REPORT ON THE INQUIRY RESPECTING FOOD-FISHES AND THE FISHING-GROUNDS.

By Hugh M. Smith, *Assistant in Charge.*

In the accompanying outline of the work of this division during the fiscal year 1899 there are considered (1) the investigations which have been undertaken in the lakes and streams with reference to the abundance, distribution, habits, etc., of the fishes and other animals; (2) a number of miscellaneous investigations in the waters of the Atlantic coast, including Puerto Rico; (3) special studies of important economic fishes; (4) the researches at the marine biological laboratories of the Commission, and (5) various minor inquiries and duties.

INVESTIGATIONS OF THE INTERIOR WATERS.

BIOLOGICAL SURVEY OF LAKE ERIE.

For a number of years past the Fish Commission has appreciated the importance of a systematic biological and physical investigation of the Great Lakes, in conjunction with the extensive fish-cultural operations which are there carried on by the Government and States and with canvasses of commercial fisheries by the Commission. It has been evident that the conditions affecting the supply of food-fishes could not be thoroughly understood and the institution of proper measures for maintaining the supply could not be brought about without a knowledge of the mutual relations of all the organisms directly or indirectly associated with the fishes, but more especially the minute animals and plants known to have a pronounced influence on the abundance and distribution of fishes.

As a preliminary step in the thorough exploitation of the Great Lakes in the interests of the fisheries and fish-culture, the Commission, in July, 1898, began a biological survey of Lake Erie. Headquarters were established at the Fish Commission station at Put-in Bay, Ohio, on South Bass Island, which is conveniently located in a part of the lake where commercial fishing is very extensive and where the artificial propagation of white-fish, wall-eyed pike, and lake herring is prosecuted on a large scale. Prof. Jacob Reighard, of the University of Michigan, was placed in immediate charge of the work, and the following persons were associated with him during the summer and fall: Prof. H. B. Ward, University of Nebraska; Dr. H. S. Jennings, Dartmouth College; Dr. Julia Snow, University of Michigan; Mr. A. J. Pieters, U. S. Department of Agriculture; Dr. W. C. Kendall and Mr. M. C. Marsh, U. S. Fish

Commission; Mr. R. S. Rowland, of the Univerity of Michigan, and Mr. R. C. Young. The superintendent of the station, Mr. J. J. Stranahan, and others connected with the hatchery, rendered assistance throughout the season.

Professors Reighard and Ward devoted some time to the designing, construction, and experimental use of a number of pieces of apparatus required in the plankton investigations, including a hydrophore (for bringing up samples of water from any required depth), a large plankton net, and an appliance for measuring the flow of water through plankton nets. They also gave special attention to the determination of the minute floating organisms preliminary to quantitative plankton work; 103 true plankton organisms were found, of which 6 were protozoans, 4 rotifers, 9 crustaceans, and 84 algæ. It is interesting to note that Apstein records 82 plankton forms from the German lakes, 6 being protozoans, 23 rotifers, 19 crustaceans, 2 spiders, 1 mollusk, 1 turbellarian, and 31 algæ. The scarcity of protozoans and rotifers in the Lake Erie plankton, as regards both species and individuals, is somewhat surprising, as these animals are abundant in Lake St. Clair and Lake Michigan at the same season. The crustaceans are quite numerous as to individuals, but not as to species, while the algæ are exceedingly abundant as regards both individuals and species. The Lake Erie plankton, therefore, as thus far studied, consists practically of algæ and crustaceans.

Dr. Jennings was engaged in the study of the protozoans and rotifers of the adjacent waters. The former were studied chiefly in an experimental way, with special reference to the influences which determine the movements of aquatic organisms and the laws by which they are regulated. Taking the common ciliated infusorian, *Paramœcium caudatum*, as a representative simple organism, its activities and reactions to chemic stimuli were fully analyzed. The work was successful in establishing general principles of much importance regarding the factors which govern the movements of such animals. Two papers of Dr. Jennings, embodying the results of these studies, were published, by permission of the Commission, in the American Journal of Physiology for May, 1899. These were "The motor reactions of *Paramœcium*" and "Laws of chemotaxis in *Paramœcium*." The region was found to be exceedingly rich in protozoa, upward of 70 species being identified, although these were only a small percentage of those observed. The adjacent swamps furnished many interesting species, including the gigantic infusorian, *Bursaria truncatella*, *Volvox*, and other related forms. Special attention was directed to the forms of which cultures could be kept in the laboratory, so that they could be obtained in large quantities.

