the bones of fish eaten is quite available to the body of the feeding fish.

Experiments with flounders demonstrated that the only loss of accumulated radiostrontium from the fish resulted from physical decay of the isotope. Sr 90 has a half-life probably close to 28 years. Young flounders which had accumulated Sr 89 and 90 were grown in flowing sea water and their radioactivity measured at intervals for 98 days. The loss of radioactivity from an individual fish was the same as the loss from decay of the initial sampling, that present in the bones from the exposure given was diluted from growth of the young fish during the observations.

Radiocesium: Cs 137 (radiocesium) is a fission product of long half-life. Unlike Sr 90, the isotope accumulates in soft tissues of the animal body.

Previous studies showed that phytoplankton organisms do not concentrate cesium and it is unlikely that they are of particular importance in passing Cs 137 to animals higher in the food chain.

Marine animals do accumulate Cs 137 to a high degree. Measurements were made of the tissue distribution of Cs 137 in clams and scallops following their exposure to sea water to which the isotope had been added. The scallops accumulated more Cs 137 than did the clams in a 14-day period. In both species the greatest accumulation was in the kidney, but concentration in the adductor muscles of the scallops was increased markedly.

Experiments employing oysters, clams and bay scallops confirmed that loss of Cs 137 does not proceed at a constant rate with time. Aside from a rather rapid rate of loss initially, there was a long continued slow loss diminishing with time.

Changes in the Cs 137 content of the different organs and tissues of the little tuna, Euthynnus alletteratus, after oral administration of the isotope were followed. Findings agreed with those of experiments using bluefish, croakers and king whiting. One day after dosing the fish, the greater concentrations of Cs 137 per gram of tissue were in the internal organs including liver, heart, spleen and kidney. Much smaller amounts were in the gonads, brain, eyes, skin, bones and muscles. The internal organs with high radioactivity lost the Cs 137 each day during the observations, whereas the gonads, brain and muscle tissue slowly accumulated the Cs 137 and increased in radioactivity during the eight days of observations. The slow rate of increase of Cs 137 content of the muscles indicates a slow rate of loss in the muscle tissue and a long retention of Cs 137. Since a great part of the weight of the fish is muscle, the total accumulation can be great and retention of this isotope in the fish as a whole can be long extended. In the blood of the tuna there was almost no difference between whole bloom and serum in Cs 137 content initially. However, the difference became very marked with time as radioactivity increased in the blood cells.

Further tests with croakers demonstrated the rapidity with which Cs 137 is taken into the body from the digestive tract. Only 15 percent of the Cs 137 given was present six hours after dosing. At this time the Cs 137 content of the internal organs was the highest observed. It is likely that the blood and internal organs, other than the spleen, reached a higher level before the first observation at six hours. The muscle tissue continued to take up Cs 137 throughout the 96 hours of the test.

In experiments in which the uptake of Cs 137 was observed from direct absorption from sea water, uptake by the internal organs was likewise rapid. The slower accumulation in the muscles resulted in a high radioactivity in the fish. In tests with croakers held in sea water containing Cs 137, uptake continued in the muscles throughout 28 days of observation. In experiments with young flounders, uptake had lessened by the 10th

day. The fish had a concentration factor 6.5 times the Cs 137 content of the sea water.

Radioruthenium: With the addition of fission products to sea water, radiostrontium and radiocesium are likely to be present in ionic form. However, this is not true of the great majority of fission products. In the main, fission products, if present in sea water, exist in the form of particles, often absorbed by particles normally present in the water. Radioruthenium (Ru 106) is one that is likely to be present in particulate form.

A few experiments were completed this year to supplement studies on the uptake of Ru 106 by plankton, fish and shellfish. The earlier experiments showed the immediate uptake of Ru 106 by phytoplankton cells and demonstrated that this uptake was related to the number of cells in the culture. Tests this period showed that the Ru 106 associated with cells was retained by them when resuspended in sea water. Removal of the contaminant from the water surrounding the cells caused a decrease in the Ru 106 content per cell only through cell multiplication - a "biological dilution". As in previous tests, filter-feeding forms, menhaden and shellfish, accumulated large amounts of Ru 106 in their digestive tracts but failed to take up appreciable amounts of the isotope in their tissues.

Mixed Fission Products: A mixture of fission products in nitric acid, with less than 45 days of decay, separated from heavy metals which had been exposed for 40 to 60 days in the reactor at the Oak Ridge National Laboratory, was obtained. The mixture was stored for 141 days after receipt to allow for decay of the great abundance of isotopes of relatively short half-life. After this time, the material was used for observations on the uptake and accumulation of isotopes by marine plankton, fish and shellfish. The studies are continuing.

Observations made on this mixture showed it to have a slow rate of decay during the next two months after the storage period. Based on a comparison of the absorption of its radiation in aluminum to that of Plutonium 32, the mixture contained many isotopes of low energy. The component showing the maximum energy was determined as praseodymium 144, the radioactive daughter of cerium 144. It was apparent from the absorption curves that the remaining radioactivity was due to a mixture of radioisotopes.

Changes in radioactivity resulting from the addition of the acid mixture to sea water were studied. Of most importance was the hydration of some of the components and particle formation. Although the particles were very small, there was a slow settling and loss of radioactivity from the sea water. Marine phytoplankton populations removed the radioactivity from the sea water rapidly and completely.

The uptake and accumulation of radioactivity by croakers immersed in sea water containing the mixture shows a rapid uptake within the first 24 hours and a continued marked uptake through 120 hours when the test was ended. The greatest accumulation was in the internal organs. Although the internal organs made up only 2.4 percent of the weight of the fish, they had 36 percent of the total radioactivity at 120 hours. Bone had considerable radioactivity and muscle very little.

Croakers were given mixed fission products solidified in gelatin and placed in their esophagi. They were returned to a tank of flowing sea water and groups sacrificed at intervals. Only a small percentage of the dose was in the digestive tract after 28 hours. However, at 28 hours only five to six percent was within the fish body and only about one to 1.5 percent after 137 hours. Of the radioactivity within the body of the fish, considerable amounts were in the internal organs, chiefly within the liver. The greatest amounts per unit weight of tissue were in bone. Muscle had very low radioactivity. The concentration in bone increased throughout the 137 hours.

Filtration of Particles: Studies of the efficiency of removal of particles from sea water by marine organisms and the uptake of elements from this filtration have received added attention in connection with investigations of the accumulation of fission products by marine species and the passage of such radioactive materials through the food chain. Much of the fission product material present in sea water is present as particles, often within or absorbed to the surface of plankton cells.

