I45 F: 930/04 15

U. S. DEPARTMENT OF COMMERCE
BUREAU OF FISHERIES

Clemson University
3 1604 019 781 816

PROGRESS IN BIOLOGICAL INQUIRIES 1929

By ELMER HIGGINS

FISHERIES DOCUMENT No. 1096

Clemson
Government Publications

U. S. DEPARTMENT OF COMMERCE
R. P. LAMONT, Secretary
BUREAU OF FISHERIES
HENRY O'MALLEY, Commissioner

Bureau of Fisheries Document No. 1096

PROGRESS IN BIOLOGICAL INQUIRIES 1929

By ELMER HIGGINS

APPENDIX XV TO REPORT OF COMMISSIONER OF FISHERIES
FOR THE FISCAL YEAR 1930

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1931

For sale by the Superintendent of Documents, Washington, D. C. - - - Price 15 cents

PROGRESS IN BIOLOGICAL INQUIRIES, 1929 [1]

By Elmer Higgins

Chief, Division of Scientific Inquiry

(With the collaboration of investigators)

CONTENTS

[1] Appendix XV to the Report of the U. S. Commissioner of Fisheries for 1930. B. F. Doc. 1096.

INTRODUCTION

Research activities of the staff of the division of scientific inquiry during 1929 have been directed toward a solution of the original problems facing the Bureau of Fisheries—the estimating of the present supply of fish, the detecting of overfishing, and encouraging the upbuilding of the fisheries. In addition to activities pertaining primarily to the great commercial sea fisheries, important inquiries have been conducted in the field of aquiculture, both as relates to the propagation and culture of inland food and game fishes and to the methods of farming oysters and other mollusks.

It may not be apparent at once that all of the bureau's investigations of the sea fisheries bear directly upon the problems of determining the supply, of gaging or foretelling its fluctuations in abundance, or in determining methods of so regulating exploitation of these resources that a maximum yield of products valuable as food or as raw material for various industries may be maintained. Perhaps the most direct approach to the question of total abundance and variations in annual supply is found in the investigation of the mackerel fisheries of the North Atlantic, where marked progress has been made during the year in analyzing the components of the commercial catch and in determining the relative abundance of the various year classes of mackerel population. Such investigations show great promise of practical application in the foretelling of the abundance of future runs of fish and thus supplying information of direct economic value to the fishing fleet and related shore industries, at the same time making it possible to guard against depletion. Similar methods of study are being applied to the supplies of weakfish, whiting, scup, butterfish, flounders, etc., that support the extensive shore fisheries of the Atlantic coast from southern New England to the Chesapeake Bay.

Corresponding to these direct studies of supply on the Atlantic coast are the investigations of the great salmon fisheries of Alaska. Here scientific studies are providing information that is rapidly bringing this important source of food within complete control. This promises the ultimate restoration of former abundance and assures the perpetuation of the supply.

Of less direct application, but of equal importance to an understanding of the fisheries, are such studies as the tracing of the course of development from egg to adult in these same species of food fishes and in the many related or competing species preying upon commercial forms or furnishing their food. Of still more remote application, but of even more fundamental importance, is the understanding of those factors in the environment that determine the fate of the myriads of fish eggs deposited in the ocean waters each season. Oceanographical studies recently undertaken dealing with the currents, salinities, temperatures, and other physical and chemical phenomena of the ocean waters, as well as the teeming invertebrate life therein contained, all bear ultimately upon fishery problems and may hold the key to the final understanding and control of variations in the fish supply.

In addition to these more theoretical researches studies on practical methods of fishery conservation have been conducted. For example, as a result of extensive experiments in Great Lake waters rec-

ommendations have been formulated for improving commercial fishing gear in order to avoid undue wastage of immature and undersized fish caught ordinarily along with marketable sizes. In the Pacific Northwest practical methods have been developed for screening the mouths of irrigation ditches and power-diversion canals to prevent the tremendous losses of young migrating salmon from following the downstream currents into the irrigation ditches, or protecting them from injury and destruction by power-house equipment. The prevention of such waste is a positive means of conservation, and progress in these lines is most encouraging.

The work of the investigators in aquiculture has continued to yield practical and valuable results. As a culmination of several years' experiments on trout culture, Document 1061, Care and Diseases of Trout, appeared late in the year. This publication, although based on painstaking scientific work, presents the information of value to the trout culturist in such simple and practical terms that it has received much enthusiastic praise from fish culturists at home and abroad. Progress has also been made in increasing the production of the warm-water pond fishes, such as largemouth bass and crappie, and in understanding the factors regulating the production of fish food in pond areas.

Mollusks, being stationary, are peculiarly adapted to successful farming, and marked improvements have been made by the bureau's investigators in oyster-cultural methods. These are rapidly being adopted by the oyster producers of both coasts. In fresh-water mussel culture numerous difficulties involved in the method of artificial propagation described in the previous report have been solved, and methods of large-scale production are being developed. As a result of these advances the old method of mussel propagation by the inoculation of stranded fishes in the Mississippi River has been abandoned as being of doubtful efficacy. The prospects for early rehabilitation of the mussel fishery in the upper Mississippi River, however, are uncertain because of the increasing menace of pollution. Plans are under way to give to the problems of river pollution during the coming year the attention that the gravity of the situation warrants.

Investigators of the division of scientific inquiry have continued to participate in the activities of the North American Committee on Fishery Investigations, an international body formed for coordinating investigations of the fisheries of the North Atlantic coastal and high sea areas. At a meeting held October 15 and 16, 1929, at Ottawa, Canada, representatives of Canada and the United States were present and gave extensive consideration to problems of fishery investigation of the cod, haddock, mackerel, and other fishes of economic importance, as well as certain oceanographical investigations of the region having international interest. Attention was given to the possible effect on the fisheries of the proposed damming of Passamaquoddy Bay, a subcommittee being appointed to examine the conditions of that area, to consider the plans of the company proposing to develop hydroelectric power, to study all available information bearing on the predictable effects of the project on the fisheries of the region, and to report findings to the two Governments. A meeting of this committee was held December 12, 1929. A report was rendered and recommendations offered for a more thorough investi-

gation of the oceanographic and biological conditions affecting the fishery, to be conducted jointly by the two Governments.

During the year 1929, 17 scientific or administrative reports were published under the supervision of the division and as a result of investigations of its staff. The list of papers follows:

Scallop industry of North Carolina. By James S. Gutsell. Appendix V, Report of Commissioner for 1928. 8°, 27 pp., 11 illus. Document No. 1043.

Progress in Biological Inquiries, 1927. By Elmer Higgins. Appendix VI, Report of Commissioner for 1928. 8°, 51 pp. Document No. 1044.

Natural history and conservation of redfish and other commercial Sciaenids on Texas coast. By John C. Pearson. Bulletin, Vol. XLIV, 1928. Royal 8°, 88 pp., 44 illus. Document No. 1046.

Experiments in marking young chinook salmon on Columbia River, 1916–1927. By Willis H. Rich and Harlan B. Holmes. Bulletin, Vol. XLIV, 1928, Royal 8°, 52 pp., 24 illus. Document No. 1047.

Coregonid fishes of Great Lakes. By Walter Koelz. Bulletin, Vol. XLIII, Pt. II, 1927. Royal 8°, 349 pp., 26 illus. Document No. 1048.

Shrimp fishery of southeast Alaska. By Frank W. Hynes. Appendix I, Report of Commissioner for 1929. 8°, 20 pp., 8 illus. Document No. 1052.

Life history of the lake herring (*Leucichthys artedi* le Sueur) of Lake Huron, as revealed by its scales, with critique of scale method. By John Van Oosten. Bulletin, Vol. XLIV, 1928. Royal 8°, 166 pp., 28 illus. Document No. 1053.

Investigation of physical conditions controlling spawning of oysters and occurrence, distribution, and setting of oyster larvæ in Milford Harbor, Conn. By Herbert F. Prytherch. Bulletin, Vol. XLIV, 1928. Royal 8°, 77 pp., 32 illus. Document No. 1054.

Check list of the fishes and fishlike vertebrates of North and Middle America north of northern boundary of Venezuela and Columbia. By David Starr Jordan, Barton Warren Evermann, and Howard Walton Clark. Report of Commissioner for 1928. Part II, 674 pp., 8°. Document No. 1055.

Salmon tagging experiments in Alaska 1927 and 1928. By Willis H. Rich and Frederick G. Morton. Bulletin, Vol. XLV, 1929. Royal 8°, 25 pp., 2 illus. Document No. 1057.

Review of weakfishes (*Cynoscion*) of Atlantic and Gulf coasts of United States, with description of a new species. By Isaac Ginsburg. Bulletin, Vol. XLV, 1929. Royal 8°, 17 pp., 7 illus. Document No. 1058.

Review of experiments on artificial culture of diamond-back terrapin. By Samuel F. Hildebrand. Bulletin, Vol. XLV, 1929. Royal 8°, 48 pp., 14 illus. Document No. 1060.

Care and diseases of trout. By H. S. Davis. Appendix 4, Report of Commissioner for 1929. 8°, 55 pp., 6 illus. Document No. 1061.

Keokuk Dam and fisheries of upper Mississippi River. By Robert E. Coker. Bulletin, Vol. XLV, 1929. Royal 8°, 55 pp., 10 illus. Document No. 1063.

Oyster industry of Pacific coast of United States. By Paul S. Galtsoff. Appendix 8, Report of Commissioner for 1929. 8°, 36 pp., 13 illus. Document No. 1066.

Condition of razor-clam fishery of Washington. By H. C. McMillin. 8°, 7 pp., 2 illus. Economic Circular No. 64.

Oyster bottoms of North Carolina (with bibliography). By Paul S. Galtsoff and H. R. Seiwell. 8°, 11 pp. Economic Circular No. 66.

In addition to these, the following papers were published in other than the bureau's series:

Influence of certain water conditions, especially dissolved gases, on trout. By J. S. Gutsell. Ecology, Vol. X, No. 1, January, 1929, pp. 77–96.

Notes on northwest Atlantic sharks and skates, by Henry B. Bigelow and William C. Schroeder. Bulletin, Museum of Comparative Zoology, Vol. LXVIII, No. 5, September, 1928, pp. 239–251, Cambridge.

A rare bramid fish (*Taractes princeps* Johnson) in the northwestern Atlantic. By Henry B. Bigelow and William C. Schroeder. Bulletin, Museum of Comparative Zoology, Vol. LXIX, No. 2, February 1929, pp. 41–50, Cambridge.

A preliminary report on the growth of the rock bass, *Ambloplites rupestris* (Rafinesque), in two lakes of northern Wisconsin. By Stillman Wright. Transactions, Wisconsin Academy of Sciences, Arts, and Letters, Vol. XXIV, November, 1929, pp. 581–595.

As in previous years, the division has again been fortunate in receiving whole-hearted and generous cooperation from various States and private agencies, thus materially increasing its investigations in both extent and effectiveness. Such cooperation, which is gratefully acknowledged, is in most cases mentioned in connection with the various investigations in the following pages. The following progress reports covering the more important investigations conducted by the division during the calendar year 1929 were prepared in the main by the investigators in charge of the various projects.

NORTH AND MIDDLE ATLANTIC FISHERY INVESTIGATIONS

Some of the country's most productive fisheries are prosecuted in the waters along the Atlantic seaboard from Maine to the Virginia capes. Exclusive of shellfish, the annual harvest gives a gross return of nearly $24,000,000 to the commercial fishermen.

Initial steps in studies of marine fisheries are to learn the life histories of the fishes themselves, their movements, the specific peculiarities in birth rate and mortality that regulate their abundance, but investigations soon reach the point where further understanding requires intimate knowledge of the significant physical and biological conditions in the sea.

OCEANOGRAPHIC STUDIES

A consolidation of the several investigating staffs in this area has made it possible to initiate in a small way an oceanographic program in accompaniment with the various fishery investigations. The cooperation of the Museum of Comparative Zoology at Harvard University in providing laboratory and library facilities for the major portion of the staff engaged in these studies has been of prime importance in making this arrangement feasible, and the advice of Dr. Henry B. Bigelow, of the museum staff at the Museum of Comparative Zoology, has been largely responsible for the planning of the oceanographic projects.

The bulk of oceanographic observations were made during five cruises of the *Albatross II* in connection with the mackerel investigations, the principal object being to estimate the success of mackerel spawning. Two other cruises were made in connection with the cod investigations. The principal object of the trip in February and March, was to determine conditions in the wintering grounds of the codfish off New York and New Jersey. A few observations also resulted from a cod-tagging trip to Nantucket Shoals in June. (See Table 1.) As a result, we have temperature and salinity surveys of the waters overlying the continental shelf between Cape Cod and North Carolina for February, April, and July; zooplankton surveys of surface and deep levels for April, May-June, and July; and surface phytoplankton surveys for the same months. In addition, there are two series of collections for the study of diurnal vertical migrations of zooplankton.

The fish eggs and larvæ of these cruises have been partially examined, and the zooplankton of all but the last cruise has been

analyzed in a preliminary way. On January 1, the data on physical oceanography still awaited analysis.

On the February cruise a series of 370 drift bottles were released on lines bearing 163° 30′ true from Montauk Point and 130° 30′ true from New York. The same sets were repeated on the July cruise. Returns from these series have been disappointingly few. Several were picked up on the beaches along the North Carolina coast and a few were returned from southern New England points. Not enough are available to warrant conclusions as to currents in the region.

TABLE 1.—*Summary of oceanographical work done in conjunction with cod and mackerel investigations, 1929*

Dat	Station numbers [1]	General locality	Number of stations occupied	Temperature and salinity observations		Collections made				
				Serials surface to bottom	Surface only	Zooplankton, surface	Phytoplankton, surface	Zooplankton, intermediate levels	Zooplankton, deep levels	Other
Feb. 24 to Mar. 5.	20384–20420	Cape Ann, Mass., to Cape Henry, Va., and out to the continental slope.	37	37	----	9	8	----	8	Young fish trawl 3 hauls.
Apr. 14 to May 18.	20421–20456	Montauk Point, Long Island, N. Y., to Bodie Island Light, N. C., and out to continental slope.	36	35	1	33	33	5	33	
May 10 to 18..	20457–20498	No Mans Land, Mass., to Bodie Island Light, N. C., and out to the continental slope.	42	1	41	41	40	----	33	Vertical distribution series at 1 station,[2] 5 volumetric surface hauls.[3]
May 28 to June 5.	20499–20542	Cape Cod Bay, Mass., to Cape Henry, Va., and out to the continental slope.	44	----	44	21	44	12	42	29 volumetric surface hauls.[3]
June 12 and 13.	20543–20547	Nantucket Shoals	5	[4] 1	----	----	----	----	----	4 hauls, young fish trawl.
July 11.....	20548–20551	Cape Cod Bay and offing of Cape Cod.	4	4	----	4	4	----	4	
July 13 to Aug. 1.	20552–20959	Cape Cod Bay to Cape Henry, Va., and out to the continental slope.	47	47	----	30	45	3	46	Vertical distribution series at 1 station; [2] 30 volumetric surface hauls.[3]

[1] Albatross series.
[2] Station was occupied 24 hours, and 4 series of horizontal zooplankton tows were taken at 5 levels.
[3] Experimental horizontal zooplankton hauls with current meter registering amount of water passing through mouth of net.
[4] Temperatures only.