Studies of the rotifers were carried on from the systematic and faunistic standpoints. The shore, bottom, and swamp rotifers were exceedingly abundant, but those of the open waters were very scarce. About 100 species of rotifers were identified, including some new and

rare forms, one of considerable interest being *Trochosphæra*, originally described from China and recently found in the Illinois River. An extended illustrated report on the rotifers is in preparation.

In addition to his other duties Professor Ward was engaged in the collection and study of the parasites infesting fish.

Dr. Snow gave attention to the determination of the microscopic aquatic plants of the neighborhood, especially those occurring in the plankton. By means of cultures the identification of many species was greatly facilitated, and species were found in the plankton that would otherwise have been overlooked. Experiments were conducted showing the rate of growth of the lower forms of algæ, and many interesting observations were made on these important constituents of the plankton. During the season 130 species were noted, of which 84 were found in the plankton, as before stated.

Mr. Pieters's inquiries were directed to the aquatic plant life in the harbor of Put-in Bay, East and West harbors, Portage River, and Sandusky Bay, and consisted in part in making an inventory of the plants and in part in a determination of the laws of their distribution. Intimate relations exist between the water-plants and the fish.

During August, September, and October, Dr. Kendall and Mr. Marsh made collections of the fishes of the Put-in Bay region and other parts of the lake, studied their food habits, and collected parasites and the contents of fishes' stomachs. Forty-two species of fish were detected at Put-in Bay, and over 700 stomachs, representing 27 species, were examined. Efforts to secure young white-fish with shore seines, small-mesh gill nets, and other apparatus were unsuccessful.

With slight modifications the hatching-room at the station was found to be well suited for laboratory purposes, being commodious, light, and supplied with gas and running water, as well as close to the dock. The diversity of the surroundings makes the Put-in Bay region an excellent place for the study of important general problems pertaining to the fisheries of the Great Lakes. As a location for summer work it has unusual advantages, and arrangements have been made for the renewal of the investigations during 1899. There is, however, no deep water near Put-in Bay, and this is a drawback to studies of the plankton and of the life-history of the white-fish and some other species. Should it be determined to establish a permanent biological station on the lakes, a more favorable site might be found, but a decision on this matter must depend on an examination of other regions.

THE SEBAGO LAKE BASIN.

Sebago Lake ranks second in size among the many large lakes of Maine, and from the fish-cultural, angling, and scientific standpoints is one of the most interesting bodies of water in the United States. It was from this lake that Girard, in 1852, received the specimens of landlocked salmon on which he based his description of *Salmo sebago*, a fish which has since come into great prominence on account of its superior game and food qualities, and has been extensively propagated

by both national and State authorities. Various other features of the fish fauna of this lake and adjacent waters are also of general interest. In pursuance of the policy of the Fish Commission of investigating the biological and physical conditions and the fishery resources of the important inland waters, Sebago Lake seemed to afford an inviting field for the inauguration of an examination of the lake systems of Maine, whose inland fishing resources are perhaps more carefully guarded and generously fostered than those of any other State. The facts that no systematic examination of the fish fauna of this lake had ever been made, that it had been the field for extensive fish-cultural operations, and that the supply of its most noted fish was apparently diminishing, were additional reasons for taking up this inquiry.

Accordingly, in 1898, Dr. W. C. Kendall, of this division, began an investigation of the Sebago basin; the work commenced on July 1 and continued until the early part of August of that year, and being resumed on May 20, 1899, was in progress at the close of the fiscal year. That part of the extensive Sebago basin which was examined during this period included Sebago and Little Sebago lakes; Thomas, Panther, Rattlesnake, Pettengill, and Chism ponds; Songo and Presumpscot rivers, and various small ponds and brooks.

The primary object of the inquiry was a thorough study of the landlocked salmon, its habits and environment. Due attention, however, was given to other fishes of the region. The physical features of the waters (depth, temperature at different depths, character and contour of bottom) and the general faunal and floral aspects were considered because of their important bearing on the salmon and other fishes.