In experiments with adult menhaden, minute radioactive plankton particles were efficiently filtered from the sea water. The fish removed brine shrimp and copepods very well, and were able to obtain in this way small particles previously filtered by those forms. Although post-larval menhaden could not remove phytoplankton cells from sea water as could the older fish, they received radioactivity from them indirectly by way of the copepods on which they did feed. Post-larval flounders and pinfish likewise took up radioactivity indirectly by way of feeding on copepods and brine shrimp. Young mullets accumulated radioactivity markedly from feeding on radioactive plankton even as small as the microplanktonic form Nannochloris. Uptake was especially great from phytoplankton cells that clumped or adhered more to the sides and bottom of the container.

Scallops and hard shell clams were observed to filter small cells, such as Chlorella and Nannochloris, less efficiently than larger species. The clams filtered the larger cells of Nitzschia less efficiently when Chlorella was also present in the suspension. However, the removal of Chlorella was greater from such suspensions than when only Chlorella was present. A mixed plankton population from a towing was filtered less efficiently than a unialgal culture of large diatoms, but more efficiently than a unialgal culture of Nannochloris.

Hard shell clams apparently filter much less water than oysters and scallops. Factors affecting the filtering rate are being investigated. Since comparisons of gill efficiency made at various times are complicated by the fact that the rate of water propulsion may be different, comparisons are now being made at the same moment and with the same water being filtered.

GULF OYSTER INVESTIGATIONS

The Pensacola, Fla., site of the Gulf Oyster Investigations offers an opportunity for study under conditions representative of much of the Gulf of Mexico coast. Information is sought on the wide fluctuations in yearly Gulf oyster production. Some areas have shown a gradually increasing harvest in the past 50 years while others have grown virtually barren of oysters. The basic causes of these changes, with the exception of damage wrought by such natural disasters as floods and hurricanes, are mostly unknown.

Ecological Relationships: To be able to interpret normal population changes and predict the commercial oyster harvest, a study was initiated of a typical Gulf oyster environment. Since 1949, daily temperature and salinity changes have been recorded, as have the yearly differences in the onset of the oyster breeding season, the duration of the setting period, the numbers of associated animals and a myriad of other data which help to describe this environment with reference to oysters.

Special studies of two snails which may be of importance in the economics of the oyster have been conducted during the past research year. One is a tiny ectoparasite, Odostomia, and the second is Melongena corona, which reaches as much as five inches in length and is able to destroy full grown oysters.

To date, populations fluctuations have not been correlated with any single environmental factor. Differences in populations of oysters a few hundred feet apart may be as great as differences in populations hundreds of miles apart. Continuing study of the more minute details of a particular environment is most likely to lead to the discovery of the obscure factors which affect populations.

Oyster Drill Biology: The carnivorous gastropod, or snail, Thais haemastoma, is one of the more important factors limiting oyster production in the Gulf. Despite many reports of its occurrence and destructiveness on coastal oyster reefs, there has been no detailed study of its ecology published and its complete life history is still unknown. Current studies have been concerned principally with growth rates, reproductive potential, tropistic responses, food preferences and rates of predation.

Sexual maturity as well as mature size of the snails are probably functions of food availability. Approximately 90 percent of the young snails initially develop a male gonad. During the first winter, when snails are about six months old, half of the new generation changes to the female sex. It is not yet known if this transition is permanent of if it may reverse itself, as is the case in some other mollusks, including the oyster.

Repeated attempts to culture the free-swimming snail larvae and maintain them experimentally until they take up the crawling habit have been unsuccessful. The duration of this important stage of their life cycle is critical, since it determines not only the potential dispersal of the larvae by water currents, but it is also a vulnerable stage in which some type of control measure might be employed. Larval cultures have been maintained for 40 days, at which time the larvae apparently all starved. Cultures currently thriving may prove more successful.

Apalachicola Bay: Apalachicola Bay, the center of Florida's commercial oyster harvest, is studied to evaluate the role of different members of the oyster community as they affect oyster production. Monthly surveys and detailed studies were made of the oyster reef complex at four stations where salinity is normally either high or low. These studies were conducted with the cooperation of the Florida State Board of Conservation, which provided boats and operators.

Monthly quantitative samples were taken at each station. Each examination included surface and bottom salinity, temperature and turbidity observations. Samples of oysters and associated organisms were obtained from measured areas by hand. Stations lying in deeper water were sampled by a diver equipped with an aqua-lung.

In the laboratory, oysters were measured, sexed, and the extent of fouling determined. All organisms living on, or in and among, the collected oysters were identified and counted. An indication of the seasonal condition of the oysters at each station was obtained by counting and weighing a 12-liter sample of culled oysters gathered at random, and measuring the volumetric yield of the drained meats.

Observations during this, the first year of the study, show that stations differ characteristically with respect to salinity levels, water currents and turbidity. Temperatures are normal for the area.

Population densities, spatfall and survival, as well as mortality in older oysters and the condition of meats, differ greatly at the stations.

Animals making up the community thus far identified include 11 species of fouling organisms which compete with the oyster for space, and 20 nonsedentary species. The oyster drill, Thais, was found consistently at only one station, but the crown snail, M. corona, was present in such numbers as to be considered a possible oyster predator. Xanthis crabs were numerous at all stations, and a species of noncommercial oyster, Ostrea equestris, has been common at one station.

Water Studies: Observations over a period of years have shown that oysters growing at two locations, a thousand feet apart, differed markedly in growth and mortality rates. It was also apparent that the amount of spawn produced and rate of spatfall were considerably greater at one station.

Since the two locations were similar in all obvious characteristics, a study was initiated to determine the nature of the water mass passing over them. Differences in the amount of available food could account for the differences noted in the two groups of oysters, for they are presumed to feed on the microscopic animal and plant constituents floating in the water. Since these are not homogeneously distributed, one of the first problems faced was the design of a water sampler which would collect representative samples of water at the two stations.

As a result of a number of experiments, equipment has been developed which collects at a uniform rate of 20 drops a minute over a period of 24 hours or longer. Thus a composite sample of all the water which has passed the collecting point is obtained and comparisons may be made with samples collected in the same manner at the other collecting station.

The samples are analyzed for the plant pigments, chlorophylls a, b and c, two types of carotenoid pigments and copper. Presumably, abundance of plant pigments will indicate a relative abundance of oyster food.

To correlate differences found in the analysis of pigments at the two stations, 1200 control animals are maintained (oysters, hard clams and scallops) in individual trays at the two locations. These are measured bi-monthly for growth and checked for mortality. The growth of both clams and oysters at the two stations in the past six months has been strikingly different. Recently 200 scallops were added to the test animals to see if the environmental factors affecting oysters and clams will also affect the scallops. Presumably all three animals, as filter feeders, obtain their nutrition from the same environmental source.

In comparisons of the different animals, weight appears more significant than either length or volume in discerning population differences. In two corresponding groups of hard clams, for example, average length and volumes differed by three and seven percent respectively, while the difference in average weight between the two groups was 24 percent.

Large amounts of plant pigment are found in the water samples taken at the less productive station, indicating the need for a re-examination of the original presumption relating to oyster feeding and suggesting that oysters and clams may not derive their primary nourishment from pigment-carrying elements in the plankton. This facet of the investigation will be closely pursued.