COD, HADDOCK, AND POLLOCK

The study of the life history of the cod, which has been in progress since 1923, was continued during 1929 by William C. Schroeder.

The field work during the past year included:

(*a*) The tagging of cod off the coast of southern New Jersey from time to time within the period from January 1 to April 8.

(*b*) A hydrographic cruise made by the *Albatross II* from southern Massachusetts to Cape Charles, Va., February 24 to March 7.

On this trip water samples and temperatures were obtained at all 37 stations that were made; plankton hauls were made at 8 and an otter trawl was used at 3 stations. Drift bottles were set out along 2 lines totaling 180 miles, one of which was off Montauk Point and the other off New York City.

(*c*) A cod-tagging cruise made June 9 to 15, by the *Albatross II*, to Nantucket Shoals.

FIGURE 1.—Oceanographic work aboard the U. S. F. S. *Albatross II*. One of a series of Greene-Bigelow water bottles with a sample of sea water from a known depth is being brought aboard.

(*d*) A cruise made from September 17 to 28 on a commercial otter trawler to the northeast part of Georges Bank, where specimens and data were collected on the cod, haddock, and other fishes.

TABLE 2.—*A summary of the number of fish tagged from 1923 to 1929*

BY SPECIES

	1923–1928	1929	Total
Cod tagged	39,496	1,169	40,665
Pollock tagged	4,799	13	4,812
Haddock tagged	10,620	134	10,754
Total	54,915	1,316	56,231

BY LOCALITIES

Browns Bank and vicinity	2,113		2,113
Georges Bank	2,002		2,002
New Hampshire and Maine	19,581		19,581
Massachusetts, north of Cape Cod	645		645
Massachusetts, south of Cape Cod	29,857	848	30,705
New York and New Jersey	717	468	1,185
Total	54,915	1,316	56,231

TABLE 3.—*A summary of the number of cod, pollock, and haddock tagged and recaptured during the years 1923–1929, inclusive*

	Tagged	Recaptured	Per cent
Cod	40,665	2,667	6.6
Pollock	4,812	101	2.1
Haddock	10,754	189	1.8
Total	56,231	2,957	

Data on the haddock and pollock were collected incidental to the cod-tagging operations. So few of the tagged haddock and pollock have been recaptured that very little can be said specifically concerning their migrations. In general it appears that some adult

FIGURE 2.—Tagging a codfish to study its migrations

haddock and pollock may remain for a year or more in one immediate locality, but both species seem more irregular in their movements than the cod. Apparently a fair proportion of the haddock along the coast of Maine immigrate to the region southeast of Cape Cod (South Channel). Neither the haddock nor the pollock migrate westward from Nantucket Shoals in the fall in such bodies as do the cod, for only an occasional one of either species reaches New Jersey.

MACKEREL

The year 1929 was of unusual interest in the mackerel investigations. For the past four years the mackerel population had consisted almost entirely of the brood hatched in 1923, and since their peak year in 1926 they had been providing definitely declining catches. The paramount question was whether a new brood would materialize

to augment the mackerel stock before the 1923 brood was so severely reduced that years of scarcity would ensue. Our 1928 data indicated the survival of a moderate number of mackerel of the 1927 brood but not enough to give assurance of offsetting the decline in the much older 1923 brood.

As was expected, the 1929 season witnessed a continued decline in the abundance of mackerel of the 1923 brood. From a catch of about 24,000,000[2] fish in 1926, these declined to a catch of about 12,000,000 fish in 1929.

The 1927 brood contributed only 2,000,000 fish. Had the year's production depended on these two broods, the fishery would have suffered a severe decline. But this was prevented by the appearance of an extraordinarily large brood resulting from the 1928 spawning season. So plentiful were mackerel of this brood that even though undesirable commercially because of their small size (about ¾-pound each), they nevertheless made up the bulk of catches during the summer and early fall. Their yield totalled more than 21,000,000 mackerel—enough fish to raise the total catch to 44,000,000 pounds, which was just under that of the peak year, 1926, and constituted a 40 per cent increase over 1928.

The advent of this apparently enormous brood will undoubtedly have profound effects on the abundance of fish, lasting through the next several years. It is the first brood that this investigation has witnessed from its beginning, and the observation of its changes in abundance is almost certain to constitute a distinct contribution to our understanding of the changes in abundance in this fishery. As early as 1928, tentative predictions on the abundance of mackerel were made in advance of the season. The forecasts thus far have proved essentially correct. But the limitations of our knowledge have confined these attempts to general terms and provisional qualifications.

The attainment of the above-indicated understanding of mackerel fluctuations has resulted from the continuation of the biostatistical study of the fishery carried on jointly by the division of fishery industries and scientific inquiry since 1925. The 1929 work continued under the direction of Oscar E. Sette, assisted by Edward W. Bailey. Most of the observations of mackerel at landing ports were made by Frank E. Firth. Robert A. Goffin collected valuable information on the fishery in the vicinity of Woods Hole and, during a short period early in the season, on the landings of the deep-sea fleet at Cape May, N. J. Field assistants, engaged primarily in the collection of data on the pound-net fishery of the middle Atlantic region, also collected considerable data on the lengths of mackerel taken on their stations. Altogether, information was secured as to date, locality, quantity, and other items on 1,430 out of a total of 2,876 fares landed by the offshore fleet. Samples from 971 fares were measured. These, together with 2,734 mackerel measured by pound-net observers, make a total of over 37,000 length measurements for the season. Scale samples were taken from 615 mackerel.

[2] The numbers of fish were calculated from: (1) The weight of the catch, which is a matter of statistical record; (2) the length composition of the catch, which resulted from our market measurements; and (3) the relation of weight to length, which was computed from weight length data on more than 2,000 mackerel

An important new series of observations was initiated in 1929 when blank books were furnished the captains of mackerel vessels in which to record their daily fishing activities and observations on the mackerel at sea. Of the 68 distributed we have already received 18 complete daily records and 22 extending over part of the season. The splendid cooperation of the vessel captains in keeping these detailed records under the rigorous conditions at sea has the bureau's fullest appreciation. These logs have been and will continue to be exceedingly useful in supplementing our data on the occurrence of schools of mackerel observed but not caught, the presence of young mackerel below commercial sizes, and the shifting of schools from one ground to another. In addition they will be of particular value in estimating fishing intensity, for from them we may secure much needed information on periods of enforced idleness due to stormy weather and other modifications of the activities of the fleet.

The investigation also included the collection and analysis of statistics with regard to the total mackerel catch and the size of the mackerel fleet, together with other data pertinent to an estimate of the intensity of fishing. These are to be treated more fully in the report of the division of fishery industries.

One of the most obvious problems arising from the phenomenon of age dominance which has been observed in the mackerel fishery is to determine the probable causes for success in some years and failure in many others. To provide information on this phase of the problem, oceanographic cruises to the mackerel spawning grounds were made during the 1929 season. Four trips were made from April to July in the waters of the continental shelf between Cape Cod and North Carolina, and additional stations were occupied at a limited number of locations in the offing of Cape Cod and Massachusetts Bay. Altogether, 288 stations were occupied during the season.

The primary object was to determine the abundance of mackerel eggs spawned in various areas and the relative success of the hatching and survival of larvæ. In addition to the townet collections made for this purpose, the usual series of temperatures and salinities at various levels were taken at most of the stations on the April and July cruises.

Judging from the examination of only part of the material collected on these cruises, mackerel eggs were approximately as abundant in 1929 as in the two previous years—the only years of which we have any record. An abundance of newly hatched larvæ in the hauls of the early June trip indicates a fairly successful hatch; but the scarcity of larger larvæ in July would make it appear that the 1929 brood was rather less successful in surviving through its early stages than was the 1928 brood, of which some very good catches of large larvæ were taken at certain stations off southern New England in July of 1928.

NEW ENGLAND SMELT

One section of the second report concerning the smelt, by Dr. William C. Kendall, was completed early in the year. This section comprises a synopsis of the classification of the smelts as presented in the literature and a discussion of the relationship of the nominal species so far as indicated by available data. A second section of

same report comprises a consideration of the salt water and fresh water smelts of the east coast of North America. This was begun long before the section just referred to was found necessary for a proper consideration of the smelts of this region. The latter study and the facts revealed by more recently acquired information, necessitated a revision of the entire manuscript. This has been done, but while the problems concerning these smelts can not be regarded as wholly solved, it is believed that the situation is made clearer by the manner of treatment. However, the highly interesting and very important question of the relationship of the "large" and "small" forms of smelts of some lakes has been complicated by the receipt from John W. Titcomb, superintendent of the board of fisheries and game of Connecticut, of two similar size classes of marine smelts from Connecticut taken during the breeding runs. The larger form appears to be of about the same sizes as observed in Maine, but those of the smaller class are smaller than any adult marine smelt that have come under observation.

This year the two brooks near Freeport, Me., which have been under observation by Doctor Kendall during the breeding season of smelts since 1924, were watched as in previous years, but not quite as constantly. Quite surely, however, not many smelts were caught during the season, as judged by report and observation. From April 4 to May 4, both inclusive, 109 fish constitute the positive records. No fish were observed after May 4. The fact that the weather was generally bad may have affected the runs, but usually in the past not even a snowstorm would prevent a run. It would appear on the whole that the prediction that the runs would be poor this year was fulfilled. This prediction was based on the facts that the runs of breeding smelts to a great extent are composed of 2-year old fish, as a rule, and that scarcely any smelts appeared in the brooks in 1927. Furthermore, the majority of the fish examined this spring were more than 2 years old.

There is evidently a pronounced decline of the smelt fishery, particularly manifested in the Casco Bay region, as evinced by reports from commercial fishermen, landings in the wholesale market of Portland, and observations in the breeding season of smelts.

There are several factors which contribute to this decline, two of which are particularly effective—one is the destruction of smelts while ascending brooks to spawn and the other is the tremendous destruction of immature smelts by seining operations during the open season.

SHORE FISHERY OF THE MIDDLE ATLANTIC STATES

An investigation of the more important species, including squeteague, bluefish, sea bass, scup, butterfish, summer flounders, whiting, and croakers, has been conducted since July, 1927, under the direction of R. A. Nesbit.

The most serious handicap to acquiring a knowledge of the status of this fishery is the lack of adequate statistical records. In 1928 the bureau provided pound-net fishermen with forms for keeping detailed daily records of their catches. These were continued in 1929, and the number of fishermen voluntarily cooperating increased to a gratifying extent.

In order to follow quantitative and qualitative fluctuations in the yield, the sampling of commercial catches begun in 1928 was continued and extended in 1929. More than 100,000 fish of several species were measured and over 6,000 scale samples taken at 8 field bases located at Montauk and Fire Island, N. Y.; Long Branch, Seaside Park, Beach Haven, and Wildwood, N. J.; Hampton and Exmore, Va.

Excellent progress was made in the analysis of biological data concerning squeteague and scup. With regard to the squeteague, it is probable that the general increase in the 1929 catch over 1928 is due to the entrance of large numbers of the 1926 brood. This dominance may be expected to make itself felt for several years.

In order to trace migrations 1,800 squeteague were tagged at Wildwood, N. J., during June, 1929. A few local recaptures were made, all within a few weeks of tagging. Little hope is entertained that additional recaptures will be reported.

Data on the scup also indicate the effects of dominance. The 1927 brood, although too small to figure in the commercial catch of 1928, was observed in unusually large numbers in the pound nets, and reappeared as expected in 1929, increasing the average catch per trap nearly fivefold over the 1928 average.

This result is the more remarkable because the abundant 1927 brood was spawned in a season of abnormally low yield—that is, relatively very few adults—indicating not only an unusual resistance to fishery strain but also that the number of survivors is to a large extent independent of the number of spawning adults.

In order to supplement the general oceanographic program discussed above, two surveys of inshore waters were carried out in 1929. A survey of Delaware Bay, under the direction of Prof. A. E. Parr, was undertaken in cooperation with the Bingham Oceanographic Collection. From the middle of May to the end of September, three cruises were made each week, with additional cruises at longer intervals during October. Several stations were occupied on each cruise, and at each station in addition to plankton or juvenile fish collections, temperature, salinity, and hydrogen-ion concentration were noted. A series of drift bottles was released in order to determine the effect of currents on migrations of fish eggs and larvæ. At the beginning of the season most of the collections were made with townets. Later, Peterson trawls were used for the capture of juvenile fishes. Spawning grounds of several of the species frequenting this region were located, and dates of maximum spawning effort observed.

The large collection of juvenile fishes have contributed much of value to our knowledge of the rates of growth of squeteague, scup, and sea bass during their first year of life. This provides a sound foundation for determination of the age of older fish.

A similar survey was carried out in Chesapeake Bay by J. C. Pearson. His collection, derived from about 300 townet hauls, includes larval and postlarval stages of 43 species as well as eggs and juveniles.

Data collected in these surveys are being analyzed in the Peabody Museum, Yale University. The kindness of the museum in providing laboratory and library facilities is gratefully acknowledged.

INDEPENDENT ACTIVITIES AT THE FISHERIES BIOLOGICAL LABORATORY, WOODS HOLE, MASS.

In accordance with the bureau's long established policy of encouraging independent research in marine biology and related subjects, the facilities of the laboratories at Woods Hole, Mass., were made available to a number of investigators from various educational institutions. Personnel so accommodated at Woods Hole included: Dr. Edwin Linton, University of Pennsylvania, studying helminth parasites of fishes; Dr. C. J. Connolly, Catholic University, color reactions of crabs; Albert J. Dalton, College of the City of New York, embryonic development of fishes; Paul S. Conger, United States National Muesum, marine diatoms; R. E. Bowen, Harvard University, the eighth nerve of fishes; Kendall W. Foster, Harvard University, coloration in fundulus; Dr. John C. Hemmeter, Johns Hopkins University, isles of Langerhans in Lophius; M. E. Holcomb, Princeton University, luminous marine bacteria; Dr. N. A. Cobb, Department of Agriculture, nematodes; Leon C. Chesley, Duke University, enzymes in fishes; W. E. Bullinton, of Randolph Macon College, spiraling in the ciliate Frontonia; Dr. F. G. Hall, Duke University, physiology of fishes; and Dr. I. E. Gray, Tulane University, physiology of fishes.

MacMILLAN LABRADOR AND BAFFIN LAND EXPEDITION

At the request of Commander Donald B. MacMillan, Doctor Kendall was detailed to accompany the expedition to Baffin Land for the purpose of studying the geographical distribution of the fishes, particularly salmon and trout (chars). A preliminary report appears in Fisheries Service Bulletin, No. 174, November 1, 1929.