The salmon of Sebago Lake attain a larger size than those of any other American lake. Their maximum weight is 25 pounds, and the average is 8 or 10 pounds. The largest captured in 1899 weighed 17½ pounds. As soon as the lake is free from ice salmon-fishing begins, the fish being then in eager pursuit of the smelt (*Osmerus mordax*), which are running up the streams from the lake to spawn. The smelt is the principal food of the salmon at this and other times. When the run of smelt is over salmon-fishing is considered as at an end, owing to the erroneous assumption that salmon will not bite again during the season. Although fishing has of late been comparatively poor and has apparently not been improved by the planting of many thousands of fry, the salmon are still fairly numerous, as shown by the numbers observed on the spawning-beds in fall. An abundance of natural food may have caused the recent diminished catch; this theory is entertained by some persons. Another explanation is that the fish descend to the sea over dams and other obstructions which prevent any return to the lake.

Whether the landlocked salmon is a distinct species or only a variety of the sea-going fish (*Salmo salar*) is a question not yet settled to the satisfaction of all zoologists, for the reason that no one has had material enough for study to enable him to reach a definite opinion. The indications are that further research will reveal enough structural differ-

ences to establish the landlocked salmon of the Sebago system as a species distinct from the sea salmon, unless intergradations be found through the various forms of landlocked salmon of Sebec Lake, Union River, Grand Lake, and the Canadian streams.

Salmon locally known as "jumpers" are found in the Presumpscot River throughout the year, and may be taken at all times with artificial fly or other lure; they do not enter the lake. These fish differ in size and color from the regular lake salmon, and reach maturity when 10 or 11 inches long. Their maximum weight is 4 pounds, but the average is only 1 to 1½ pounds. The "jumpers" subsist largely on insects and insect larvæ. A critical examination of the large series of those fish that was preserved may show that they are specifically distinct from the landlocked salmon, although it is more probable that they will prove to be simply the landlocked form that has been modified by a restricted habitat.

Smelts are the most abundant fishes inhabiting the lake. During warm weather they live at a depth of 100 to 150 feet. At times they rise to the surface, and for some unknown reason migrate in large bodies, acres in extent, from one part of the lake to another. During such movements salmon may usually be observed in the vicinity. The Sebago smelts represent two forms, one reaching maturity when 5 or 6 inches long, the other becoming much larger (from ¾ to 1½ pounds).

Other species inhabiting this lake are brook trout (*Salvelinus fontinalis*), pickerel (*Lucius reticulatus*), horn-pout (*Ameiurus nebulosus*), sucker (*Catostomus commersonii*), eel (*Anguilla chrysypa*), sun-fish (*Eupomotis gibbosus*), black bass (*Micropterus dolomieu*), yellow perch (*Perca flavescens*), white perch (*Morone americana*), fresh-water cusk (*Lota maculosa*), and various cyprinoids.

Little Sebago Lake has a fish fauna similar to that of the larger lake, but, so far as known, contains no salmon. Black bass and pickerel are the principal game-fish, the former being very abundant and attaining a large size. Thomas Pond is connected with Sebago Lake by a short stream obstructed by a milldam. Trout-fishing is good here in spring and summer, and an occasional salmon is taken, but it is always a long, slender male, known as a "racer," probably a survivor of plants made in the pond a number of years ago. Panther and Rattlesnake ponds contain trout, and have been stocked with salmon; the latter, however, are never caught, although sometimes observed in Panther Pond on gravelly shoals in fall.

GREAT SALT LAKE.

For a number of years the citizens of Utah have from time to time agitated the question of utilizing for fish-cultural purposes the waters of Great Salt Lake, and have expressed the wish that the general government, through the U. S. Fish Commission, would make the necessary investigation to determine the feasibility of the project. The Commission has also been importuned to make experimental plants of fish and other animals in the lake and its tributary streams. While it was

known that the salinity of the open lake is so great as to preclude the possibility of the acclimatization of useful marine animals, it had been suggested that in certain bays or arms of the lake, in which the rivers discharge, and where the density is lowered to a point somewhat less than that of ocean water, it might be possible for oysters and clams, crabs, terrapins, and even fish to survive and multiply.