Economic Loss From Drills: Large areas of good oyster bottom along the Gulf Coast are commercially barren of oysters and the annual loss to industry on the producing reefs is considered large, due, mainly, to predation by the small snail, Thais haemastoma, locally known as the conch or oyster drill.

The true importance of the oyster drill in Gulf waters in unknown, and current studies are designed to determine the extent of economic losses due to the drill and to discover, if possible, a means of reducing these losses.

Approximately 500,000 acres of estuarine waters in Mississippi and Northwest Florida have been surveyed. Of 135,000 acres in Northwest Florida, 4,600 acres of nonproducing bottom suitable for oyster culture were located. This bottom would have little or no oyster mortality from either drill predation of fresh water influx in normal years. The remainder of the area surveyed was unsuitable because of poor bottom type, high salinity waters conducive to drills, low salinity waters too fresh for oysters or domestic pollution restricting the successful harvest of shellfish.

The determination of oyster mortality caused by the drill is complicated by the fact that many of the holes drilled are at the margin of the valves where detection is difficult. Experiments indicate that nine out of 10 oysters are drilled

in this manner and that probably 90 percent of oyster mortality caused by drills is not identified.

When a drill feeds on an oyster after drilling through its shell, the valves of the oyster usually gape before the drill has finished feeding. Usually one-fourth of the oyster tissue remains when shells gape open, meaning that the drill must destroy a fourth again as many oysters because of food lost to scavengers such as crabs and small fish who take part of its kill.

Under laboratory conditions the oyster drill can reach sexual maturity in eight months and deposit healthy, fertile eggs. Since the larval stage finds the drill free swimming and transported by water currents, it is apparent that, when the drill population has been reduced or wiped out by fresh water or other causes in a particular area, it is possible to have a reproducing population again within less than a year after conditions return to normal.

Hermit crabs, common on the Gulf coast, must occupy a snail shell for the protection of their soft bodies and, as they grow, they must obtain progressively larger shells. Large numbers of these crabs select shells of the oyster drill. Hermit crabs in search of a shell will kill an oyster drill to obtain its shell. Through this predation, the crabs may be of importance in nature in reducing oyster drill populations. Studies to come will determine whether the crabs normally kill snails, or utilize already empty shells.

A special study established the burying habit of the oyster drill. On some bottom types as many oyster drills were found buried as were found on the bottom surface at water temperatures when snails were actively feeding and crawling. Normally, as water temperatures drop below 12°C. this habit becomes more general and presents a definite problem in determining the extent and densities of snail populations. Standard collecting devices for sampling oyster reefs only remove snails from the bottom's surface.

Several kinds of collecting gear were used to sample oyster reefs and shell areas to recover snails. From experiments with tongs, commercial and experimental dredges and hand picking, a dredge equipped with a liner of quarter-inch galvanized hardware cloth was found to produce the best results, for it prevented the smaller drills from dropping through the dredge.

Sample collections of oyster drills for taxonomic study are being made throughout the Gulf area in conjunction with the survey in hopes of resolving present confusion in the species status of two varieties of snails now studied.

An experiment has been initiated in the Mississippi Sound to determine the rate of oyster destruction on productive and depleted reefs caused by drills. This will supplement survey data for determining economic loss to the Mississippi oyster industry.

A possible biological control measure for the oyster drill has been found in an as yet unidentified parasite which has been observed on both the drill and boring clam. In one instance the parasite was observed to invade the gonad of the host, destroying the tissue and causing what is known as biological castration. An intensive study of the possibilities offered by these parasites was begun as the research year ended.

Hard Clam Growth: In 1954 a joint investigation was begun by several widely separated research agencies to determine the growth of the hard clam at geographical locations extendings from Maine to Alabama. The clam utilized were reciprocal crosses obtained by the Milford Laboratory from northern and southern species of hard clam, and the pure seed of parent stocks. It was intended that the clams remain under similar physical conditions so that differences in growth rates of samples of one stock could be attributed to different environments and differences in growth rates of the four stocks at one location could be attributed to hereditary factors.

While significant, the results forcefully demonstrate the difficulties involved in duplicating physical conditions at different locations. Plastic screening used satisfactorily for trays in New Jersey became clogged in Alabama waters and caused the death of the clams by stopping water circulation over them. Nearly half the clams held at Pensacola were lost for this reason before the difficulty was identified.

The pure stock of clams of the southern species survived at Pensacola but died out at other laboratories where its loss has been attributed to the too cold winters. At Pensacola more than half of the original samples are alive and growing well. The pure stocks, both of northern and southern clams, are growing better than the hybrid crosses. At northern locations the reverse is true and the hybrids are reported growing better than the one surviving stock of the pure species, which has been interpreted as typifying the expected hybrid vigor.

The clams from this experiment have been divided into pairs and located at two adjacent stations where they are used as test animals in the study of local environmental factors. Within two months of the separation, changes were noted in the growth rates of one of the groups. It is quite probable that the differences will eventually become as great as those between the clams grown in Florida waters and those in New England.

General: In the past year exhibits of living marine life have been prepared and lectures presented on conservation to 500 secondary school students, 40 science teachers, to scout groups and local business men's clubs. Staff members participated in sessions of the Gulf States Marine Fisheries Commission and attended and participated in a seminar at the Gulf Coast Research Laboratory in Mississippi. A group of 200 oysters from the Gulf were shipped to Japan where they are being used in heredity experiments.

CHESAPEAKE BAY SHELLFISH INVESTIGATIONS

The development of information on life history, ecology and cultivation of oysters pertinent to the effective management of the Chesapeake Bay area oyster industry is the task of the Chesapeake Bay Shellfish Investigations at Annapolis, Maryland.

State of the Fishery: Oyster setting in the summer of 1955 in Eastern Bay Md., on shell plantings was not commercially significant. Setting on clean test shells in spat collectors, however, was 50 times greater than on planted shells. Timing the planting and the start of setting could help to reduce this difference by lessening the exposure of shells or clutch to fouling organisms.

Oyster sets in other parts of upper Chesapeake Bay were light. At Gibson Island, in the head of the Bay region, no spat were found on planted or wild shells. In the Bay 20 miles south of Gibson Island at Gum Thicket only nine spat per bushel of shell were found.

The survival of oyster larvae is a factor in the magnitude of the set. The first appearance of late stage larvae in the plankton usually corresponded with the start of setting, and the peak number of these larvae corresponded to the maximum set for a weekly period. Spawning was continuous throughout the summer, but mass survival of larvae to the late stages was restricted to the middle week of July.

Gonad thickness, measured at regular intervals during the summer, again showed evidence of build-up and discharge of sex products at separate periods during the spawning season. In Eastern Bay there were two such periods and in Chesapeake Bay most stations has three cycles of development and discharge. Resorption of sex products was practically complete at most stations by the middle of October.