Not much was added to what was already known concerning the distribution of the salmon. There is no special salmon fishery of much importance north of latitude 55°. Those caught farther north appear to be incidental to the trap fishery for cod. According to report occasionally a few salmon are caught as far north as Ryans Bay.

Northern chars, called "sea trout" are abundant all along the Labrador coast and were found in two places in Frobisher Bay, Baffin Land.

The brook trout (*Salvelinus fontinalis*) also occurs as "sea trout" in southern Labrador and probably as far north as the species occurs in coastal fresh waters. The most northern point of occurrence of this trout was in the tidal portion of a stream flowing into Nain Bay. Young fish of both species were found at low tide between tide limits at several places in Labrador. Some brooks would contain only one or the other of the two forms. A small lake or pond at Nain, so far as could be ascertained, contained only young or dwarfs of the sea trout type. The males were highly colored like adults. The outlet of the pond contained only the *fontinalis* form, some of which were 8 or 9 inches long. It is difficult to conceive how these particular waters were populated, for the foot of the outlet is obstructed by a waterfall so formidable that it seems hardly possible that trout could surmount it and there is no inlet, though possibly in some seasons there may be another outlet from the head of the pond which

would admit fish from another stream which flows into the harbor at Nain.

The most abundant of shore fishes in Labrador were the rock cod (*Gadus ogak*) and sculpins (*Ancanthocottus grœnlandicus*).

The rock cod is of inferior quality, quickly softening after death, and then difficult to clean. However, when freshly caught and soon cooked it is by no means unpalatable.

The common cod is abundant in deeper water.

The "fresh water cod" of Labrador was authoritatively found to be the lake trout (*Cristivomer namaycush*). Alfred C. Weed of the Field Museum, who accompanied a previous MacMillan expedition to Frobisher Bay, Baffin Land, and caught the alleged fresh-water cod in a lake there, recently advised Doctor Kendall that in the stomachs of some of the fish he found numerous sea urchins. From this fact it may be inferred that the lake is fresh only at the surface.

Besides the fishes brought back by the expedition, the collections comprise a number of marine invertebrates.

SOUTH ATLANTIC AND GULF FISHERY INVESTIGATIONS

SHORE FISHES OF NORTH CAROLINA

The collection of fish eggs and young fish, begun at Beaufort, N. C., a few years ago, was continued. During 1929 a special effort was made, by varying the methods of collecting and by sampling many localities, to complete series indicative of the various stages in the growth of as many species as possible.

To date 24 local species of fishes that have been definitely identified are represented more or less completely in the collections by series showing the various stages in development. Drawings illustrating the development have been made for all these species, and descriptions have been prepared for several. It may be stated here that the series often are not as complete as desirable and that it takes much time and perseverance to complete them. Furthermore, an effort has been made to determine the rate of growth during the first year of all the food fishes taken during the course of making collections of young fish. This work is in charge of Dr. Samuel F. Hildebrand, director of the Bureau of Fisheries laboratory at Beaufort, N. C., who is assisted by Dr. James S. Gutsell (part time) and Louella E. Cable.

TERRAPIN CULTURE

The cooperative terrapin cultural work of the North Carolina Department of Conservation and the Bureau of Fisheries begun in 1924, has been continued at the Beaufort station. On May 17, 1929, the brood of 1928, numbering 5,778 animals which had been kept in the nursery house during the winter, was turned over to the North Carolina State Fish Commission for liberation. The average length of all the animals liberated was close to 1⅓ inches. Many were 1¾ inches long, quite a few were as much as 2 inches in length, and a few 2¼ inches. However, the average length was greatly reduced by those animals that did not grow at all, of which a considerable

number has been present each year since the beginning of the experiments with winter feeding.

In the fall of 1929 the new brood, amounting to 7,770 individuals, was placed in the nursery house to be fed during the winter. Several different kinds and combinations of food are employed in the feeding experiments. Last winter (1928–29) good results, from the standpoint of growth, were obtained by feeding oysters and also with a mixture of fresh fish and corn meal; shrimp bran alone was found unsatisfactory, but in combination with fresh fish it seemed to hold some promise. Most of the feeding experiments of last winter are being continued and several others have been undertaken for this winter (1929–30).

Unfortunately, during a hurricane which visited Beaufort and vicinity on October 2, 1929, the high water and strong wind combined broke the walls of two of the pounds containing slightly in excess of 1,700 adult breeding terrapins. The animals quickly made their escape, but subsequently about 150 were recovered.

A review of the experiments conducted since the beginning of the work in 1909 at the fisheries station at Beaufort, N. C., with the artificial cultural of diamond-back terrapins was prepared by Dr. Samuel F. Hildebrand, who is in charge of the terrapin cultural work of the bureau. (Doc. No. 1060.)

BAY SCALLOP

Study of the bay scallop was continued at the request of the North Carolina Department of Conservation and Development. In January J. S. Gutsell investigated a report of scallop mortality attributed to microscopic worm parasites but apparently attributable to the delayed lethal effect of water freshening.

In November, Doctor Gutsell made an investigation of the productive condition of scalloping areas. In general, adult scallops proved to be scarce. In western Bogue Sound they were more numerous than elsewhere.

ACTIVITIES OF THE FISHERIES BIOLOGICAL LABORATORY, BEAUFORT, N. C.

The work of the Beaufort (N. C.) station has been mentioned in the section of this report dealing with the investigations on young fishes, oysters, scallops, and diamond-back terrapins. Extensive repairs to the main laboratory building, begun in 1928, were continued and completed, and a residence was built. New electric wiring and fixtures were installed in all the buildings. Much of the plumbing was renewed and the system was greatly extended, including the installation of a pressure system and wash basins and water pipes in all the dormitory rooms. A small power boat was added to the floating equipment. These additions, improvements, and repairs greatly increase the usefulness and convenience of the station.

Elmer Higgins, chief of the division of inquiry, spent the summer at the station continuing the study of the life history of the mullet, begun several years ago but interrupted by other duties. Dr. Henry Federighi spent the year prior to his resignation in September at the station studying the life history of the oyster drill, and Dr. R. H. Luce worked on oyster culture during June, July, and August.

FIGURE 3.—Fisheries Biological Laboratory at Beaufort, N. C.

Independent investigators who studied at the Beaufort Biological Laboratory included the following: Dr. Bartgis McGlone, University of Pennsylvania, studies on body temperatures; Dr. W. C. George, University of North Carolina, blood of Balanoglossus; Dr. J. I. Hamaker, Randolph Macon College, distribution of calcareous sands; A. S. Rose, University of North Carolina, experiments in self-regulation of ascidians; Miss Ezda Deviney, Florida State College for Women, regeneration in ascidians; M. C. Yoder, Lenoir Rhyne College, echinoderms; E. E. Brown, public schools, Greensboro, N. C., midsummer birds; and Dr. Hoyt S. Hopkins, New York University Dental College, muscles in bivalves.

GULF COAST STUDIES

The study of the collections of fishes made at various times by different investigators on the coast of Texas was continued by Isaac Ginsburg and extended to include other places on the Gulf coast. Special attention was given to the commercially important family of Sciænidæ, with particular attention to racial studies of the common species of that family. A comparison was made of the Gulf and Atlantic populations of these species.

For some time there has been felt a need for a manual of the marine fishes of the Gulf coast, that will give descriptions of the species to facilitate their identification and such pertinent facts in their life history, habits, and economics as are known at present. A beginning was made to produce such a manual, and it is hoped to devote such time to it as may be spared from other duties until it is completed.

GREAT LAKES FISHERY INVESTIGATIONS

In 1929 work on the Great Lakes, under the direction of Dr. John Van Oosten, was confined largely to Lake Erie as was true in 1927 and 1928, although the work on experimental herring pound nets begun in the fall of 1928 on Saginaw Bay in Lake Huron and referred to in the 1928 report was continued in the spring and fall of 1929, and some data on the biology of the pike perches of Lake Ontario and of the whitefish and lake trout of Lake Michigan were collected.

COMMERCIAL FISHERIES

Virtually all the data from Lake Erie, except those on age and growth, collected in 1927 and 1928 have been compiled though not analyzed in detail. Length frequencies of all the species taken in both the experimental nets (see reports for 1927 and 1928) and the commercial nets have been made, and tables on the relative destructiveness of various-sized meshes in trap nets and gill nets have been compiled. Some of these tables served as a basis for the new regulations passed in Ohio. Much time was also devoted to a revision of the commercial fishing laws in Michigan and Indiana, and recommendations were drawn up for Wisconsin, Minnesota, and New York. All the States except Minnesota have now introduced the recommended method of collecting statistics of the daily catch together with the amount of gear employed.

The 1929 field work was devoted almost entirely to the collecting of biological and statistical data on the various species of commercial importance at Erie, Pa.; Conneaut, Lorain, Vermilion, Huron, Sandusky, and Port Clinton, Ohio. In all, some 49,819 measurements were made and scales were collected from 27,097 specimens. These data were obtained by H. J. Deason, B. H. Hill, and Dr. Stillman Wright aided by four temporary assistants, the States of Ohio and of Pennsylvania each furnishing two men.

An analysis of the blue pike, yellow pike, and sauger material of 1928 indicates that in each species the 3-year fish predominated. The 2-year group predominated in the yellow-pike material of 1927, suggesting that in this species the 1926 year class was dominant in the population. In addition to a study of the life history of these pike perches, an attempt is being made to ascertain the systematic relationship between the blue pike, the yellow pike, and what appears to be an intermediate form sometimes designated as the gray pike. For this study adult pike perches of Lakes Ontario, Erie, and Huron are being examined in addition to a large series of larval and postlarval specimens kindly loaned to us by the State of Ohio.

Analysis of the scales of the ciscoes taken in gill nets in 1927 shows the catch to be comprised almost entirely of 2 and 3 year fish, while the whitefish samples of 1927 taken in gill nets and trap nets consisted principally of 4 and 6 year fish, the 5-year group being almost entirely absent.

The work in Lake Huron on the experimental herring pound nets, referred to in the 1928 report, will not be completed until the spring of 1930 but the data collected so far show the following:

1. In the fall of 1928 no herring escaped through the larger meshes of the net for each size group was represented in approximately the same proportion in the catch of the various nets. (2 inches, 2¼ inches, and 2¾ inches.)

2. In the spring of 1929, however, some sorting seems to have taken place for the percentage of small herring in the lifts decreased progressively with each successive increase in the size of the mesh employed. (2 inches, 2½ inches, 2¾ inches, and 3 inches.)

3. The number of herring that gilled before the fish were cornered increased progressively with each increase in the size of the mesh employed.

4. Virtually no immature whitefish or yellow pickerel were gilled in the experimental nets.

The interesting inconsistency in the apparent reaction of the herring to the different-sized meshes in the fall of 1928 and in the spring of 1929 may possibly be explained on the basis that there were more small herring on the grounds in the spring of 1929 than in the fall of 1928 and, hence, the effectiveness of the nets in sorting would appear to be greatest in 1929, or that since the data were secured during the spawning season, the herring of 1928 were less aware of their surroundings because of sexual excitation and exerted less effort in escaping from the traps than those of 1929.

In addition to the work on experimental pound nets, biological data, such as length and weight measurements, sex, maturity, and scales, were collected for the important species of Saginaw Bay, especially the yellow pike, lake herring, and whitefish. Some 20,018 fish were measured and 5,176 scales were collected.

LIMNOLOGICAL STUDIES

In the years 1927 and 1928 the State of Ohio Division of Fish and Game carried on a limnological investigation of the western end of Lake Erie in connection with studies on the distribution of larval and postlarval fish. It was arranged with the Ohio organization to have Dr. Stillman Wright take charge of the limnological work for the year 1929. A laboratory was established at Put in Bay, Ohio, early in May, with two scientists in residence. During the period from June 15 to September 15, the full staff of six investigators was present, and the survey was continued until November 1 with a reduced staff.

The area covered is that west of a line drawn from Point Pelee to Cedar Point. The entire area is shallow and receives the waters from three large rivers which carry the industrial wastes from the cities of Toledo, Monroe, and Detroit. The purpose of the investigation was to make a general survey of the physical, chemical, and biological conditions with particular reference to pollution and its effect on the fish population. Chemical studies included analysis for dissolved oxygen, free and fixed carbon dioxide, and hydrogen-ion concentration. Qualitative and quantitative studies of both phytoplankton and zooplankton were made to determine the vertical, horizontal, and seasonal distribution of the various planktonts. Observations were also made of the distribution of pathogenic and natural lake bacteria and of bottom organisms. A party working independently studied the distribution of larval and postlarval fish in the same area. The data are being prepared for publication.

COOPERATIVE SURVEY OF LAKE ERIE

The cooperative survey of Lake Erie, begun in 1928, was continued in the season of 1929. To the original institutions cooperating with the Bureau of Fisheries, which included the New York State Conservation Department, Ontario Department of Game and Fisheries, Health Department of the city of Buffalo, and the Buffalo Society of Natural Sciences, was added this year the Ohio Department of Fish and Game and the United States Coast and Geodetic Survey. From these institutions a staff of 10 investigators was recruited, many of whom spent much of the time actually in the field aboard the United States Fisheries steamer *Shearwater*, which was assigned to the undertaking.

During the winter period, extensive improvements and alterations were made aboard the *Shearwater*, including the installation of a laboratory aboard, living quarters for five investigators, and various mechanical improvements.

The area of the survey was extended to cover the entire lake, with the exception of a portion of the western end, which was subjected to intensive investigation by the cooperative investigators of the State of Ohio and the Bureau of Fisheries, as previously mentioned. Actual field studies were pursued from May 15 to September 20 and consisted of four extended cruises from Buffalo to Put in Bay, requiring usually about 15 days, and numerous shorter cruises in other sections of the lake for intensive investigations of the hydrography

and related physical problems. In all, 50 fixed stations were occupied on the longer cruises, providing records on about 270 series of observations distributed through 4,435 statute miles traversed by the vessel.