In September, 1898, Dr. H. F. Moore was ordered to Utah, and spent about a month in studying the physical conditions of this lake near the mouths of Bear, Weber, and Jordan rivers, and in ascertaining the availability for aquiculture of several brackish springs in the vicinity of the lake. A report* on this investigation will be found among the appendices in the present volume.

Great Salt Lake has a length of 80 miles and a maximum width of 35 miles, the area in 1898 being about 1,750 square miles. The drainage area of the Great Salt Lake basin is about 54,000 square miles. Nearly all the fresh water entering the lake is discharged by the three rivers named. The density of the open lake in November, 1897, was 1.168, or more than seven times the maximum density in which oysters will grow.

It was appreciated by the Commission at the outset that the only possible chance for acclimatization experiments was in those parts of the lake where the rivers debouched. It was found, however, that the zone of mixed water was not only very narrow, but also had no fixed position, moving irregularly back and forth under the influence of several agencies beyond control. To attempt, therefore, to introduce oysters, crabs, or marine fishes in the lake would be manifestly useless. The objections to the planting of such animals are based on physical rather than on biological conditions, as there is an abundant food supply, brine shrimp (*Artemia gracilis*), insect larvæ, and minute plants being very numerous. While it is not improbable that oysters could be raised in suitably constructed ponds fed by some of the brackish springs, the venture would be costly and might not prove financially successful, even if feasible as an experiment.

While the results of the investigation were thus entirely negative as regards the practicability of introducing useful animals into the lake, the work was useful in setting the question at rest and in providing definite data with which to answer those persons who have cherished the belief that the lake might be thus utilized.

Attention may be drawn to the probability of increasing the fish supply of this region by introducing cat-fish and other hardy species in the fresh-water sloughs near the mouths of the rivers. Efforts to secure a run of shad or other anadromous fishes in the rivers entering the lake will, however, undoubtedly fail. Considerable numbers of young shad have been deposited by the Commission in these streams, but there are no evidences of their survival.

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*An inquiry into the feasibility of introducing useful marine animals into the waters of Great Salt Lake. By H. F. Moore. Report U. S. Fish Commission 1899, pp. 231-250.

DISTRICT OF COLUMBIA.

Studies of the fish life of the District of Columbia and vicinity, which had been in progress for several years, resulted in the preparation of a preliminary report* on the subject by Dr. H. M. Smith and Mr. B. A. Bean. Although the food and game fishes of the region have received considerable attention, there has been little notice taken of the smaller species which are important as food for the others, and no list of the fishes of the locality has been published.

The observations and collections so far made show a more extensive fish fauna than has generally been attributed to the region, while further inquiry will doubtless disclose the occurrence of other species. The number of species at present known is 81, of which about 30 are of direct economic value. The work of the Commission in acclimatizing useful fishes has been very successful in the Potomac, some of the best species having been introduced. Among those which have become abundant are the large-mouth black bass, small-mouth black bass, calico bass, and crappie. One of the most interesting features of the District fauna is the regular or accidental appearance of typical salt-water fishes, about a dozen of which have thus far been recorded.

SAN PEDRO RIVER, ARIZONA.

This stream is one of the southern tributaries of the Gila River, a branch of the Colorado. It rises in Mexico and pursues a northerly course of about 130 miles in Arizona before joining the Gila. The fish fauna of the river has been practically unknown. In the spring of 1899 Dr. P. H. Kirsch, formerly fish commissioner of Indiana, but now residing in Arizona, volunteered to make an examination of the fish life of this river for the Commission and prepare a report thereon. The inquiries began in the vicinity of Benson, and will be extended so as to embrace the entire basin of this river.

BASIN OF THE COLUMBIA RIVER.