Condition: Condition of oysters in the summer of 1955 in a plumpness sense was poor. Glycogen, the measure of

plumpness or fatness, began to drop from the winter and spring high of 26-30 percent at the end of May and fell to six to eight percent at the end of August. This followed the pattern of seasonal changes observed in most other years. The after-spawning recovery brought glycogen levels to 14-16 percent by early October and back to full plumpness by the end of December.

One measurement of favorable oyster environment is through determination of chlorophyll a, an index of available phytoplankton. Seasonally, this index showed low phytoplankton volumes in June. It increased steadily through the summer and more than doubled the June level by September. Geographically, chlorophyll a showed a differential phytoplankton distribution in the Bay. Samples from stations on the western side of Chesapeake Bay had a consistently higher level of the index material than those on the eastern side.

Survey: Maryland oyster resources were surveyed in cooperation with the Maryland Department of Tidewater Fisheries and Maryland Department of Research and Education. Included in the 1955 survey was examination of 94 oyster bars in Marlyand waters.

Survey findings showed in general terms the distribution and production of oysters to be expected for the next few years. It provided a check, also, of the validity of estimates based on previous surveys. Comparisons of current findings with those of a 1954 survey indicates less marketable oysters available and a smaller spatfall. The reduced spatfall should show in harvests two to three years hence.

Where setting on state shell plantings could be compared directly with natural setting, rates were usually found higher on the 1955 planted shells. The impact of this improvement did not improve the general setting level enough to make it equal to the fishing mortality.

Drill populations appeared in Tangier and Pocomoke Sounds, which had previously been free of these predators. This may, in part, account for the pronounced reduction of spat counts in this area. The size of the drill population seems to be a function of the wetness or dryness of a few successive seasons. For the past several years salinities increased by area dryness have permitted a migration of drills from the normally saltier water south of the sounds. The wet years of 1945-46 greatly reduced the drill population that had built up in the sounds prior to 1945. A wet season or two will possibly reduce the current drill crop in a like manner.

The 1955 oyster seed crop is less than that of 1954 because of low setting rates obtained this season on seed areas.

Oyster Drill: To test the effectiveness of traps as an oyster drill control measure a program under the Saltonstall-Kennedy plan has led to studies in York River, Virginia and Chincoteague Bay, Md.

Trapping drills continued throughout the year at test plots on Wormley Rock on the York River. The catch of drills diminished from November through March and no drilling activity was apparent. No drills were taken in January and February. During the period of summer activity a slight reduction in drill catch was noted. At the end of the summer a freshet covered the test plot and for a period of several weeks the catch was greatly reduced.

At the conclusion of drill activity in December, planted shells on the trapped and untrapped areas of the York were examined for survival of 1955 spatfall. A 75 percent survival was found for the three acres trapped with 280 traps, or 93 per acre. On the untrapped area the survival rate was 53 percent.

Spat bags protected from drills caught 4.7 spat per shell per season in the area as compared to .47 spat per shell caught on the planted shell in the

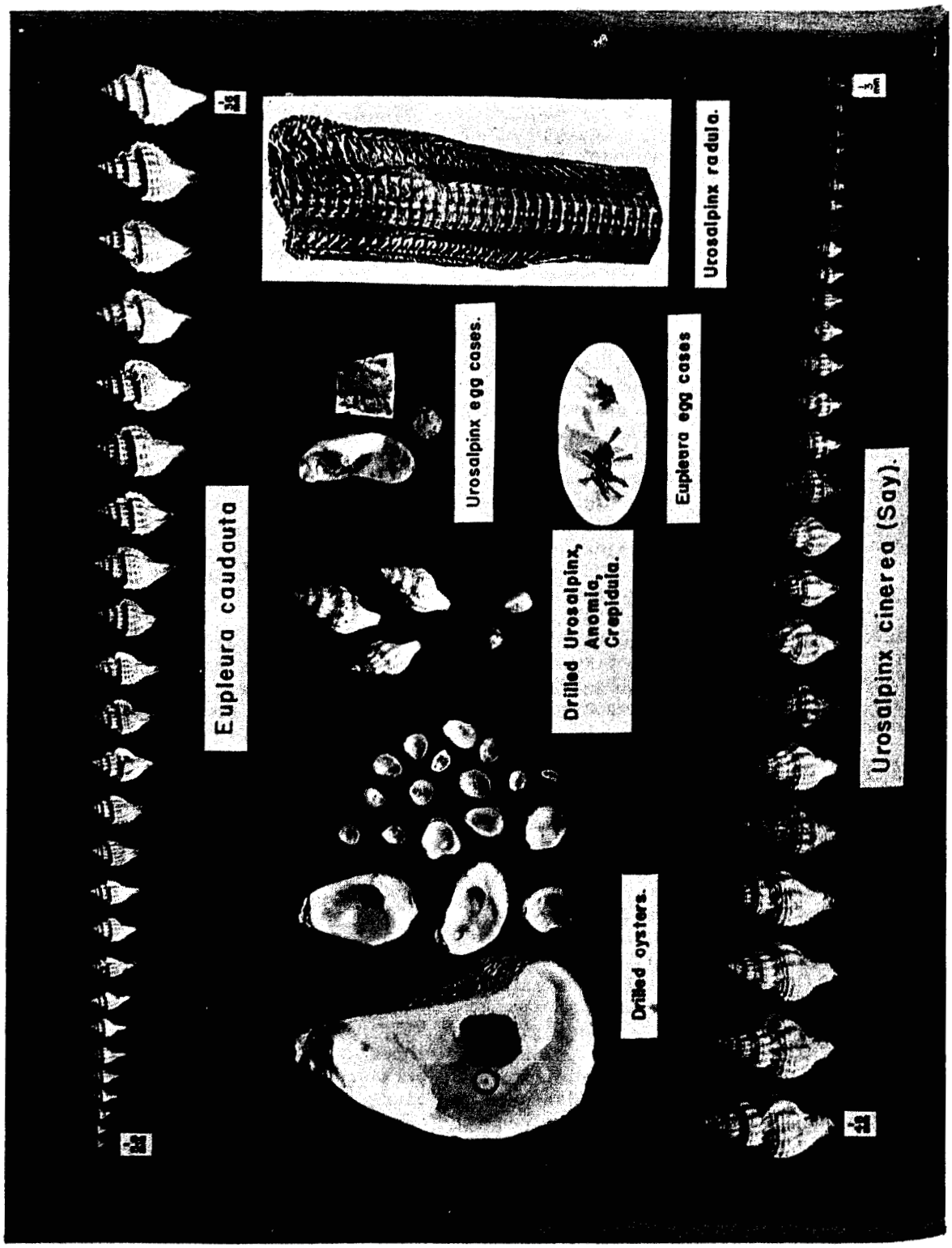


Fig. 31--Growth and life history of the oyster drills Eupleura caudauta and Urosalpinx cinerea and drilled oysters are shown in this photo.

trapped area and .42 spat per shell in the untrapped area. The difference between the catch on spat bags and planted shells represents the loss due to the unseen causes such as drills feeding on newly set oysters, fouled shells and death of tiny spat from other predators and disease which would not affect the suspended shells. From observations made elsewhere on the voracity of young, newly hatched drills, it is likely that a substantial part of the spat loss, whose death was not specifically earmarked, was due to drill predation.