Routine physical observations were carried out, such as sounding for depth and for bottom samples, vertical and horizontal distribution of temperature, rate and direction of the movements of water, and determination of transparency. Chemical observations included the determination of dissolved oxygen, carbon dioxide, total alkalinity, and hydrogen-ion concentration, as well as occasional quantitative determinations of other elements and compounds. Biological observations included exact quantitative and qualitative determination of nanno-plankton and of the net plankton, and rough quantitative and qualitative determinations of net plankton, both vertically and horizontally, and similar determinations for macro-plankton, including young fish. Additional collections were made with seines

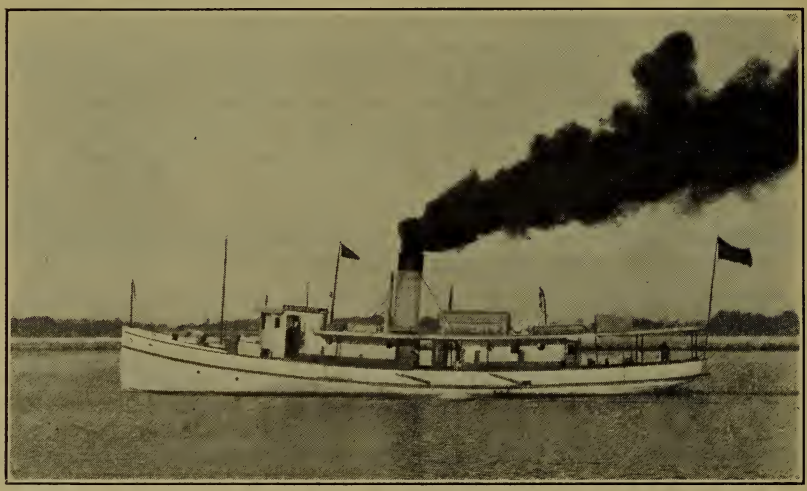

FIGURE 4.—U. S. F. S. *Shearwater* engaged in the cooperative survey of Lake Erie

and trawls to determine the distribution and relative abundance of young fish too large to be taken in plankton nets.

The results of the survey having immediate practical value may be summarized as follows: Physical observations established the fact that in addition to the cold-water mass previously discovered in the deeper eastern portion of the lake, a thermocline exists in the shallow western portion, during a part of the year, covering the greater part of the bottom of the lake with cold water. This thin layer of cold water in the western part is broken up, however, by late summer storms, and the deeper cold-water area varies materially throughout the season in both extent and position. The movements of the bottom cold-water mass are apparently governed by meteorological conditions, especially wind movements, and these in turn produce rhythmic oscillations of the surface waters as well as major displacements. Despite these considerable water movements, no currents were discovered that were strong enough to account for the destruction of nets.

Chemical observations show that pollution is not at present a serious menace to the fishery, being limited to the vicinity of the few large cities. Biological observations confirm the findings of the previous year's work and indicate that the natural production of small organisms, both plant and animal, upon which the fish life depends is adequate to support a much greater adult fish population than at present exists in the lake.

Although there is a considerable amount of valuable information on the adult fish of Lake Erie, little attention had been given previously to the survey begun in 1928 to the larval and early stages of development of the various fishes. The newly hatched fish seldom resembles its parent in external appearance, so that careful study was necessary to identify and describe the considerable number of species taken in the juvenile and larval stages. At the close of the summer's work, 14 species were described and figured, making it possible to follow the life histories of the more important forms with relative completeness.

When the technical data collected in the course of this survey are fully analyzed and the combined reports published, a sound foundation will be afforded for more exact studies of the commercial fishery and for an understanding of the movements and habits of the various food fishes now believed to be suffering from overfishing.

STUDIES IN WISCONSIN LAKES

GROWTH OF FISHES

The investigation of growth rates of fishes in lakes of northern Wisconsin, carried on by the bureau in 1927 and 1928, has been discontinued; and the Wisconsin Geological and Natural History Survey has taken over the problem. No fish were collected in 1929, but the scales taken in the previous years are being studied in the laboratory of the survey at the University of Wisconsin.

The results of the investigation of the rock bass have been reported in a recently published report. The paper may be summarized as follows: The growth curve of the rock bass, as indicated by a study of scales of fish from Trout and Muskellunge Lakes, Vilas County, Wis., typically has the double sigmoid form. The rate of growth in the second period of rapid growth is greater than that in the first. The first period occurs in the first year and the second in the fifth year. More individuals grow most rapidly in the fifth year than in any other; the second largest number grow most rapidly in the sixth year, and the third largest number in the fourth year. The rock bass of collections from Muskellunge Lake made in 1927 and 1928 grew at approximately the same rate. These collections were made in the same general locality and are regarded as representing a single population. Rock bass taken from Trout Lake in 1927 showed a much more rapid rate of growth than those taken in 1928. The two collections were made in different localities and are regarded as representing two distinct populations, each with a characteristic rate of growth. In comparing the two lakes for these years, it was found that in 1927 the rock bass of Trout Lake showed a more rapid growth rate; while in 1928 the condition was reversed, with those in Muskellunge Lake showing the greater development.

LIMNOLOGICAL STUDIES

Limnological investigations on the lakes of northeastern Wisconsin were continued during the summer of 1929 in cooperation with the Wisconsin Geological and Natural History Survey. The Trout Lake laboratory of the survey was opened on June 21, and work was continued until September 10.

The field party consisted of E. A. Birge, Chancey Juday, W. L. Tressler, Mrs. W. L. Tressler, J. P. E. Morrison, Edward Schneberger, Hugo C. Baum, biologists; Frederick J. Stare and F. Lowell Taylor, chemists. In addition chemical analyses of residues obtained by evaporating 3 or 4 liters of water, were made by C. H. Winning, T. F. Setterquist, and P. C. Cross, the work being done in the chemical laboratory of the University of Wisconsin.

The field studies included such physical items as the temperature, the transparency, the color and the conductivity of the water, and the rate at which the sun's energy is absorbed by the water in the different types of lakes. The chemical items consisted of the determination of the hydrogen-ion concentration, dissolved oxygen, free and fixed carbon dioxide, nitrate nitrogen, phosphorus, silica, chlorine, and total residue. The biological phases of the work included quantitative studies of the net and centrifuge plankton and of the bottom fauna, and a general survey of the large aquatic plants; a special collection of the molluskan fauna of the district was made. Observations were made on 293 different lakes and lakelets during the summer of 1929; of this number 157 had not been visited hitherto and 136 had been visited in former years. Series of samples covering the entire depth of the lake were obtained from 36 of these bodies of water. Adding to these the series of samples taken in previous years, such observations have now been made on every lake in the northeastern district which has a known maximum depth of 20 meters or more; many series have also been taken in shallower lakes, such as those with maximum depths falling between 6 and 20 meters.

Up to the close of the 1929 season, 479 lakes and lakelets have been visited during the progress of this investigation. This number includes all of the larger and more important lakes of the northeastern district. Several hundred lakelets in this area have not been visited, and only a few of the numerous bog ponds and lakelets have been studied; the present plans do not include an extensive survey of these smaller bodies of water in the near future.

PACIFIC COAST AND ALASKA FISHERY INVESTIGATIONS

The passing of the White law in 1924 greatly strengthened the powers of the Department of Commerce, acting through the Bureau of Fisheries, in making adequate regulations for the care and perpetuation of the fishery resources of Alaska. Recognizing that the regulations, to be most effective, must be based on a scientific knowledge of the species exploited, the bureau has, from the first, devoted efforts toward the study of the more important problems. Many of the investigations have been concerned with purely local practical problems but others of broader and more general application have had an important place on the program. The practical value of the

results has been sufficient to warrant a gradual increase in the work done in this field.

New investigations begun during the past year have included a study of the homing instinct of pink salmon in southeastern Alaska, the investigation of the red salmon of the Copper River and the investigation of the red salmon of the Bristol Bay district. The work is under the direction of Dr. Willis H. Rich.

The staff engaged in these investigations has been brought together in quarters provided by Stanford University in the Natural History Museum. Ample laboratory space has been provided; and laboratory furniture, the ichthyological library, and a considerable amount of apparatus is made available by the university without cost to the Government. These arrangements have been made through the fine cooperation of the university authorities, especially Prof. J. O. Snyder.

ALASKA SALMON

Tagging experiments.—Continuing the series of salmon-tagging experiments that have been conducted in Alaska since 1922, approximately 4,000 salmon were tagged in central Alaska during the summer of 1929. Of this number 1,900 were tagged in Cook Inlet and about 2,100 in Prince William Sound. The work was done by Seton H. Thompson under the direction of Dr. W. H. Rich.

The Cook Inlet operations consisted of seven experiments in which four species of salmon were tagged. Approximately 41 per cent of the fish were sockeyes, 41 per cent pinks, 12 per cent chums, and 3 per cent cohos. The experiments were conducted at four different localities—Flat Island, Nubble Point, Cape Starichkof, and Nikishka Bay. Tagging was done during the early part of the season, and again during the latter part of the season when the run was at its maximum. About 600, or 31 per cent of these tagged fish, were recovered and reported.

The Prince William Sound tagging operations were conducted in nine experiments at five different localities during the early part, the height, and the latter part of the season. Of the number tagged, approximately 97 per cent were pinks, and the remainder were mostly chums. About 500, or 21 per cent, of the tagged fish were reported taken in different parts of Prince William Sound.

The results of these experiments are now being tabulated and studied, and it is expected that a report will be submitted for publication within a few months.

Statistics of the Alaska salmon fisheries.—The work of compiling and tabulating these data has been continued by Dr. W. H. Rich and E. M. Ball, assistant, Alaska service, and is now practically complete. Tables have been prepared showing the catch in each district from the beginning of the industry up to and including 1927, and the analysis of these tables is now under way. The preparation of a second number in the series of statistical reports dealing with the fisheries of central Alaska will be completed within a few months.

Karluk River investigations.—The intensive study of the red salmon runs of the Karluk River, Kodiak Island, Alaska, have been continued by W. H. Rich, A. C. Taft, and M. W. Brown. Another

experiment was begun, which involved the marking of 50,000 seaward migrants during June, 1929. The seaward migration this season appeared to be extraordinarily heavy. It was derived chiefly from the unusually large spawning escapement of 1926, when a total of approximately two and a half million adults passed through the counting weir. The returns from this experiment will therefore be awaited with great interest. The run of adult red salmon at Karluk in 1929 was exceedingly poor—a condition that had been anticipated and discussed in a report published in 1927.[3] As a result of this poor run, the commercial fishing operations at Karluk were so restricted during the past season that it was impossible to secure reliable data as to the number of marked fish in the run from previous marking experiments, nor was it possible to satisfactorily sample the run for a study of the age groups and other related problems.

A second report dealing with the red-salmon runs of the Karluk River has been nearly completed. It includes the presentation of all data accumulated since 1926, especially the results of the markings experiment begun in 1926.

Of the 46,700 fish marked in 1926, between 25 and 30 per cent returned as mature fish. This is a much higher return than was expected a priori and on the basis of the returns from similar marking experiments conducted at the hatcheries on the Columbia River.

In addition to estimating the survival, there was a second and corollary purpose in instituting these marking experiments. This was to determine the total number of seaward migrants and the age groups represented. The 46,700 migrants marked in 1926 made up an unknown proportion of the total number, but it was a proportion which could be expected to remain constant until the fish returned at maturity, provided that there was no differential mortality between marked and unmarked fish. In controlled experiments conducted on the Columbia River it has been shown that there is practically no increased loss following marking. Our computations show the total number of seaward migrants in 1926 to be approximately 7,500,000.

This is the first attempt to calculate the size of the seaward migration at Karluk by means of marking experiments combined with careful and extensive sampling of the runs for marked fish. The results are interesting and it is believed that they are fairly reliable, but it will necessarily be several years before we can have data that will enable us to determine the relative accuracy with which we can calculate the total number of migrants produced by a given spawning escapement.

In connection with the annual weir count of the spawning fish we have, then, the means of determining the following variables involved in the productivity of the stream: (1) The number of fish in the spawning escapement, (2) the number of migrants produced by each spawning escapement, and (3) the number of fish from each migration which survive to maturity. The value of such data accumulated over a series of years can scarcely be overestimated. It

[3] Investigations concerning the red-salmon runs to the Karluk River, Alaska. By Charles H. Gilbert and Willis H. Rich. Bulletin U. S. B. F. XLIII, 1927 (1928), Part II, pp. 1–69, Document No. 1021.

will be of the utmost value in the formulation of conservation measures which will both insure the maintenance of these great natural resources and, at the same time, allow the maximum catch for commercial purposes.

The study of conditions on the spawning grounds at Karluk Lake was continued by W. H. Rich and M. W. Brown. The lake was visited in July and again early in September. Physical conditions appeared to be satisfactory so far as temperatures and water supply were concerned, but, on account of the very poor escapement, the spawning grounds were seeded more sparsely than in any year since regular observations were started. A fairly good escapement was reported during September, however, and it may be that this will be sufficient to produce a moderate run in 1934—the year in which most of the

FIGURE 5.—A salmon counting weir in Alaska. Enumerators count each fish that passes through the opening shown in the foreground

progeny of the 1929 escapement will return as adults. Otherwise the prospects for 1934 are by no means bright. In addition to observations on the spawning grounds, plankton samples and temperature records were secured which have been submitted to Prof. Chancey Juday of the University of Wisconsin for study.

Chignik River investigations.—An intensive investigation, similar to the one at Karluk, is in progress at Chignik by H. B. Holmes. As at Karluk, this investigation has for its chief objective the determination of the relation between the number of fish in the spawning escapement and the resultant number of mature fish.

The irregularities in the life history of the fish that cause difficulty in scale interpretation are confined to the time the fingerlings spend in fresh water before migrating to the ocean. A study of this part of the life history was started in 1928.

Observations during the first season were confined mainly to the seaward migration of fingerlings. A more intensive study of the young fish was undertaken in 1929 by Mr. Holmes, assisted by a temporary assistant, and had for its purpose the tracing of the growth of the fish from the time they emerge from the gravel of the spawning grounds until they migrate to the ocean.

Bristol Bay investigations.—Bristol Bay comprises one of the most important red-salmon producing areas in Alaska. The annual pack averages approximately a million cases valued at about $10,000,000. The study of the salmon runs here was interrupted by the death of the late Dr. C. H. Gilbert but is now being taken up by A. C. Taft. During the past year a boat-catch analysis of the Nushagak region has been begun. The data were made available through the courtesy of the Alaska Packers Association of San Francisco. From their books it was possible to get data for the individual catch per boat from 1903 to 1928. This work extends and supplements the statistical review of the fisheries of Bristol Bay made by Rich and Ball (Document No. 1041). From a preliminary study it appears that there is a very high correlation between the catch per boat per season and the total catch per season. It would thus appear that, for the Nushagak region, the total catch provides an entirely adequate measure of the abundance of fish from year to year. The study of numerous scale samples from Bristol Bay has also been started as a basis for a detailed investigation of the age-group composition of the runs in the several districts.

Copper River red salmon.—A comprehensive investigation of the Copper River red salmon was undertaken by Seton H. Thompson in the season of 1929. These fish formerly provided an important element in the salmon resources of Alaska but in recent years have shown signs of serious depletion. Scales were taken from a sample of the commercial catch each day during most of the season. In the latter part of August and in September, observations were made on the more accessible spawning grounds.

Pink salmon investigations.—In view of the growing demands of the commercial fishery upon the pink salmon of Alaska, an investigation for the purpose of studying their life history and the causal factors underlying the fluctuations in their abundance was started in the summer of 1929 by Dr. F. A. Davidson. The point considered most pressing for early settlement was whether or not the "parent-stream theory" applies to the pink salmon, as the relative strength of the homing instinct will influence the drafting of protective regulations to insure abundance in the future.