Lake Chelan, Washington.—In August, 1898, Prof. B. W. Evermann visited Lake Chelan, Washington, for the purpose of determining the general features of the fish fauna, and whether any species of salmon resort to it or its tributaries for spawning purposes. This lake is one of the largest bodies of water in the interior of the Northwestern States, and is by far the largest lake in Washington. It is located wholly in Okanogan County, and extends in a generally northwesterly direction for 60 or 65 miles, its width varying from three-fourths of a mile to 2 miles. It occupies the bed of an old glacier, and on the north is surrounded by high mountains of the Cascade Range, but at the lower end there are only hills. The lake discharges into the Columbia River through an outlet—the Chelan River—8 or 9 miles long, the descent from the lake to the Columbia of 445 feet being broken by a series of rapids and cascades. While the falls are quite high during low water, it is thought they do not constitute a barrier to passage of fish when

* List of fishes known to inhabit waters of the District of Columbia and vicinity.

there is high water in the Columbia. The lake water is very cold, but never freezes except in the bays. The elevation of the lake surface is 1,108 feet; and the maximum known depth is 1,499 feet.

Among the fishes inhabiting the lake are the following, all of which are more or less abundant: Bull trout (*Salvelinus parkei*), lake trout (*Salmo clarkii*), sucker (*Catostomus macrocheilus*), squaw-fish (*Ptychocheilus oregonensis*), chub (*Mylocheilus caurinus*), white-fish (*Coregonus williamsoni*), and fresh-water cusk (*Lota maculosa*). It is the general opinion among people living in the vicinity that no kinds of salmon ever reach the lake. Further study of the fishes and the other animal resources of this lake would prove interesting, and a small party might well devote a season to the investigation.

Kootenay Lake and River.—Kootenay Lake and its tributaries are in the basin of the Upper Columbia River, and are of importance in connection with the extensive studies of the salmon and other fishes of that stream that have been carried on by the Commission in recent years. The Kootenay is a large stream rising on the slopes of Mount Stephen and Mount Lefroy in British Columbia; it flows south into Montana, then west and northwest through Idaho, and then back into British Columbia, where it widens into Kootenay Lake, which extends north and south about 100 miles. The lake is peculiar in having its outlet on the west side about equally distant from the two ends, and the flow of water is thus from both ends toward the middle. The outlet, Kootenay River, is about 50 miles long, and flows into the Columbia. It is a very rapid stream, full of cascades and turbulent rapids. Although perhaps no one of the falls forms a barrier to the ascent of salmon, it seems almost impossible that fish would be able to surmount the entire series. For a distance of about 90 miles the upper part of Kootenay River is approximately parallel with and only a few miles from the Columbia, but flows in an opposite direction. It then trends toward the west and runs within a few rods of Upper Columbia Lake, the source of Columbia River. It is reported that several years ago a channel was cut between these waters and that boats were thus enabled to pass from one to the other; though no longer used for such purposes, the water connection is said to still exist.

A preliminary examination of this region was made by Prof. B. W. Evermann in August, 1898. Kootenay Lake was visited at Nelson, British Columbia, 200 miles north of Spokane, Washington, and inquiries as to the lake and river were made at Bonners Ferry, Kootenay Falls, and Yakt, on the Great Northern Railroad. The fishes ascertained to inhabit these waters include sucker (*Catostomus macrocheilus*), squaw-fish (*Ptychocheilus oregonensis*), white chub (*Mylocheilus caurinus*), several trouts (*Salmo*), locally called "lake trout," "brook trout," "rainbow trout," and "salmon trout;" white-fish (*Coregonus williamsoni*), and red fish (*Oncorhynchus nerka*). The small form of the red-fish was found in several creeks in the vicinity of Nelson, and seems to be generally distributed throughout the region. It is utilized to a limited extent for

food, and is regarded as a food-fish when first seen in the streams. It has the same habits exhibited by the little red-fish of the Idaho lakes; it is observed only in the fall, and then in the small streams where it goes to spawn. The fish is probably resident in the region, though the evidence is not conclusive.

Lake Cœur d'Alene, Idaho.—This lake has considerable interest to the Commission because of an attempt to establish therein the common white-fish (*Coregonus clupeiformis*) of the Great Lakes. In February, 1889, the Commission planted 1,930,000 white-fish fry in 8 lots, and had reason to believe that the cold, clear, deep water of the lake would prove suitable to that species. On several occasions since the deposits were made, representatives of the Commission have visited the lake and searched for white-fish, but have learned nothing indicating that the fish have survived. Several reports of the capture of the introduced species have from time to time been received, but the evidence has indicated some other fish. In August, 1898, Prof. Evermann made a short visit to Lake Cœur d'Alene in order to secure additional information on this subject and to determine the advisability of a thorough investigation regarding the results of the plants and the adaptability of the lake to this species of food-fish.