In Chincoteague Bay drill trappings was also on a year-round basis. Activity almost ceased by the end of November, but at no time during the year was there a total absence of drills. No freshets or adverse conditions affected the test area during the year.

A program of oyster drill control is in operation in Chincoteague Bay. Clean shells were planted on four plots of four acres each at the rate of 800 bushels to the acre and treated in the following manner:

Plot one was trapped with 40 traps to the acre from April 15 through the end of June. Drill traps were dipped in copper sulfate solution when drill egg cases became abundant on the bait oysters.

Plot two was cleaned with a dredge with a fine mesh bag prior to shelling. The area was trapped with 40 traps per acre from the time the shells were planted to the end of June 1956.

Plot three was planted with shells early in June 1955, and trapped with 40 traps per acre from the time of shelling through June 1956.

Plot four had nothing done to it except estimation of the size of the drill population. This is the control to establish the natural state of the bottom in this area.

The catch on each plot showed two distinct peaks with a period between them of a very much reduced catch during the end of July and the first of August. From the second peak, which appeared in the catch of August 20, the numbers declined rapidly from more than 100 drills per day to less than four per day.

On plot one a definite step to control the recruitment was made by immersing all traps in a copper sulphate bath at the peak of egg case disposition. No such steps were taken on plot three. On plot two treatment consisted only of physically cleaning the bottom of all loose debris before shell planting, which removed some of the egg cases deposited there in the late spring.

All plots were trapped alike to remove the juvenile and adult drills. The copper sulphate method of killing drill embryos in the egg cases appeared to be effective in reducing the recruitment on plot one--more so than the manual cleaning of plot two, where apparently some egg cases were left on the bottom with embryos to develop and hatch.

Shells planted on experimental plots were examined in December for 1955 spatfall. The sampling was made at three places on plot one and three places on plot three. No oyster spat were found in the three bushels of shells examined from plot one, and only four spat were found on the same quantity of shells from plot three. Shells were not too dirty, but they were badly fouled with Anomia. On shells from plot one, 1,870 Anomia were found on 195 shells, or about 10 per shell.

In two samples of shells from plot three 1,053 Anomia were found on 210 shells and 773 on 209 shells, about five and four, respectively, per shell.

Copper Fencing: As part of a project to design a fence which would stop oyster drills, laboratory experiments

were conducted at Boothbay Harbor, Maine, to determine if these Gastropods would cross all metals. Clean copper proved effective in tests where iron and zinc had no repellant action. Copper and brass screen fences, two inches high, repelled drills in currents up to .45 knots during the tests.

Copper and brass fences lose their effectiveness if in contact with a more active metal, such as iron. Under these conditions, iron ions, which do not repel oyster drills, are released instead of the repellant copper ions. Practical applications cannot be recommended until further research is completed.

Completed Maine field tests using the mud snail, Nassa, confirm the results of laboratory experiments, but indicate ionization rates of metallic copper decrease enough during the first month of usage to lessen the effectiveness of the barriers.

The Chincoteague Bay project was carried out with the cooperation of the area station of the Maryland Department of Research and Education. All shells used for planting on the experimental plots in Chincoteague Bay were furnished by the Maryland Department of Tidewater Fisheries.

Drill Dredge: Trapping methods are feasible drill controls only when they can be applied in shallow waters not having heavy boat traffic. To meet the conditions where trapping is unfeasible, such as the open waters of lower Chesapeake Bay, a drill dredge with a suction cleaning device is being developed. The small-scale pilot model removes drills at the rate of 800 per hour when the drill population is 25,000 per acre. The catch for one day of dredging would be 6,400 drills, which exceeds the season catch of drills by York River traps.

If the dredge could remove drills at this rate on the trapped area, it would take only one day of dredging to accomplish the results of a season's trapping with 93 traps per acre tended weekly. This is speculation, but encouraging because the trapping was able to remove enough drills to permit a better survival of spat than was found on an untrapped area. Experiments to improve the dredge design are continuing.

Contract Studies: The Virginia Fisheries Laboratory under a Service contract has been conducting a study of the oyster drills of Chesapeake Bay in cooperation with the Chesapeake Shellfish Investigations. A wide range of studies encompassed by this contract will provide a good picture of drill population, its composition and effect.

CLAM INVESTIGATIONS

Chief concern of the Clam Investigations at Boothbay Harbor, Maine, is the rehabilitation of the New England soft clam fishery. So severe is the decline of the fishery that production in Maine fell from 9.8 million pounds in 1946 to 2.6 million pounds in 1955.

Prior research by the Investigations, which were started in 1948, established that increases in populations of the predatory green crab were largely responsible for soft clam population decreases north of Cape Cod.

The reasons for green crab increases and methods for controlling their predations were sought during the 1955-56 research year. A secondary study sought methods of management improvement in the hard clam fishery and of collection of juvenile hard clams for private fishing.

Green Crab Abundance: Green crabs have been trapped in Maine and Massachusetts yearly since 1953 to provide data on which to base estimates of abundance and to correlate fluctuations with such environmental factors as temperature and known green crab predators. Yearly means for 1955 were higher in both States than for the previous two years.

In 1955 the program was expanded to include traps in Rhode Island and Connecticut and will be continued through

1956 to determine if the cold water of the 1955-56 winter caused a population decrease.

Predation Experiments: Three experiments to determine what effect crab predation had upon clam population were set up in different parts of Sagadahoc Bay, Maine, during the summer of 1955. Each experiment consisted of two adjoining plots 10 feet square, one fenced to exclude crabs and the other left unprotected. Each plot was planted with seed clams averaging 25 mm. in length and with an initial concentration of 71 per square foot. At the conclusion of the experiment in November the difference between survival in the fenced and unfenced plots was not significant. In the third experiment, located closest to the area of greatest crab cover, the unfenced plot had fewer clams than the fenced.