The field work began in July and was confined to the territory of southeastern Alaska, this district being chosen on account of the extensive pink-salmon fishery it supports. Samples of the pink-salmon populations of 12 important streams, located in the various fishing districts, were taken for the purpose of ascertaining the possibilities of making a racial analysis of their populations.

Forty-six pink-salmon streams located in the various fishing districts in southeastern Alaska were visited and data collected on the physical and chemical characteristics of the stream and on the spawning populations.

COLUMBIA RIVER SALMON

Salmon-marking experiments conducted on the Columbia River in cooperation with the Oregon Fish Commission have been continued by Mr. Holmes. A report by W. H. Rich and H. B. Holmes, covering experiments with chinook salmon, has been published during the year and a similar report by Mr. Holmes, dealing with sockeye salmon, is nearing completion.

Field work during the year 1929 was restricted to the recovery of mature fish which had been marked as fingerlings. The majority of the recoveries were from an experiment with spring chinook salmon conducted at the Oregon Fish Commission's hatchery on the McKenzie River. This experiment was designed to furnish information on the very practical problem of how long fingerlings should be retained at the hatchery in order to produce the greatest number of adult fish. The experiment involved 5 lots of 50,000 fingerlings which were marked and liberated in May, June, July, and September, 1925, and March, 1926, respectively, when the fish were 8, 9, 10, 12, and 18 months old, respectively (age including period of incubation). This particular experiment failed to indicate any preference for one age of liberation over another. The results of this experiment agree with previous experiments in showing that the chinook salmon which spawn in the McKenzie River start their spawning migration early in the season, and that chinook salmon have a strong tendency to return not only to their "parent" river system, but also to the particular tributary in which they spent the early part of their lives.

ALASKA HERRING

In June, 1929, a scientific report was submitted for publication by George A. Rounsefell, summarizing the investigation from its beginning in 1925. It contains a brief description of the fishery, its methods, and development; and sections dealing with the general life history, the independence of the populations of various localities, the spawning habits, the determination of age and rate of growth, the changes in the condition of the fish, the composition of the catch with its relationship to natural fluctuations in abundance, analysis of the statistics of the catch, and a summary of the evidence of depletion.

During 1929 field work was carried on in both southeastern and central Alaska by George A. Rounsefell and Edwin H. Dahlgren, temporary assistant. Before making a detailed analysis of the daily herring catch records for each boat, which are being constantly collected, it is necessary to have a fairly accurate knowledge of the localities inhabited by each race of herring. This will allow areas to be laid out for statistical and biological use, each of which will embrace as homogeneous a population (from a racial standpoint) as possible. To this end racial data were taken in southeastern Alaska and Prince William Sound on about 7,000 specimens from the commercial catch. In addition, in southwestern Alaska, a small boat was chartered and samples of herring were caught with gill nets in several localities in the inside waters, and preserved in formalin for later examination. No commercial fishery of any importance

exists in these localities at the present time. In those localities which the scientists were not able to visit during the summer, series of samples were taken and preserved in formalin by the bureau's patrol service.

RAZOR CLAMS

As long as the razor clam industry retains its present value, certain facts must be gathered annually, that they may be made available for future comparison and that they may serve as an index to the condition of the beds. A general survey of the industry including the intensity of digging, the area being exploited, and the age of the clams in the commercial catch, is essential.

During the season of 1929, observations were confined to the vicinity of Cordova, where the most important Alaska fishery is located. Statistics designed to show the intensity of fishing have been gathered, and a study is being made of the age composition of the commercial catch in order to detect evidence of depletion. New collections of shells from the bars were made by Seton Thompson, and a part of them have been measured and recorded, under the direction of Dr. F. W. Weymouth of Stanford University, with the intention of comparing the growth rate of the clams on different bars in that locality.

CONSERVATION OF FISH BY MEANS OF SCREENS AND LADDERS

The investigation on the conservation of fish by means of screens and ladders was begun in 1928 and continued in 1929 under the direction of Shirley Baker, consulting engineer, assisted by U. B. Gilroy. The purpose of this investigation is to develop and install mechanical and electrical devices which will prevent fish from entering irrigation ditches. Enormous numbers of fish, chiefly salmon, which have entered these ditches, are killed each year when the ditches are dried up at the end of the irrigating season.

The activities under this investigation during 1929 were as follows: (1) The construction and operation of six electric fish screens on waterways of major importance, together with extensive experimentation on these devices for the purpose of simplifying and improving them; (2) the installation of a mechanical revolving fish screen; (3) the installation of a large concrete fish ladder; (4) studies of models and designs of fish ladders as well as the specifications for the fish ladders required at a number of locations; (5) analysis of the effects of five major hydroelectric developments proposed for the Northwest with the specifications of the necessary structures required for fish protection; (6) study of the practice of the Canadian Government in the matter of fish ladders; and (7) miscellaneous services rendered to State commissions and commercial bodies in the interest of fish conservation.

MECHANICAL FISH SCREENS

The most practical and economical type of mechanical fish screen is the one that has been adopted by the Oregon Game Commission and the Washington Division of Fisheries. This screen consists

essentially of a cylinder of heavy wire mesh material, placed in an appropriate supporting structure and made to revolve on a horizontal axis in the direction of the stream flow. The motive power is furnished by paddle or bucket wheel placed in the ditch below the screen, and a necessary by-pass channel is provided for the return of the fish to the main stream. The economic field of application for screens of this type seems to be the small to moderately large diversions.

As part of the work of this investigation the Bureau of Fisheries has designed and is now completing the installation of a revolving screen of this type on the Atanum ditch of the United States Indian Service. This ditch diverts water from Atanum Creek, about 17 miles southwest of Yakima, Wash.

Atanum Creek is frequented by both salmon and steelhead, and for a number of years there has been heavy loss of downstream migrants into this unscreened ditch.

W. R. Coleman, superintendent of fish screens and fish ladders for the Oregon Game Commission, has assisted in design and construction. The entire cost of the installation has been borne by the United States Bureau of Fisheries.

ELECTRIC FISH SCREENS

Early in the investigation the possibilities of the electric screen were realized. In the summer of 1926 Prof. F. O. McMillan, department of electrical engineering, Oregon Agricultural College, and J. E. Yates, engineer, Pacific Power & Light Co., Portland, Oreg., conducted experiments on the electric fish screen at Bonneville hatchery, Oreg.[4] In the spring of 1928 Messrs. McMillan and Yates installed for the California-Oregon Power Co. an electric fish screen in the tailrace of the power plant at Gold Ray on the Rogue River in Oregon. In September, 1928, H. T. Burkey of Pasadena, Calif., holder of United States patents on the electric fish screen requested opportunity to show his device, which was afforded him at the Delph Creek hatchery, Oreg., where he set up a small installation for a demonstration. Though made in still water and against trout this demonstration was sufficiently interesting to warrant a large-scale test under actual field conditions. This installation was made by the United States Bureau of Fisheries in the Tieton Canal of the United States Reclamation Service and was operated for a month.

These experiments seemed to justify making permanent installations with the result that plans were adopted and carried out to place electric fish screens of this type at the following locations: (1) Sunnyside Canal, Yakima project, United States Reclamation Service; (2) Tieton Canal, Tieton project, United States Reclamation Service; (3) Wapato Canal, Wapato project, United States Indian Service; and (4) intake of Gold Ray power plant, California-Oregon Power Co.

[4] Electric Fish Screen (with bibliography); by F. O. McMillan. Bul., vol. 44, 1928. 34 pp., 21 illus.

EFFECTIVENESS OF SCREENS

For the past two years the Division of Fisheries, State of Washington, has done valuable work in the interests of fish conservation, by maintaining a special investigator in Yakima County during the irrigation season to secure data on the presence of fish. On this work hundreds of miles of ditches and stream channels are patrolled weekly.

In the fall of 1929 the United States Bureau of Fisheries and the State division of fisheries cooperated in the work of the final check on the ditch system, Fred R. Lucas, representing the bureau. In this work the projects reported on were covered in their entirety. The results constitute data of a very high degree of accuracy.

Sunnyside electric screen.—The Sunnyside Canal, main diversion of the Yakima project, United States Reclamation Service, diverts water from the Yakima River, near Yakima, Wash. The capacity of the canal is 1,500 second-feet. The irrigation season of 1929 extended from March 15 to October 21. During the greater part of the season the canal carried from 1,200 to 1,500 second-feet. The check revealed a total of 640 salmon and steelhead left stranded in the system. Of this number 480 were actually caught and counted. In length, the fish averaged from 3¼ inches to 5 inches. It is reported that in former years the Sunnyside and Wapato systems were likely to show hundreds of thousands of such fish. The results indicate the operation of the electric screen to have been a success.

Tieton electric screen.—The Tieton Canal of the United States Reclamation Service diverts water from the Tieton River at a point about 35 miles northwest of Yakima, Wash. Capacity of the canal is 320 second-feet, and this flow is maintained throughout most of the irrigation season. Because this diversion is located in the mountains many miles from any power line, it was necessary to install a power unit for furnishing electricity to the screen. This was accomplished when the United States Reclamation Service, displaying a fine spirit of cooperation, installed at their own expense a hydroelectric generator on the Tieton ditch and built a transmission line three-fourths of a mile long to bring the power to the screen. The electric screen went into operation three and one-half months after water diversion started, consequently, the effect of the electric screen can not be determined from check on the fish in the ditch at the end of the season. In comparison with 1928 this year's check showed more small salmon and steelhead and less large ones. The fish in the Tieton River, both above and below the diversion point, were much more numerous this season than in 1928. All factors considered, the use of the electric screen is regarded as successful.

Wapato electric screen.—The Wapato Canal of the United States Indian Service diverts water from the Yakima River at a point about 3½ miles upstream from the Sunnyside Dam. The capacity of the canal is 1,800 second-feet, and throughout the major portion of the irrigation season this huge flow is maintained. The irrigation season is from March 15 to November 18. A check of the system showed the total number of salmon and steelhead to be about 900, of which 381 were actually caught and counted. The average length of the fish was from 3½ inches to 5 inches.

The efficiency of the Wapato electric screen can not be determined from the number of fish left in the ditch at the end of the season because, for a time, fish passed into the system through the Old Indian Canal which was unscreened. Taking this into account, the results indicate that the electric screen was a success. For the purpose of comparison a check was made at the end of the irrigation season on the Selah-Naches ditch where there is no screening device. This ditch, operated by a private irrigation company, diverts water from the Naches River (a tributary of the Yakima) in the same district with the Sunnyside and Wapato Canals. The ditch capacity is about 300 second-feet. In the check up on this ditch there was found a total of 5,900 salmon and steelhead 3 to 8 inches long. Of this total 5,389 were actually caught and counted. All the fore-

FIGURE 6.—The Wapato electric fish screen. Chain electrodes are seen hanging in front of the diversion gates

going installations were under the competent care of W. N. Wagner, inspector United States Bureau of Fisheries.

Gold Ray intake screen.—The purpose of this electric screen is to prevent downstream migrating salmon and steelhead from being drawn into the power turbines. The Gold Ray Power House of the California-Oregon Power Co. is situated on the Rogue River near Medford, Oreg. Water is diverted to the turbines through an open channel blasted in rock. The screen was electrified June 3, but results were not satisfactory. Experimentation with a view to improving conditions was carried out throughout the summer. Early in August a survey of the distribution of the electric field set up in the water was made by Prof. F. O. McMillan. This revealed high and undesirable voltage gradients at the chain electrodes and along the masonry wall at the south side of the intake.

As a means of alleviating this condition of high-voltage gradients and following very encouraging results at an experimental electric screen erected for this purpose in the Gold Ray sluiceway, the use of the grounded type of screen was abandoned and a screen insulated from ground and employing a double row of large diameter pipe electrodes was installed. Operation of this screen was continued until late in November, but no real check on its efficiency was possible because the season for downstream migration of fish had almost wholly passed. The operation of the grounded screen throughout the migration season without question diverted some fish from the intake channel, but it is doubtful if the number so diverted was more than 25 per cent of the total number of such fish encountering the screen. It is felt that greatly improved results will be obtained with the new screen the coming season.

Gold Ray sluiceway experimental screen.—During the late summer considerable experimenting was done with a view to determining the best type of electric screen for operation against downstream migrants. The first experiments were made with the grounded type of screen as employed at all previous installations. The action of the fish was noted under a variety of conditions. Various arrangements of spacing electrodes and ground element with voltages ranging from 45 to 110 volts were tried. The action of the fish in the electrified zone was erratic. Resort was then had to a screen insulated from the ground, and highly satisfactory results were obtained.

Gold Ray tailrace screen.—Three heavy runs of salmon and steelhead pass up the Rogue River each season on their way to the spawning beds. For the accommodation of these upstream migrants two fish ladders are maintained at Gold Ray Dam, one being at each abutment of the dam. The discharge from the power-house tailrace returns to the river about 500 feet downstream from the dam. During periods of large overflow the volume of water in the main channel is sufficient to keep most of the fish safely headed up past the tailrace to the fish ladders. When, however, the overflow at the dam is diminished and a considerable part of the river flow is being taken through the power house, these fish are attracted into the tailrace. Trapped in this channel they wear themselves out fighting the strong flow from the turbines and are thus prevented from reaching their goal up river. In the spring of 1928 the California-Oregon Power Co. installed and, for a time, operated an electric fish screen in this tailrace. The results obtained encouraged further investigation, and to this end the power company has cooperated with the Bureau of Fisheries in bearing one-half the expense of all work done on the Gold Ray electric screens this season.

The object of the experimental electric screen installed by the bureau in the tailrace was twofold. Primarily the purpose was to screen this waterway against the entrance of upstream migrating fish and thus divert them upstream to the fish ladders. It was also desired to study the possibility of directing fish to some definite point in a channel by means of an electric field. With this latter purpose in view the screen was installed well up in the tailrace and diagonally across it. At the upstream end of the screen a fish trap or box of timber construction was placed; the object being to see if the fish upon coming in contact with the electrified-zone of water would con-

tinue to work up along the edge to the unelectrified section of channel occupied by the trap. After several weeks of operation, during which time many fish were stopped by the electric screen, but none were found to enter the trap, further work with the latter was abandoned.

Throughout the season many people had an opportunity to observe hundreds of salmon and steelhead in contact with the electric field. Some of these fish were stopped at the weak fringe of electrical effect just downstream from the ground pipe. The majority would penetrate the electrified zone for from 5 to 8 feet, where they would break water in a mighty leap and, turning around, swim rapidly out of the tailrace. A very few fish were seen to pass through the screen, but this was exceptional. A happy feature of the season's operation was the almost complete absence of killing or stunning of fish due to contact with the electric field. High success has attended the operation of this screen. It is estimated that, during the summer, upward of 5,000 salmon and steelhead attempted to pass through the electric field. Brief shutdowns of the power house were made upon several occasions for cleaning fish out from above the screen. The results of these checks indicate that the efficiency of the screen may conservatively be taken as from 95 to 98 per cent.