The native fishes of this lake, so far as known, are bull trout (*Salvelinus parkei*), black-spotted trout (*Salmo clarkii*), western white-fish (*Coregonus williamsoni*), two suckers (*Catostomus catostomus* and *C. macrocheilus*), squaw-fish (*Ptychocheilus oregonensis*), minnow (*Leuciscus balteatus*), short minnow (*Agosia nubila*), dace (*Rhinichthys dulcis*), and blob (*Cottus rhotheus*). The falls in the Spokane River, about 6 miles below the lake, are effective barriers to the ascent of salmon, none of which have ever been known to reach the lake.

While several additional reports of the taking of the common white-fish were heard, Professor Evermann's inquiries led him to believe that the planted fish have not survived. The evidence, however, is inconclusive; and the outcome of the plants may remain a matter of speculation until a thorough examination of the lake is made. The methods of fishing now pursued in the lake are not adapted to the capture of the white-fish. Gill nets of relatively fine mesh, such as are used for white-fish in the Great Lakes, will be required in order to demonstrate the existence of this fish in Lake Coeur d'Alene. The fishery resources of this fine body of water are of sufficient prospective importance to warrant a comprehensive investigation by the Commission while the normal conditions are still undisturbed by commercial fishing. The survey should extend over several months and continue late enough in fall to cover the spawning season of the common white-fish. Supplementary to the examination of this lake, attention should be given to tributary streams and several smaller lakes in the vicinity, especially Herman Lake, in which the yellow perch (*Perca flavescens*) is said to be very successfully introduced, and lakes at the headwaters of the St. Joseph and Cœur d'Alene rivers.

SACRAMENTO BASIN.

In conjunction with special studies of the salmon in the Sacramento Basin, elsewhere referred to, Mr. Rutter and Mr. Chamberlain made extensive collections of the fishes and secured interesting new data concerning the distribution, abundance, etc., of the fishes in the various parts of the basin; several undescribed species were obtained. About 25 days in August and September were mainly devoted to visiting the streams tributary to Pitt River and the headwaters of Feather River and Mill Creek. Collections were also made in Goose Lake, Grasshopper Lake, Eagle Lake, and Susan River, on the road between the headwaters of Pitt and Feather rivers.

MUSSELS OF MISSISSIPPI RIVER.

The business of utilizing the shells of the native fresh-water mussels (*Naiades*) in the manufacture of buttons has been established in the United States within a comparatively few years, the headquarters of the industry being in Iowa and Illinois, in the basin of the Mississippi River. The rapid increase in the business has resulted in extraordinarily active fishing operations, and has led to the fear that the available supply of shells might become exhausted. At the request of a number of persons who were interested in the industry along a part of the Mississippi River, the Commission undertook an investigation having for its object the determination of the present conditions and methods, the mussels utilized, and the measures, if any, necessary to the maintenance of the mussel supply. The writer was assigned to this inquiry, and in July, 1898, visited the centers of the business. Special attention was given to the species of mussels utilized in button-making, their peculiarities, abundance, distribution, destruction by natural agencies, and the effects of fishing on the supply. A report* which embodies the results of this investigation is printed in the Bulletin of the Commission for 1898. The same volume also contains another timely paper on this subject, namely, "The pearly fresh-water mussels of the United States, their habits, enemies, and diseases, with suggestions for their protection," by Mr. Charles T. Simpson, of the U. S. National Museum.

Of the hundreds of species of mussels inhabiting the Mississippi basin, comparatively few are adapted for buttons, and at the present time only about a dozen species are used, but other valuable species exist in various streams to which the button-makers may eventually resort. The requirements of a shell, from the standpoint of the button-manufacturer, are sufficient thickness, uniform color of the various strata, and toughness. The following species fulfill these conditions and are now utilized at the button factories on the Mississippi, the common names being those employed by the fishermen and factory-men: "Niggerhead" (*Quadrula ebena*), "bluepoint" (*Quadrula undulata*), "yellow sandshell" or "yellow-back" (*Lampsilis anodontoides*), "slough sandshell" (*Lampsilis fallaciosus*), "mucket" (*Lampsilis ligamentinus*),

*The mussel fishery and pearl-button industry of the Mississippi River. By Hugh M. Smith.