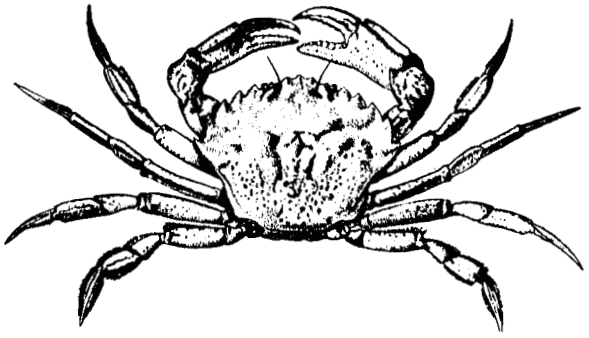


Fig. 32--Green Crab

Since green crabs in Sagadahoc Bay are smaller than those in other areas and do not range as widely, it is possible that only a few of them reached the experimental plots. It is also possible that the majority of clams used in the experiments were able to burrow deeply enough to escape the smaller crabs. Further experiments will explore these possibilities.

Green Crab Tagging: Experiments to develop a tag which would be suitable for use on small green crabs and which would remain through a shedding were begun in the fall of 1955. Preliminary experiments indicated that circular metal tags 3/16ths of an inch in diameter could be inserted under the posterior edge of the carapace without extreme mortality and could be detected with an electrical device. In subsequent experiments large crabs survived tagging better than small crabs even though the tag was larger. Crabs averaging 44.8 mm. in width tagged with quarter inch diameter disks had a 10.3 percent mortality, whereas crabs averaging 38.4 mm. tagged with a one-eighth inch disk suffered 48 percent mortality.

Further experiments show promise of developing a tag which will remain through a molt and which may have application in studies of other commercially important crustaceans.

Fencing: After a number of experiments with varying designs, it was found that a fence of low wire screen with a four-inch board flange to which a four-inch strip of zinc flanging was fastened and bent downward 60 degrees at the top was effective in keeping crabs from clam flat areas. The addition of the zinc flange came after aqua-lung observations showed the crabs were surmounting the horizontal board flange with relative ease. Similar fences have been installed by two towns in Maine and two towns in Massachusetts, where they are apparently successful.

Lindane Poisoning: Experiments conducted by the Maine Department of Sea and Shore fisheries showed that Lindane (Gamma Isomer of Benzene Hexachloride) was toxic in four hours to both lobsters and green crabs in dilutions of one part in 10 million parts of water. The exclusion of lobsters by the fencing experiments which were conducted at Sam's Cove, Me., provided an excellent test site for poison experiments.

A 20 percent solution of Lindane in a hydrocarbon base was mixed with chopped fresh herring and allowed to stand overnight. At low tide the poisoned bait was spread around the shoreline within the fenced area. Examination 24 hours

later found most of the visible crabs either dead or paralyzed. The average crab trap catch in the area for 17 days following the distribution of the poisoned bait was 84.5 percent less than the average catch for the 18 days preceeding the experiment. After 33 days the area was examined and only one live crab found within the fenced area, as opposed to 56 outside the fence.

There was little evidence of harm to other organisms in the area. The use of moderate quantities of bait treated with a form of Lindane which is nearly insoluable in water and the proper placement of the bait in the intertidal zone contribute to its safe usage. A large scale experiment in the future will further test the effectiveness of this means of control.

Food of Green Crabs: Stomach analyses of 1,291 thatch bank crabs and 1,294 crabs dredged from the subtidal zone showed that thatch bank crabs utilize plant foods more than the dredged crabs which appear more dependent on animal foods. Animal foods were present in 68.6 percent of all thatch bank crabs and 89.5 percent of all dredged crabs. Plant foods were found in the stomachs of 45.3 percent of all thatch bank crabs and 28.7 percent of all dredged crabs.

Collections from two locations in Plum Island Sound, Mass., indicate that crabs utilize recently-set mollusks, as high percentages of the stomachs contained young soft clams and mussels. Observations are being extended to include crabs ranging from Maine to Rhode Island.

In a preliminary experiment to determine how green crabs find food a 20-gallon aquarium was divided into two parts at one end with a glass partition and soft clams were allowed to bury themselves in sand in one part, while the other portion was left barren. Crabs introduced into the aquarium moved almost at random over the entire bottom until the first clam was found. Once the first clam had been discovered the others were soon dug out and eaten. Only 12 of 68 clams remained after 24 hours.

In another experiment crabs which had eye-stalks removed to eliminate sight stimuli were placed in the same aquarium. These crabs showed no movement toward living clams but burrowed into the sediment and remained there for several days. When the juice of a crushed Venus clam was introduced, the crabs came out of the sediment and moved toward the juice. These experiments will be continued using larger tanks.

Green Crab Parasites: The most promising hope of biological control of green crab predations is the Rhizocephalid barnacle Sacculina carcini which can cause parasitic castration of green crabs. Although this parasite is common in European green crab populations, it has never been reported in the United States. Its introduction cannot seriously be considered until it is established that it does not attack lobsters. A general survey will continue to seek other parasites which might offer potential controls for the crabs.

Soft Clam Census: Since 1949 an annual soft clam census has been conducted in Sagadahoc Bay, Me., to determine the productivity of this bay in terms of the number of bushels of clams which can be taken each year without harm to supply and to determine the effects of predators on the clam population.

The estimated population of the bay has dropped from 40.2 million clams in 1949 to 8.3 million in 1955. From 1949 to 1951 heavy commercial digging depleted stocks in the area, and after 1951 the steady increase in green crab abundance and the resultant predation has added to the reduction.

Soft Clam Reproduction: One of the early objectives of the Clam Investigations was to determine whether or not the decreasing supply of clams was a result of lack of reproduction. Therefore, part of each yearly program has been the sampling of plankton to determine the seasonal occurrence and relative abundance of clam larvae. In addition, regular sediment samples from the clam flats

have been taken to determine the success of setting, survival and growth throughout the year.

Plankton sampling was discontinued as a routine part of the program in 1956. Seven years' sampling in different areas of the coast have indicated that sufficient clam larvae are produced each year to result in substantial sets. This seems to occur commonly no matter how scarce the local adult clams may be. Adequate sets have been noted consistently, with the clams eliminated by the green crab predation as they reach 5 to 6 cm. in length.

Level Bottom Fauna: In cooperation with Danish scientists and research groups on the Atlantic and Gulf coasts a survey of the distribution of animals on "the level sea bottom" was initiated in January, 1955. Worldwide cooperative research of this type will one day lead to the delimitation of animal communities in relation to ecological factors. Information on the productivity of bottom dwelling animals is also being gathered and will add to knowledge of food available to commercial fisheries as well as the competition between species for this food. The immediate problem has been to map a survey of all species in the area from low tide level to a depth of 200 meters, and an evaluation of their biomass.

Two small areas near the seaward end of the Sheepscot River estuary were sampled in 1955 with a small clamshell type bucket known as a "Petersen" grab. Samples were 0.1 meter square and about 6 to 7 cm. deep in soft muddy bottoms. Sample stations were located 300 feet apart in shallow water and 600 feet apart in the deep portions.