Electrification of Savage Rapids screen.—At the Savage Rapids Dam on the Rogue River the Grants Pass irrigation district operated a pumping plant to deliver a total of 110 second-feet of water to two high-line ditches. Several years ago the Oregon Game Commission installed a "roller-towel" type of mechanical screen in front of the intakes to prevent downstream migrating salmon and steelhead from being sucked into the turbines. With this large-mesh screen remaining stationary it is known that great numbers of small fish are drawn through it to the turbines. This summer, at the request of the Oregon Game Commission, and with that body and the Oregon Fish Commission bearing the expense, the United States Bureau of Fisheries converted the installation to an electric screen. In this work Prof. F. O. McMillan served in a consulting capacity.

Naches power house electric screen.—In February, 1929, the Pacific Power & Light Co. announced its willingness to install at its own expense electric fish screens at the company's power intakes in Yakima County and requested the United States Bureau of Fisheries to specify and design the screen; accordingly the bureau specified the materials and designed the screens for the Naches and Fruitvale plants. These screens were similar to the installations being made in the Government ditches.

FISH LADDERS

The field work of 1928 included the inspection of practically all fish ladders in the States of Washington, Oregon, Idaho, and Montana. Studies of these installations and observations of the habits of migratory fish revealed certain basic principles which should govern the design of fishways. The activities of 1929 have included: (1) The practical application of these basic principles in the construction by the United States Bureau of Fisheries of a new fish ladder at the Sunnyside Dam of the Yakima project, United States

Reclamation Service; (2) field inspection and preliminary work on the design of a new fish ladder for the Sprague River Dam of the United States Indian Service; (3) conference with the chief engineer of fishways, Canadian Government; (4) field inspection of the dam sites of several proposed power developments, and the study of models and designs of fish ladders for the purpose of specifying the required structures of these projects.

The Sunnyside fish ladder.—Four important runs of anadromous fish journey up the Yakima River each season; these being the spring and summer runs of the chinook salmon, the steelhead, and the fall run of the silver salmon. To reach the spawning beds these fish must pass over the Sunnyside Dam. This concrete overfall dam has a crest length of 500 feet and a height of 7.5 feet from stream bed to crest, which is increased to 10 feet by the additional flashboards. These flashboards are maintained in position for the major portion of the irrigation season. At times of high flow the upstream migrants can negotiate the jump at this dam, but with the flashboards in place and under the condition of small overflow that prevails during most of the irrigation season, the jump becomes impossible for most fish. Realizing the unfavorable conditions existing at the Sunnyside Dam the United States Bureau of Fisheries designed and constructed this fall, a ladder of large pool design which has already proved itself a real factor in fish conservation on the Yakima River.

Preliminary work on Sprague River fish ladder.—The assistance of the United States Bureau of Fisheries has been sought by the Oregon Game Commission to improve conditions at the Sprague River Dam of the United States Indian Service, near Chiloquin, Oreg. In response to this appeal the bureau plans to construct an adequate fish ladder at the site. Conditions at the site have been inspected and the necessary measurements and data secured. It is the intention to design and build this structure during the coming summer, providing sufficient funds are available for the work.

Study of Canadian practice.—In November, under instructions from the Commissioner of Fisheries, a visit was made to Ottawa, Ontario, for the purpose of interviewing the engineers engaged in fish-ladder work for the Department of Marine and Fisheries, Canadian Government. William Found, the departmental head, and Charles Bruce, chief engineer of fishways, were most cordial in placing all of the Canadian material at the disposal of the bureau's engineers.

Fish ladders at new power projects.—During the past year the scope of this investigation has been considerably enlarged on account of obligation of the Bureau of Fisheries to specify the fish ladders required at two major power developments on the Columbia River. It is believed that this service is highly important. The projects referred to are Rock Island development of the Washington Electric Co. and the Kettle Falls development by the Washington Water Power Co.

INVESTIGATIONS IN TROUT CULTURE

At the present time practically all the investigations in connection with trout culture are being carried on at the bureau's experimental hatchery at Pittsford, Vt., under general supervision of

Dr. H. S. Davis, in charge aquicultural investigations. The work at this hatchery, which is under the immediate supervision of R. F. Lord, is primarily concerned with brook trout, and a large stock of these fish of various ages is maintained for experimental purposes. Small numbers of rainbow, steelhead, and black-spotted trout are also kept at this station, and during the past summer the stock was increased by a shipment of grayling eggs from Montana. In order to accommodate such a large and varied assortment of fish a large number of small ponds and raceways are required, and these are being increased as rapidly as funds will permit.

During the past season the brook trout spawned at this station produced approximately 950,000 eggs. These eggs were taken from several strains of fish originally obtained from widely separated sources so that trout of quite different ancestry will be available for breeding purposes. In addition to the brook-trout eggs, several thousand rainbow eggs were also taken. It may be of interest to note that there are two strains of rainbow trout at the station, one spawning in the spring and the other in the fall.

FEEDING EXPERIMENTS

The feeding experiments carried on during the summer of 1929 were planned along the same general lines as in the previous year. Fingerling and yearling brook trout were utilized in these experiments, the fingerlings being kept in hatchery troughs, while the yearlings were held in outdoor raceways. Twenty-one lots of fingerlings, containing 1,500 fish each, were kept on experimental diets which were designed primarily to furnish additional data on the feasibility of utilizing dry meals in rations of fish of this age.

Dry feeds for fingerling brook trout.—As a result of the experiments during the last two years in feeding substitutes for fresh meats to fingerling trout, it is believed that it is entirely practicable to use certain dry products in combination with fresh meat at a considerable saving over the cost of a straight fresh-meat diet. These experiments have shown that fingerlings fed a mixture of fresh meat and certain dry products do fully as well as fish on a diet of fresh meat alone, and in some instances even better. It is not believed however, that in most instances it will be found practicable to feed these dry products to fish under 2 inches in length.

Only a few dry products have been found to give satisfactory results with small fingerlings. Clam meal has made by far the best showing of any of the dry products tested, but unfortunately the supply of this meal is very limited. Dry buttermilk and dry skim milk have also been found to produce good results and, everything considered, are probably the best dry products for feeding small fingerlings which are available in quantity. As high as 25 per cent of these meals when mixed with beef liver has been found to yield results comparable to those obtained with liver alone.

After the fingerlings reach a length of 4 to 5 inches a wider range of dry meals is available, such as shrimp meal and vacuum-dried fish meals.

Dry feeds for yearling brook trout.—The experiments with yearling brook trout during the summer of 1929 were conducted on a larger scale than ever before, 24 lots of fish being placed on experi-

mental diets. The results were very consistent and in general agreement with those obtained in previous years. The advisability of using dry meals in the ration as a measure of economy was fully demonstrated and it is confidently believed that by the utilization of these products the food bill can be reduced at least one-third without adverse effects on the growth or mortality.

While the results of these experiments clearly indicate that trout can not be kept successfully on dry foods alone for any length of time, they also show that the amount of fresh meat required is less than was formerly thought to be the case. Excellent growth accompanied by low mortality was obtained with rations containing as high as 60 per cent of dry meals and it is probable that the amount of meat can be still further reduced without appreciably lowering the efficiency of the ration.

Unfortunately, owing to local conditions, it has been found impracticable to continue the feeding experiments during the winter at the Pittsford station. Since it is evident that the practical value of these experiments is dependent to a large degree upon the length of time they can be continued without interruption, it is highly desirable that facilities be provided elsewhere for carrying on feeding experiments throughout the year. Furthermore, the investigations at Pittsford have shown that the nutritional requirements of other species of trout are in some respects quite different from those of brook trout. Consequently it will be necessary to conduct similar experiments with rainbow and brown trout before the most desirable rations for these fish can be worked out.

BREEDING EXPERIMENTS

As noted in previous reports, experiments in selective breeding have been carried on at the Pittsford station during the past three years. Owing to the necessity of rearing a large brood stock in preparation for the breeding work it was possible to mate only a few pairs of fish previous to 1928. In the fall of that year 34 pairs were mated and the offspring kept in separate compartments in hatchery troughs during the following summer. These fish were all kept under as nearly identical conditions as possible so that the young of different parents would be directly comparable. Although all the parents were specially selected fish it was found, as was to be expected, that the young in different lots showed marked differences in rapidity of growth. The variations in growth among the fish in each lot were, however, much less than is usually the case among fingerlings of mixed parentage. In some lots the average growth was over three times that of other lots, and there is no question but that this difference in the growth rate must be ascribed very largely, if not entirely, to difference in parentage. Only those lots of fingerlings showing exceptional vigor and rapidity of growth are to be retained for further breeding work.

During the present season an even larger number of individual pairs have been mated and the eggs and young will be kept separate throughout the spring and summer. For the first time it has been possible to mate selected young of known ancestry and the results of these matings are awaited with a great deal of interest.

While it will, of course, require several years before results of permanent value can be expected from this breeding work the outlook is very encouraging and there is every reason to believe that in this way it will be possible to produce a marked improvement in the quality of hatchery fish. The marked differences in the vigor and growth of the offspring of different pairs are especially noteworthy. In many instances the parents of these fish showed little difference in either size or vigor and in ordinary hatchery practice would have unquestionably been considered of equal value for breeding purposes.

Value of various sized fish for stocking purposes.—In order to obtain more accurate data regarding the survival of hatchery fish when used for stocking purposes, arrangements have been made to stock several streams in the vicinity of the Pittsford station with fingerling trout of various sizes. It is planned to stock a stream

FIGURE 7.—Spawning selected pairs of trout used in breeding experiments at the Pittsford (Vt.) experimental hatchery. By careful selection of the parents, a superior strain of brood fish is developed

with trout of a certain age for two or three years and through cooperation of the local fish and game associations obtain data on the catch of a number of anglers on the stream. Later the same stream will be stocked with fish of a different size and the catch of the same anglers compared with their catch in previous years. In this way it is hoped to obtain data which will have a direct bearing on the much-discussed problem of the relative value of trout of different ages for stocking purposes.

Propagation of graylings.—During the summer of 1929 a shipment of several thousand grayling eggs was received at the Pittsford station from the Meadow Creek (Mont.) substation of the bureau. These eggs were received in exceptionally good condition and hatched with very little loss. Although it is generally believed that grayling are very difficult to rear no trouble was experienced in getting the fry to feed on very finely ground beef liver. They made a very rapid

growth on this diet, and the losses were comparatively light. The grayling fingerlings continued to thrive throughout the summer, and on October 1 many had reached a length of 2 to 2.5 inches. With the arrival of cold weather the growth rate was reduced, but the fish remained healthy; and there is every reason to believe that they will survive the winter in good condition.

It is planned to use part of these grayling to stock a suitable stream in the vicinity of Pittsford, while the remainder will be reared to maturity at the hatchery.

DISEASES OF TROUT

Investigations on the parasites and diseases of trout were continued, special attention being paid to the gill disease which has been found to be one of the most serious diseases with which the trout culturist has to deal. It is a very widely distributed disease, having been found in trout and salmon from the New England States to the Pacific coast. Undoubtedly the disease has been prevalent at trout hatcheries for many years, but its true nature has only recently been recognized. Formerly losses which were evidently due to this disease were ascribed to the water supply and other obscure agencies. Fortunately, as noted in previous reports, the disease is easily controlled if the appropriate measures are taken on the first appearance of the infection.

An epidemic of "popeye" which caused serious losses among fingerling black-spotted trout and sockeye salmon at the Birdsview (Wash.) station was found to be associated with infection of the kidney by a myxosporidian parasite. This parasite, which is apparently an undescribed species of Myxidium, occurs in the lumen of the kidney tubules causing pathological changes in the epithelial lining. The "popeye" condition is due to the accumulation of serous fluid in the abdominal cavity and other parts of the body and it is probable that this is the result of the kidney infection.

INVESTIGATIONS IN POND FISH CULTURE

The investigations in pond fish culture at the Fairport (Iowa) station, under the immediate direction of Dr. A. H. Wiebe, were continued along the same general lines as in previous years under the general supervision of Dr. H. S. Davis. The object of these experiments is to devise better and more efficient methods of propagating and rearing the so-called warm-water game fishes, including the large and smallmouth black bass, the white and black crappie, and the bluegill sunfish.

Experiments with golden shiner and blackhead minnow as forage.—Since previous experiments had shown the advisability of utilizing forage minnows in rearing both large and smallmouth bass, the investigations during the past year were designed primarily to furnish further information regarding this phase of bass culture. Experiments with the golden shiner and blackhead minnow have shown that as a forage fish for bass the shiner is superior to the blackhead. There still remained, however, a possibility that both species of minnows in a pond would prove superior to either one alone, since they differ widely in their feeding and breeding habits.

However, this did not prove to be the case, for the ponds stocked with golden shiners alone produced approximately 8,000 largemouth fingerlings per acre, while the ponds stocked with both shiners and blackhead minnows only produced approximately 4,100 largemouth fingerlings per acre.

Number of forage fish required.—Additional information was obtained on the number of forage fish required to give the best results in rearing ponds. Each year the number of adult shiners placed in the ponds has been increased since experience has shown that practically all the minnows were devoured by the bass before the ponds were drained in the fall. This resulted in cessation of growth and an increase in cannibalism. During the past season the rearing ponds were stocked with about 700 adult shiners to the acre, and this is probably not far from the proper number to use in ponds containing only fingerling bass. Obviously when the ponds contain brood fish in addition to fingerlings the number of forage fish must be correspondingly increased.

Number of bass fry and adults for stocking ponds.—The number of bass fry required to produce the best results has also received attention, and we are now stocking the ponds with about 25,000 advanced fry per acre, which is considerably more than have been used in the past. Possibly as a result of increasing the number of fry the maximum production of bass fingerlings was increased from 10,000 to 11,500 per acre.

The total number of bass fingerlings produced at the Fairport station in 1929 was not as great as anticipated, owing to the fact that the bank of the largest rearing pond was washed out shortly after the pond had been stocked for the summer and about 90,000 fry and forage fish escaped into the river.

The experiments indicate that better results can be obtained when the ponds are not overstocked, and that if the brood fish are in good condition much smaller numbers are required than is usually realized. Overcrowding the fry has a tendency to increase cannibalism, with the result that ordinarily less fingerlings survive the summer than is the case when smaller numbers are present at the beginning of the season. Consequently when the fry are to be reared in the same pond with the brood fish only a few pairs of adults are required to the acre. The fecundity of large brood bass is well illustrated by one of the spawning ponds which was stocked with 17 large females and 7 males. These females produced an average of over 6,500 fry each. At this rate 4 females would produce enough fry to stock a rearing pond 1 acre in area. It is of interest to note that our records show that these same females averaged at least 5,500 fry in 1928.

Rearing bass brood stock.—It has also been shown that it is perfectly feasible to rear bass to maturity in small hatchery ponds, and additions to the brood stock at Fairport are limited strictly to fish which have been reared in the station ponds. Each year a few of the best fingerlings are reserved for brood stock, and it is believed that in this way it will be possible to get better fish than by the old method of depending on wild fish for propagation purposes. No difficulty has been experienced in rearing these fish, and during the past season fry were obtained from both 2 and 3 year old fish which

had been reared in the station ponds. One lot of 2-year-old bass containing 10 females and 5 males produced an average of over 1,200 fry to each female.

Experiment with smallmouth black bass.—As in 1928, one pond was stocked with 19 smallmouth bass and with adult shiners for forage. The fry were allowed to remain in the pond with the brood fish throughout the summer. When drained on October 1 the pond yielded 6,010 3-inch fingerlings, which was at the rate of approximately 7,000 to the acre. The success attained with smallmouth bass during two successive seasons has been somewhat surprising inasmuch as conditions in the ponds are quite different from those usually considered essential for smallmouth bass.

Propagation of bluegill sunfish and crappie.—Two small ponds devoted to the propagation of bluegill sunfish gave a surprisingly large production so far as numbers are concerned. The production in one pond was at the rate of 136,280 fingerlings per acre. In the second pond the yield was at the rate of 298,280 fingerlings to the acre, but the fish were considerably smaller than in the first pond.

The results with crappie during the season of 1929 were very unsatisfactory, probably largely due to the poor condition of the brood stock.

Fertilizing ponds.—During the past three years the ponds, with few exceptions, have been fertilized with a mixture of superphosphate and dry sheep manure. This fertilizer has given uniformly good results, but during the past year comparative tests with this mixture and soybean meal indicate the superiority of the latter as a fertilizer for fish ponds. Final judgment should be reserved, however, until further tests are made.

INVESTIGATIONS IN THE UPPER MISSISSIPPI WILD LIFE AND FISH REFUGE

The investigations in the Upper Mississippi Wild Life and Fish Refuge, supervised by Dr. H. S. Davis, were continued under the immediate direction of Eugene W. Surber. A number of sloughs in the vicinity of Trempealeau, Wis., were selected for intensive work and most of the activities of the past season centered around these sloughs. They are connected with the river only during periods of extreme high water and appear to afford suitable conditions for the propagation of bass and other game fishes.

Preparation of sloughs for bass culture.—The sloughs selected for experimental work were cleared of brush and coarse vegetation early in the season after which they were seined so as to remove predacious fish, such as pickerel and gar-pike, which might interfere with the propagation of more desirable species. Unfortunately, plans to propagate black bass in the sloughs were not realized owing to the impossibility of obtaining a stock of brood fish. Nevertheless, work on cleaning up the sloughs was continued and several are now ready for stocking early in the spring of 1930. A supply of adult largemouth bass has been obtained for brood stock, and these fish are being wintered in a spring-fed pond at Trempealeau.

Limnological observations.—Although it was found impossible to rear fish in any numbers during the summer of 1929, extended limnological observations were made at regular intervals. These obser-

vations are being continued through the winter so there will soon be available detailed information regarding condititions in the sloughs throughout the year. The limnological work includes the collection of samples of the plankton and bottom fauna and determinations of dissolved oxygen, free and fixed carbon dioxide, and alkalinity at 2-week intervals.

Studies of the plankton and bottom organisms have shown that the sloughs are very rich in fish food and are apparently capable of supporting a much larger fish population than is present usually. However, Mr. Surber has found that in most of the sloughs the supply of dissolved oxygen becomes rapidly depleted after they freeze over, and that by the middle of December the oxygen content is below 0.5 parts per million. In several instances fish half dead from asphyxiation came up to the holes that had been chipped in the ice for making the collections. It is evident that under such

FIGURE 8.—Cleaning slough for rearing bass fingerlings in Upper Mississippi River Wild Life and Fish Refuge

conditions very few fish can survive in the sloughs through the winter. Doubtless it is owing to this fact that sloughs which are overflowed only at infrequent intervals usually contain very few fish even though there may be an abundance of food available. These studies indicate that, in general, the small slough fishes eat the food that is most available in their particular environment and exercise little choice or selection. There are, however, numerous exceptions to this rule, especially among the minnows.

CONTROL OF AQUATIC VEGETATION

One of the greatest problems in connection with fish cultural work in the sloughs is the control of aquatic vegetation. Unless the plants are kept within bounds the sloughs become choked with a rank growth of both emergent and submerged aquatics which absolutely

prevent the use of a seine and may have an adverse effect on the fish and other animal life. Removal of this excessive plant growth by the usual means is a very laborious process and is also highly objectionable for other reasons. A chemical treatment which will destroy the coarser plants without injury to the fish or serious interference with the food supply would be a great help in utilizing the sloughs for fish propagation.

During the past summer preliminary experiments in treating the sloughs with sodium arsenite gave most encouraging results. It was found that a solution of this chemical when sprayed on the surface of the water in sufficient quantities to produce about 2 parts of arsenic trioxide to a million parts of water caused the destruction of such plants as *Ceratophyllum demersum*, *Potamogeton interior*, *P. foliosus*, *Heteranthera dubia*, and *Elodea canadensis*. The effects of the treatment are apparent within two or three days, when

FIGURE 9.—Installing a Hesen fry trap for the capture of fry from a slough stocked with adult black bass, Upper Mississippi Wild Life and Fish Refuge. The fry are then removed to rearing ponds where they are free from the danger of being eaten by their hungry parents or by other species

the plants sink to the bottom and decay. Of course the decomposition of the plants will remove dissolved oxygen from the water, and there is danger of deficiency of this gas when the treatment is administered to dense vegetation. In only one case was there any evidence that the fish were injured by the treatment and in this instance, owing to the large amount of vegetation present, the use of the weed killer was followed by a marked oxygen deficiency.

Plankton and bottom samples were collected in ponds treated with sodium arsenite, but the study of these has not yet been completed. However, some preliminary examinations of the collections indicate that some of the plankton organisms increased and others decreased as a result of the treatment.

Recently Dr. A. H. Wiebe has conducted a series of experiments at the Fairport station on the effects of arsenic on fish in aquaria.

Largemouth black bass, crappie, bluegill sunfish, bullheads, and goldfish were used in these experiments, and it was found that the fish were not injured appreciably by a concentration of arsenic trioxide as high as 7 parts per million. Since the fish were kept in these high concentrations of arsenic for several days without injury, it is apparent that no danger to the fish need be anticipated from the use of arsenic in concentrations sufficient to kill vegetation.

OYSTER INVESTIGATIONS

Oyster investigations carried out under the direction of Dr. Paul S. Galtsoff during 1929 consisted in the experimental study of oyster culture in New England, Georgia, Texas, and Washington; in a study of the physiology of adult and larval oysters; in the survey of the oyster bottoms of the States of Alabama and Delaware; in a study of the effect of pulp-mill wastes on oysters in Puget Sound; and in an investigation of the biology of the natural enemies of the oyster—the oyster drill and the starfish.

EXPERIMENTAL STUDIES IN OYSTER CULTURE

NEW TYPE OF SEED-OYSTER COLLECTOR

Experiments carried out by H. F. Prytherch in cooperation with the Bluepoints Co. and the Connecticut Oyster Farms Co. have resulted in the development of a practical and efficient method for collecting and transplanting heavy or intensive oyster sets.

In certain oyster-growing regions, such as South Bay, Long Island, and the tidal flats in the South Atlantic States, the setting of oysters is often so intensive that a high percentage of the spat die from overcrowding, lack of oxygen, food, etc.; and those surviving are so closely cemented together and misshapen as to be of little value as seed oysters. A cheap collector for use under such circumstances was devised by Prytherch in 1923, consisting of cardboard egg-crate partitions which were covered with either paraffin and coarse sand or asphalt. The final step in perfecting this type of collector and making it of practical value is credited to W. H. Raye, president of the North Atlantic Oyster Farms, who used a coating of lime, cement, and sand which has improved the collector in many respects. By covering the cardboard with this mixture, we have essentially a series of compartments lined with a thin layer of shell-like substance which has been found suitable for collecting thousands of spat and holding them until they are large enough to be broken apart and separated as single seed oysters.

During the past summer 2,000 set collectors of this general type were tested out in South Bay, Long Island, and Milford Harbor, Conn. The size of the collector was increased so as to consist of 25 compartments giving a total of approximately 1,000 square inches of surface per collector. In South Bay the setting was quite heavy and covered almost every collector with from 50 to 200 spat per square inch of surface. By comparing the growth and survival of spat on the partition collectors with those attached to oyster shells on the same area, the superior value and efficiency of the new method can be seen.

On a single oyster shell having an average of approximately 20 square inches of surface, there rarely can be produced more than 25 or 30 year-old seed oysters, regardless of whether the original set numbered 100 or 1,000 spat per shell. However, the same amount of surface on the partition collector is capable of producing from 200 to 400 seed oysters, or approximately 15 times as many per square inch as can be grown on the shells.

With a set averaging 50 spat per square inch, as was obtained in South Bay, there is a loss of over 98 per cent on the shells and only 70 per cent on the collectors. A single representative collector taken from South Bay in September yielded by actual count 13 200 single seed oysters or the equivalent of what could be produced on a bushel of shells. By separating the seed oysters from the collectors when

FIGURE 10.—Cardboard seed oyster collectors, developed by bureau investigators, showing 1930 set in Long Island Sound

they are a few months old it is possible to get a much larger and better shaped year-old oyster than can be grown from sets obtained on shells.

The new type collector can be planted directly over the shells and will greatly increase the productivity of such oyster-setting bottoms.

NEW ENGLAND

Studies in oyster culture in New England, carried out by H. F. Prytherch, were conducted from the headquarters established at Milford, Conn., and extended to Long Island Sound and Great South Bay, N. Y.

Spawning and setting of oysters in Long Island Sound.—Since the production of seed oysters in Long Island Sound has been shown

by previous investigations to depend largely upon climatological and hydrographic conditions in this region, it became evident that additional records and observations would have to be made each year to assist the industry in its oyster cultural operations and to increase our knowledge and understanding of the controlling factors. For this purpose, several cruises were made in cooperation with the State Shellfish Commission of Connecticut and the Connecticut Oyster Farms Co. to secure data as to the temperature and salinity of the water, the abundance of adult oysters, and especially the quantity of spawn which they had developed. The average air temperature during the spring and early summer months was 4.3° F. above normal, and could be correlated as in previous similar years with the production of a large quantity of eggs in the reproductive organs of the oyster. The summer was exceptional, however, in two respects; that is, the discharge of fresh water from the rivers into Long Island Sound was the lowest that it had been in several decades, and the spawning and setting of oysters was over a month later than usual. Water temperatures were favorable for oyster spawning the latter part of July, which is the usual time; but this event did not take place until nearly the middle of August, when the salinity was reduced by heavy rains on August 11 and 12. The development and setting of the oyster larvæ was also greatly retarded and covered a period of over 30 days, which is twice as long as any that had been recorded previously.

A cruise was made from New Haven Harbor to Black Rock Harbor for the examination of shell plantings, which showed that a light set had occurred on September 14 to 18 and that it was widely distributed over both inshore and offshore beds.

GEORGIA

In April Dr. R. H. Luce, temporary assistant, made hydrographical observations in tidal rivers near Doboy Island, and collected and examined the spat collectors (brush) which were planted there in the summer of 1928. These observations have shown that oak brush may be used as an excellent spat collector and that the catch of oysters on the larger pieces of brush (3 to 6 centimeters, 1¼ to 2½ inches, in diameter) was decidedly better than on the smaller branches and twigs. Of the brush planted in three different localities in the Doboy Island region, one planting (Duplin River) was very successful, one (North River) failed completely to catch oysters, while the third one (Doboy Island) caught but a small number of spat. An analysis of hydrographical conditions shows that the failure of plantings of 1928 in North River and Doboy Island can hardly be attributed to any other factor than the unusual amount of fresh water in this region from the middle of August through September. The success of the Duplin River brush may be attributed to the fact that this river is a "dead" river, in that it ends in salt marsh and has no supply of fresh water at its head, so that the freshet of August, 1928, probably did not affect it.

TEXAS

In cooperation with the State Game, Fish, and Oyster Commission of Texas, Dr. A. E. Hopkins made, during the spring and

summer, an extensive study of the influence of hydrographic conditions upon the oysters in the bay waters near Galveston. The investigations centered in a field laboratory on Offats Bayou, an arm of the West Bay portion of Galveston Bay. Water temperatures and salinity records were made daily near the laboratory and frequently at other places throughout the bay.

Spawning.—The oysters started spawning at the end of March, at a temperature of about 25° C. (77° F.), and larvæ became extremely abundant in the water especially during the following two months. A fairly exact estimate of intensity of spawning was obtained by townet collections of free-swimming larvæ. The time and abundance of setting was determined by planting wire bags filled with shells in favorable locations. These were brought to the laboratory periodically for examination. The period of spawning near Galveston lasted from the end of March until at least September 1, and probably continued for another month, for the oysters still contained spawn. The bulk of the spawning, however, occurred in April, May, and June.

Setting.—Considerable evidence was obtained to show that the salinity of the water is a controlling factor in the setting of oyster larvæ in this region. Although the water may be well populated with oyster larvæ, they will not attain the setting stage unless the water contains 20 to 21 parts of salt per thousand. This is probably why attempts to rehabilitate reefs and establish new ones by planting oyster shells during spring and summer have failed. However, to plant shells when the salinity is high enough should surely succeed, for setting would then occur before the shells could become coated with slime.

Wire bags of shells were planted, and the set obtained proved tne adequacy of this method in Gulf waters. As many as 40,000 spat per bushel of shells were obtained during two weeks at the height of the setting period. Spat grew in the warm water at the rate of about 0.3 millimeter a day in diameter, or 1 inch in two and one-half months.

Salt analyses, Galveston Bay.—With the cooperation of W. B. Wardlow, of the Texas Department of Health, quantitative analyses of the salts in various parts of Galveston Bay were made. The results show a remarkable variation in the proportion of the constituent salts present. Such fluctuations in the salts in solution in sea water may probably be of great importance in the life of the oyster and other organisms. The oyster is highly sensitive to such changes in the water, and its feeding behavior is readily influenced by sudden changes.

WASHINGTON

Investigations in oyster culture in the State of Washington were carried out by H. C. McMillin. Headquarters were established on Totten Inlet (Oyster Bay) in April. Temperature and salinity records were kept throughout the season. Spat collectors were put out in all of the oyster-producing bays on the lower end of Puget Sound and in Willapa Harbor. Plankton samples were taken in the open bay at high tides and in the dikes at low tide.

A careful examination of all the beds of the State was made to discover the presence of forms which had been brought in with the

imported Japanese seed oysters. It has been found that the Japanese drill occurs in restricted areas, while the eastern drill is more generally distributed; up to date it has not affected the principal centers of oyster production. About 20 other species of Japanese forms have been introduced in Puget Sound and many of them thrive, becoming potential sources of danger.