Roughly 10 samples a week were taken with the grab, one at each station, and from these material was sorted and preserved. It was passed through a series of screens suspended in a bottomless box hung over the side of the vessel. The finest mesh screen had openings of approximately 1.5 mm. and provided an arbitrary division between the marcofauna and microfauna. Mud and other materials were washed through the screens by running sea water pumped from the boat, and the organisms retained on the screen were retained in jars and returned to the laboratory. Soil samples and bottom temperatures were taken at most stations.

Identification of the animals obtained in the 83 samples thus far taken in the survey has proven a time consuming task. Most of those from the Phylum Mollusca and the Phylum Annelida have been classified and several miscellaneous Phyla are nearing completion. There have been 5,126 individual molluscas examined from 36 species and 2,444 polychaetes from 52 species recorded. Several species in each group are still unidentified. The Arthropoda and Nemerta are the two largest groups remaining for taxonomic work.

Hard Clam Survey: Annual surveys of the abundance, distribution and size composition of the hard clam population of Greenwich Bay, Rhode Island, have been made since 1950. A total of 338 stations were sampled in 1955, the majority with a clamshell bucket which takes a five square foot bottom sample. Stations in water too shallow for the sampling vessel, were sampled with tongs or a rake.

Results of the 1955 survey show areas of high and low density in roughly the same parts of Greenwich Bay as in previous years. The middle and eastern parts continue to hold up the best of all areas and the high density areas at the mouth of two western coves remain. The area slightly north of the geographical center of the Bay remains barren, as it has for the six years of the survey.

Hard clam abundance showed a decline in 1955, following a trend begun in 1951. For the second straight year the legal size (over 46 mm. in length) population has shown a decline and it appears that fishing and natural mortality are affecting this population since recruitment has been low for several years. The decline in the sublegal (15 to 46 mm.) has not been as steady as that of the legal size population, but general abundance of small

clams has been so low from 1953-55 that only small additions to the total population could be expected.

Hurricane protective structures proposed for Narragansett Bay, Rhode Island, might enclose 85 percent of the productive hard clam beds. To determine the potential effect of such construction Clam Investigations personnel joined with members of the River Basins Studies and the Rhode Island Division of Fish and Game in a complete survey of the upper Bay. Preliminary results, which include more than a thousand of two thousand stations to be sampled, show a marked scarcity of sublegal hard clams. From these results it would appear that the whole of upper Narragansett Bay is suffering from a lack of good setting or from poor survival of juvenile clams.

Catch Statistics: Yearly estimates of catch statistics are made for Greenwich Bay by interviews with fishermen working the area. The 8.75 million hard clams estimated for 1955 exceeded the 1953-54 totals and was nearly the same and the 1951 and 1952 catch. Nearly a third of this catch represents production from a high density area on the north shore of the Bay which had been closed in 1954 by the Rhode Island Department of Fish and Game when the yearly census showed a high concentration of hard clams just below legal size. The area was opened briefly in March, 1955, but closed again when large catches depressed the market. The area was reopened in July and fishing pressure soared, with as many as 250 boats per day fishing--more than four times the highest monthly average for the whole of Greenwich Bay during this season.

The high productivity of the single north shore area tends to paint an excessively optimistic picture when it is included with catch estimates for the Bay as a whole. Without the March and July peaks caused by returns from the area, the figures show that Bay productivity in 1955 was about the same as 1954, which was considered by fishermen as a poor year.

The proportion of "necks" (47 to 66 mm. long clams) in 1955 was the lowest during the six years of the study, while the catch of "large" (over 66 mm.) hard clams was the highest. Nearly twice as many "large" clams as "necks" were taken per boat per day, as compared with nearly equal proportions of these size groups in 1950.

Hard Clam Reproduction: A knowledge of the early life history of the hard clam is important in the study of other aspects of hard clam populations and essential in the development of seed collecting methods. For this reason, studies on larval ecology and setting habits have been a continuing part of the hard clam investigations.

Analysis of data collected from 1953 through 1955 indicates:

1. That a direct relationship exists between the abundance of mature larvae and the density of the subsequent set. The more mature larvae present, the more abundant will be the subsequent set as measured by the number of juveniles per square foot of bottom.

2. That there is a direct relationship between the abundance of mature larvae and the horizontal distribution of the subsequent set. The greater the abundance of mature larvae, the more widely distributed horizontally will be the set.

3. That there is no consistent relationship between the abundance of early or young larvae and the density or distribution of the subsequent set.

Spat Trap Studies: A dependable source of seed is a prime requirement for successful hard clam farming. With isolated exceptions, natural sets are of too low a density to be satisfactory sources. The tidal spat trap, which is an attempt to solve the seed source problem, is essentially a box which is filled and emptied by the tide and which has check valves and filters arranged so that clam larvae are confined once they enter the box.

have been taken to determine the success of setting, survival and growth throughout the year.

Plankton sampling was discontinued as a routine part of the program in 1956. Seven years' sampling in different areas of the coast have indicated that sufficient clam larvae are produced each year to result in substantial sets. This seems to occur commonly no matter how scarce the local adult clams may be. Adequate sets have been noted consistently, with the clams eliminated by the green crab predation as they reach 5 to 6 cm. in length.

Level Bottom Fauna: In cooperation with Danish scientists and research groups on the Atlantic and Gulf coasts a survey of the distribution of animals on "the level sea bottom" was initiated in January, 1955. Worldwide cooperative research of this type will one day lead to the delimitation of animal communities in relation to ecological factors. Information on the productivity of bottom dwelling animals is also being gathered and will add to knowledge of food available to commercial fisheries as well as the competition between species for this food. The immediate problem has been to map a survey of all species in the area from low tide level to a depth of 200 meters, and an evaluation of their biomass.

Two small areas near the seaward end of the Sheepscot River estuary were sampled in 1955 with a small clamshell type bucket known as a "Petersen" grab. Samples were 0.1 meter square and about 6 to 7 cm. deep in soft muddy bottoms. Sample stations were located 300 feet apart in shallow water and 600 feet apart in the deep portions.

Roughly 10 samples a week were taken with the grab, one at each station, and from these material was sorted and preserved. It was passed through a series of screens suspended in a bottomless box hung over the side of the vessel. The finest mesh screen had openings of approximately 1.5 mm. and provided an arbitrary division between the marcofauna and microfauna. Mud and other materials were washed through the screens by running sea water pumped from the boat, and the organisms retained on the screen were retained in jars and returned to the laboratory. Soil samples and bottom temperatures were taken at most stations.

Identification of the animals obtained in the 83 samples thus far taken in the survey has proven a time consuming task. Most of those from the Phylum Mollusca and the Phylum Annelida have been classified and several miscellaneous Phyla are nearing completion. There have been 5,126 individual molluscas examined from 36 species and 2,444 polychaetes from 52 species recorded. Several species in each group are still unidentified. The Arthropoda and Nemerta are the two largest groups remaining for taxonomic work.