PHYSIOLOGY OF ADULT AND LARVAL OYSTERS

Temperature effect on feeding of Gulf coast and Japanese oysters.—Dr. P. S. Galtsoff continued a study of the physiology of feeding and spawning of oysters. Several experiments on the effect of temperature on the rate of feeding were carried out in April at the temporary laboratory established at Offats Bayou, near Galveston, Tex. It has been found that similar to the behavior of oysters from Cape Cod and Long Island Sound, the oysters from the vicinity of Galveston Bay respond to the changes in temperature in the same manner as those growing in the northern waters. The rate of feeding increases with the increase of temperature, reaching the maximum at about 30° C. (86° F.) Cessation of feeding occurs at the temperature between 7° and 9.5° C. (45° and 49° F.); that is, at the same temperature which causes the cessation of feeding in northern oysters. The conclusion seems inevitable that the warm waters of the Gulf of Mexico fail to produce any physiological changes in the ciliary mechanism of the gills. A study of the effect of temperature on the feeding of Olympia (Wash.) oysters (*Ostrea lurida*) and the Japanese oyster (*Ostrea gigas*) was made at the Jacques Loeb laboratory of Hopkins Marine Station, Pacific Grove, Calif. The maximum rate of feeding of the Japanese oyster (4 liters, or approximately 1 gallon, per hour) occurs at the temperature of 25° C. (77° F.); the optimum temperature for feeding of the Olympia oyster is between 25° and 30° C. The highest rate of feeding of the Olympia oyster is between 500 and 600 cubic centimeters (approximately 1 to 1½ pints) per hour. Japanese oysters cease feeding at the temperature of 6° to 7° C. (43° to 45° F.); Olympia oysters stop feeding at the temperature of 8° to 10° C. (46° to 50° F.).

Factors which affect spawning.—A study of spawning of oysters has been continued and experimental work was carried out at Woods Hole, Mass., Galveston, Tex., and Pacific Grove, Calif. The experiments were undertaken for the purpose of determining the factors which control the discharge of the sex products of the female and male oysters. The results obtained during last year confirm the conclusions previously reached and reported in the annual reports for 1927 and 1928, and add some new facts which were unnoticed in previous experiments. It has been observed during the experiments at Woods Hole that the spawning of male oysters can be stimulated not only by the addition of eggs or egg water, but also by the addition of the sperm. In the latter case, the latent period of the reaction—that is, time elapsed between the addition of sperm and the beginning of the reaction—is about 10 minutes, the same duration as in the case of stimulation of the female by sperm. Since the active principle of the sperm suspension does not pass through collo-

dion membrane and is probably located in the body of the spermatozoa, the hypothesis was advanced that it acts upon oysters through the digestive tract. Indirect evidence in support of this view is found in the fact that particles suspended in the water surrounding the gills reach the stomach in about 10 minutes. Experiments carried out with Japanese oysters supported all the findings made in the experiments with the eastern species. The only difference was that the critical temperature below which spawning of the Japanese oyster does not occur, is 25° C. (77° F.) instead of 20° C. (60° F.) as has been determined for the American species; and that without the addition of sperm a temperature of 30° C. (86° F.) instead of 27° C. (81° F.) induces spawning of the Japanese oyster. The males of *Ostrea gigas* respond to the addition of eggs even at a temperature of 10° C. (50° F.). Since the temperature of Puget Sound rarely reaches 15° C. the failure of this species to propagate here is explained.

Potential fecundity of oysters.—The potential fecundity of oysters—that is, the number of eggs developed by the female—was studied by Dr. Paul S. Galtsoff at Woods Hole laboratory. A female oyster, placed in a glass tank and having an upper valve attached to a recording apparatus, was induced to spawn. After the reaction was finished, the water was vigorously stirred and the number of eggs was enumerated by taking four samples of 100 cubic centimeters of water and counting the eggs in a Sedgwick Rafter camera. It was found that the female, which was 5 inches long and 4 inches wide, discharged 109,000,000 eggs (this figure is correct within 10 per cent). This figure is much higher than all estimates made by previous observers (from 2,000,000 to 60,000,000). When this oyster was dissected, it was found that the gonads were still full of eggs, the thickness of the gonad layer being about 0.7 centimeter. Since previous experiments have shown that one female may spawn 6 or 7 times during the season, the conclusion can be reached that one oyster may produce nearly half a billion eggs.

Effect of temperature on heart beat.—A study of the effect of temperature on heart beat was carried out by H. F. Prytherch at the laboratory of the University of Pennsylvania.

In their natural environment, oysters are subjected to water temperatures ranging from approximately 0° to 30° C. (32° to 86° F.). By observing the heart beat at different temperatures throughout this range, we are able to determine the relative degree of activity of the metabolic and other physiological processes of the organism, such as feeding, respiration, development of the gonads, etc. The average of all these experiments shows clearly that an increase in temperature produces an increase in the rate of beat. The heart beat was observed to stop at low temperatures ranging from 2.5° to 5° C. (36.5° to 41° F.), which supplies further evidence of the hibernation of the oyster during cold weather. The study of heart beat also shows the relative importance of water temperature during the spring and summer months on the growth, development, and ripening of the reproductive products. Since metabolic processes are directly proportional to temperature, it is evident that fluctuations from the normal temperature will have a direct bearing on the oyster industry.

Phenomenon of setting.—A study of the physiology of the oyster larvæ was continued by H. F. Prytherch at Milford, Conn. It was discovered in 1928 that copper salts would produce setting of a fully developed oyster larva, or in other words, cause it to go through the processes necessary for its attachment and metamorphosis. By using extremely minute quantities of this metal, it was possible to obtain for the first time detailed observations and photographs of this important stage in the life history of the oyster.

The setting of the larva is a biological reaction of a most positive character, which occurs in nature under rather definite physical conditions. In Milford Harbor, setting was observed to occur during the period of low slack water, which differs from all other stages of tide in that the salinity and hydrogen-ion concentration of the water are lowest and the temperature highest. In other words, setting occurs at a stage of tide when the effect of river discharge is greatest on the physical condition of the water over the oyster beds. By experiments carried out during the past two summers, it was found that changes in salinity, temperature, oxygen content, and hydrogen-ion concentration would not produce the setting of the larva in a single instance. However, when the salinity was reduced by the addition of river water instead of distilled water, setting took place, which indicated that either some substance or physico-chemical change introduced by river water was responsible for the producing of the setting reaction.

A series of experiments was then undertaken to test the effect of the various chemicals occurring in river water on the setting of the larva. Various concentrations of the chlorides, carbonates, and sulphates of sodium, potassium, calcium, and magnesium gave negative results, as did also sodium nitrate and nitrite and compounds of aluminum, lead, zinc, tin, silver, and iron. The only substance that gave a positive setting reaction was copper in the form of a pure metal or as a carbonate, sulphate, or chloride. Concentrations of 1 part copper to 500,000 or 1,000,000 parts of water were sufficient to produce setting and initiate almost immediately the beginning of the attachment process.

In river water, copper occurs in extremely small amounts and at periods of low slack water there are undoubtedly enough free metal ions to stimulate the larva and cause setting. In water of low salinity (16 per mille) the process of setting required 15 to 30 minutes; while in salinites of 25 to 28 per mille, the larva seemed to experience considerable difficulty in secreting the byssus and cementing fluid and did not become attached for 2 or more hours after exposure to copper ions. This phase of the setting problem will be taken up in greater detail during the coming summer.

The studies thus far show quite conclusively that the copper brought down by the river may become a factor which controls the time and place of attachment of oysters.

SURVEYS OF OYSTER BOTTOMS

Alabama.—In April, 1929, at the request of I. T. Quinn, Alabama State Conservation Commission, Dr. Paul. S. Galtsoff made a survey of the oyster bottoms with the view of determining the

extent of the damages to oyster reefs caused by the flood and finding a method for the rehabilitation of the destroyed bottoms. The State conservation department cooperated in this work by providing a suitable boat with equipment and by supplying the necessary labor. The party, consisting of Drs. P. S. Galtsoff, R. H. Luce, State Deputy A. Ackridge, and several members of the "sea food emergency committee of the Mobile Chamber of Commerce" visited all the principal public reefs in Alabama waters and determined the percentage of oysters killed. The destruction of oysters was found to be so extensive that the necessity of immediate rehabilitation of the reefs was self-evident. The percentage of survivors on the reefs of Mobile Bay varied from 0 to 6.6 per cent; 15 per cent of the oysters survived at Grants Pass. The oysters on the principal reefs in Alabama waters (White House, Cedar Point, Grants Pass) were

FIGURE 11.—Oyster fleet, Delaware Bay

either completely destroyed or their number was so reduced that the reefs can not become productive unless they are rehabilitated by the planting of new stock. Oysters along the southern shore of Mississippi Sound were not affected by the flood.

The following recommendations for the rehabilitation of the destroyed oyster bottoms were made: (1) Establish spawning beds; (2) plant cultch (shells) in the immediate vicinity of the spawning beds; (3) restock the reefs with seed oysters; and (4) during the rehabilitation period, the reefs should be closed to all oyster fishing and efficiently patrolled.

Delaware Bay.—From September 1 to the latter part of November, a survey of the oyster industry of New Jersey and Delaware in Delaware Bay was made by W. H. Dumont. The area of natural beds producing seed oysters is approximately 8,000 acres in New Jersey and 400 acres in Delaware. Comparing these figures with

the data for 1910–11, it is found that this is an increase of about 15 per cent for the New Jersey side and a decrease of about 50 per cent for Delaware. The planted bottom under lease from the States is 29,600 and 6,800 acres, respectively.

Effect of pulp-mill wastes on oysters in Shelton Bay.—In compliance with numerous requests made by the oystermen of Shelton Bay, Wash., a study of the effect of sulphite waste liquor discharged by the pulp mill has been undertaken. A temporary laboratory has been established in one of the floating "oyster houses" in Totten Inlet near Olympia. The work, which was begun in November, 1929, is being carried on by Dr. A. E. Hopkins and H. C. McMillin. A complete report of these investigations will appear at a later date.

CONTROL OF ENEMIES

Starfish.—An investigation for the control and elimination of starfish on oyster beds in Long Island Sound, N. Y., where it is the most serious natural enemy of the oyster, was carried out from June to September by Miss Louise Palmer. The life history and growth of the animal were studied, and a series of experiments was carried out to ascertain the susceptibility of starfish of different ages to various chemical substances. It has been found that starfish of Cold Spring Harbor, Long Island, spawn the first and second weeks of July and set on the grass and shells the first or second week of August. The spawning temperature varies from 23.5° to 26° C. (74° to 79° F.).

The minute stars are very destructive to the newly set oysters, and consequently are objects of special consideration for eradication. Unfortunately, starfish are not very sensitive to environmental changes or the presence of toxic substances. It has been found, however, that concentrations of copper sulphate from 20 to 150 parts per million, while not affecting young oysters are very effective in killing starfish. This effect is not dependent on temperature. The study of the methods of controlling starfish will be continued, and it is hoped that a practical solution of the problem will be found.

The oyster drill.—A study of the biology of the oyster drill, carried on at Beaufort, N. C., by Dr. Henry Federighi since 1926, has been completed, and the report was submitted for publication. The results of this investigation made possible the recommendation of certain measures to control this destructive species, some of which had already been mentioned in previous reports. A new method of catching drills has been developed and successfully tested at Beaufort. It consists in using small concrete pillars, which are placed on the infested oyster bottom. Because of the tendency of the drills to creep upward, the animals gather on the pillars and are then taken out and destroyed. Pillars of the size of 12 by 10 inches have collected as many as 500 drills in 3 days.

FRESH-WATER MUSSEL INVESTIGATIONS

Mussel culture.—The new system of mussel culture worked out for the bureau by Dr. M. M. Ellis at the Fairport station during the summer season, and at the University of Missouri under the supervision of the bureau during the college year, has made the advances

outlined for it in last year's annual report. It was then stated that particular attention would be given to developing individual mussel culture units to handle a greater number of glochidia at a time. The capacity of these units has been tripled in the course of the last six months, so that each unit will now handle one and one-half million at a time. Several such units have been operated to capacity, several times producing some five or six million young mussels in the course of the summer and fall. These were held sufficiently long to determine that they were normal and healthy. Then at intervals portions of them were analyzed to determine proportions of essential chemicals at the various periods.

The young mussels actually produced in the few mussel culture units used were sufficiently great in number to warrant the assumption that the large-scale production of mussels is established as economically feasible. Two million of the young mussels produced at Fairport were removed to the University of Missouri by car, where they arrived in perfect condition. This made certain that young mussels may be transported safely to streams for planting.

Further experiments at the university regarding this last problem have shown that transportation may be made with maximum success during the first three days after completion of metamorphosis from the glochidial stage, or after a period of three weeks from this date.

Mussel surveys.—During the summer of 1929 considerable attention was given to the problem of determining chemical requirements of waters suitable for the planting of mussels. A trip was made by Doctor Ellis and Mr. Chamberlain to mussel waters of Arkansas, Louisiana, Texas, and Mexico where many waters were examined ranging from some very decidedly alkaline to others distinctly acid. Notes were also made of the mussel fauna, if any, present in each. At the same time the mussel resources of the Rio Grande Valley, on both sides of the international boundary, were given a hurried survey.

Texas has not had a reputation in the past as a mussel-producing State, but as a result of the increased cost of commercial mussel shells during the past few years, it has proved economic to ship shells to the pearl button manufacturing centers in the Middle West and in the East. As a result the mussel resources of Florida and of Texas, but particularly of the latter, have been given increased attention during the past two years. The hundreds of miles of irrigation canals built in the citrus section of the lower Rio Grande Valley were found to contain an extensive supply of mussels of commercial value. In addition several rivers in Texas have produced many carloads of shells during the past year.

Depletion.—The evidence of further mussel depletion in most of the heavily worked mussel waters of the country during the past year has been striking. A survey during the past summer of the formerly productive Lake Pepin, between Minnesota and Wisconsin, has shown a pronounced decline in mussel population.

The same depletion has been evident in many mussel waters with the result that the price of raw material has most seriously mounted. How far the newly developed mussel territory in Texas and Florida will meet the deficiency is not yet known. Some effort to meet the

deficiency by importing fresh-water mussel shells is being made. A small number of tons of Chinese shells have been imported. Mexican resources are being looked into. Two companies are sending representatives to South America. Canada has mussels of commercial value but so far permits only the most limited and restricted shelling for domestic use only. Siamese shell resources are being examined by Dr. H. M. Smith, adviser in fisheries to the Siamese Government.

The most cordial cooperation in the bureau's mussel work has been extended by the various State departments. All are ready to assist to the utmost when the bureau's new mussel culture system is definitely started on large-scale production. This assistance will be both the closing of more mussel territory to protect the planting of young mussels and the furnishing of stock mussels for the actual propagation work.

○


6
7
8
9
10
70