Hard Clam Survey: Annual surveys of the abundance, distribution and size composition of the hard clam population of Greenwich Bay, Rhode Island, have been made since 1950. A total of 338 stations were sampled in 1955, the majority with a clamshell bucket which takes a five square foot bottom sample. Stations in water too shallow for the sampling vessel, were sampled with tongs or a rake.

Results of the 1955 survey show areas of high and low density in roughly the same parts of Greenwich Bay as in previous years. The middle and eastern parts continue to hold up the best of all areas and the high density areas at the mouth of two western coves remain. The area slightly north of the geographical center of the Bay remains barren, as it has for the six years of the survey.

Hard clam abundance showed a decline in 1955, following a trend begun in 1951. For the second straight year the legal size (over 46 mm. in length) population has shown a decline and it appears that fishing and natural mortality are affecting this population since recruitment has been low for several years. The decline in the sublegal (15 to 46 mm.) has not been as steady as that of the legal size population, but general abundance of small

clams has been so low from 1953-55 that only small additions to the total population could be expected.

Hurricane protective structures proposed for Narragansett Bay, Rhode Island, might enclose 85 percent of the productive hard clam beds. To determine the potential effect of such construction Clam Investigations personnel joined with members of the River Basins Studies and the Rhode Island Division of Fish and Game in a complete survey of the upper Bay. Preliminary results, which include more than a thousand of two thousand stations to be sampled, show a marked scarcity of sublegal hard clams. From these results it would appear that the whole of upper Narragansett Bay is suffering from a lack of good setting or from poor survival of juvenile clams.

Catch Statistics: Yearly estimates of catch statistics are made for Greenwich Bay by interviews with fishermen working the area. The 8.75 million hard clams estimated for 1955 exceeded the 1953-54 totals and was nearly the same and the 1951 and 1952 catch. Nearly a third of this catch represents production from a high density area on the north shore of the Bay which had been closed in 1954 by the Rhode Island Department of Fish and Game when the yearly census showed a high concentration of hard clams just below legal size. The area was opened briefly in March, 1955, but closed again when large catches depressed the market. The area was reopened in July and fishing pressure soared, with as many as 250 boats per day fishing--more than four times the highest monthly average for the whole of Greenwich Bay during this season.

The high productivity of the single north shore area tends to paint an excessively optimistic picture when it is included with catch estimates for the Bay as a whole. Without the March and July peaks caused by returns from the area, the figures show that Bay productivity in 1955 was about the same as 1954, which was considered by fishermen as a poor year.

The proportion of "necks" (47 to 66 mm. long clams) in 1955 was the lowest during the six years of the study, while the catch of "large" (over 66 mm.) hard clams was the highest. Nearly twice as many "large" clams as "necks" were taken per boat per day, as compared with nearly equal proportions of these size groups in 1950.

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A tidal spat trap was tested in Wickford Harbor, Rhode Island, in 1954 and 1955. Results indicate that it collects hard clam larvae in approximately the same numbers and composition as occur in the surrounding water and that the resulting set in the trap is of the same magnitude as that occurring in the harbor. Apparently the density of the set resulting from filtering the tidal flow into the trap cannot be expected to exceed that which occurs in certain parts of the harbor. However, since the larvae will set and apparently thrive in the trap, it may be possible to greatly increase the set by increasing the volume of water filtered.

Studies begun in 1956 provide for operation of traps supplied with water pumped at up to 4,800 gallons per day per filter screen. The tidal flow supplies only 200 gallons per day per screen. The original tidal traps are being kept in operation to serve as controls.

Hard Clam Predators: Identification of hard clam predators and determination of the sizes at which predation is the most severe is the goal of this study which seeks means for control of predators on planted stocks of hard clams. Work to date has been confined to the two best known predators in Rhode Island, the mud crab, Neopanope texana, and the oyster drills Urosalpinx cinerea and Eupleura caudata.

Laboratory and field experiments have indicated that mud crabs are especially destructive of hard clams smaller than 50 mm. in length. A 1955 field experiment tested the protection against predation offered hard clams by eight mesh per inch saran screening, four mesh per inch galvanized iron hardware cloth and only the protection of the soil in which the clams were buried.

Of 1,000 clams planted in each of three test plots, those protected by the saran screening fared the best. A total of 691 were recovered alive, 19 were found drilled and recovery of hinge pieces showed 19 had been victims of crabs. Unknown causes killed 172 and 107 were unaccounted for.

The plot protected by hardware screen had 161 survivors, 15 drilled and 51 killed by crabs. Two hundred seventy-five were dead from unknown causes and 498 were unaccounted for.

On the unprotected plot only 11 clams survived. Five were drilled, 130 killed by crabs, 109 dead from unknown causes and 745 unaccounted for.

Because of the crab's ability to break small hard clams into very small pieces which are impossible to recover by screening, it can safely be assumed that many, perhaps most, of the unaccounted-for clams were killed by crabs. In 1956 additional experiments have been set up to determine if mud crabs can be excluded from clam beds by fences similar to those which have proved successful with green crabs.

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1955. Infectious pancreatic necrosis in brook trout. A.M.A. Archives of Pathology, vol. 60, pp. 26-28.

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Thorne, Donald L.	Lab. Elec.	Pacific Salmon	Seattle, Wash.
Thrailkill, James R.	Fish. Biol.	South Pacific	La Jolla, Calif.
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 Cleve, Richard	Fish. Biol.	Marine Section	Seattle, Wash.
Van Landingham, John W.	Phy. Sci. Aid	POFI	Honolulu, T.H.
Van Oosten, John	Fish. Biol.	Great Lakes	Ann Arbor, Mich.
VanHaagen, Richard H.	Elec. Scient.	Pacific Salmon	Seattle, Wash.
Vieira, Manuel	Stat. Assist.	North Atlantic	Woods Hole, Mass.

Name	Title	Investigation	Location
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.
Wallace, Wade K.	Fish. Aid	Gulf	Galveston, Texas
Watson, Frank H.	Fish. Aid	South Pacific	La Jolla, Calif.
Weaver, Charles R.	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 F.	Fish. Biol.	Clams	Boothbay Harbor, Me.
Wells, LaRue	Fish. Biol.	Great Lakes	Ann Arbor, Mich.
Wheeler, Ray S.	Fish. Aid	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.
Wilson, Alfred J.	Fish. Aid	Gulf Oysters	Pensacola, Fla.
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.
Wood, Edward M.	Fish. Biol.	Sal. Nutr. Lab.	Willard, Wash.
Woodall, Arthur N.	Chemist	Sal. Nutr. Lab.	Willard, Wash.
Worlund, Donald D.	Stat.	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. Aid	POFI	Honolulu, T.H.
Yount, Maxine D.	Fish. Aid	South Pacific	La Jolla, Calif.
Yuen, Heeny S. H.	Fish. Biol.	POFI	Honolulu, T.H.
Zein-Eldon, Zoula P.	Chemist	Gulf	Galveston, Texas

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