"pocketbooks" (*Lampsilis capax* and *L. ventricosus*), "deerhorn" or "buckhorn" (*Tritigonia verrucosa*), "butterfly" (*Plagiola securis*), and "hatchet-back" or "hackle-back" (*Symphynota complanata*). The leading species are the "niggerhead," "yellow sandshell," and "mucket," the first-named being more important than all others combined. It is shapeed like the common quahog (*Venus mercenaria*), and has a very thick and heavy shell, with a black or dark-brown epidermis and a glistening white nacre. The maximum size is 4½ or 5 inches and the average about 3 inches. It is often found over large areas, preferring muddy sand and muddy gravel, but also frequenting sandy bottom.

The mussel fishery is conducted along about 200 miles of the Mississippi, in Iowa and Illinois. The shoalness of the river makes every part accessible to rakes and tongs of the fishermen and renders the exhaustion of the grounds more certain, speedy, and complete. Although the fishery is under ten years old and in most places began within two or three years, it has already had such a marked effect on the mussel supply that the early exhaustion of the beds seems inevitable under present conditions. While physical and natural agencies—such as freshets, droughts, muskrats, etc.—are known to destroy at times large quantities of mussels, overfishing, the unnecessary destruction of small mussels, and the absence of any seasonal restrictions on the fishery, combined with the slow growth of the mussels and the long time required for the recuperation of the beds, are undoubtedly responsible for the recent great reduction in the supply.

The industry has attained such proportions, it represents so much invested capital, and employs so many people as factory-hands and fishermen that its suspension would prove a calamity to many communities. During the first six months of 1898 there were 49 button factories in operation along this part of the Mississippi; these employed over 1,400 people, who received $134,000 in wages. Upward of 1,000 additional persons were engaged in fishing. The mussel output during this period was about 4,000 tons, for which the fishermen received about $39,000. The output of factories was over 1,160,000 gross of buttons and "rough blanks," with a market value of $253,000.

In view of the general desire of those pecuniarily interested in the industry that the Commission recommend measures which seem necessary for the preservation of the mussel beds and the consequent maintenance of the industry, the following suggestions are given in the report cited, attention being directed to the fact that the States have sole jurisdiction over the matter: (1) The gathering of small mussels should be prohibited and a minimum legal size for each important species should be prescribed by law; (2) immediately previous to and during the spawning season the principal species should be unmolested, and a close season should be fixed by law; (3) provision should be made for the prevention of damage to the beds by sewage and factory refuse; (4) button manufacturers should exercise greater care in utilizing the shells, in order that the waste of raw material, which is now considerable, may be reduced.

INVESTIGATIONS IN COAST WATERS.

REDISCOVERY OF THE TILE-FISH.

The discovery of the tile-fish (*Lopholatilus chamæleonticeps*) in 1879, its apparent extinction in 1882, and the subsequent searches for it have been repeatedly referred to in the reports of the Commission and in other publications. The rediscovery of the fish in great abundance on its former grounds in the summer of 1898 constituted one of the most noteworthy investigations of the Commission and one of the leading features of the fishing industry during the year.

Search for the tile-fish from 1883 to 1891 gave only negative results, although in 1892 and 1893 a few scattering specimens were taken by the *Grampus* as an outcome of about five months' work. Subsequent years yielded no new information till 1897, when a Gloucester schooner accidentally set trawls on the former grounds and caught 30 specimens, as noted in the report of this division for 1897.

In 1898, in connection with the biological investigations of the Commission at the Woods Hole laboratory, the *Grampus* made three trips to the edge of the continental plateau in the vicinity of the 100-fathom line, south of southern New England and Long Island, for the purpose of determining the abundance of the tile-fish and the region over which its range extends. On each occasion the fish was found, and on two trips comparatively large numbers were taken. The first cruise, which began August 12, extended to a point about 70 miles off No Man's Land. When the trawls were set, 8 fine tile-fish were caught. As the vessel was insufficiently equipped with lines and bait, she returned to Woods Hole to refit, and sailed again for the tile-fish grounds on August 30. Sixty miles off Block Island the trawls were set three times on August 31, and 7, 47, and 19 tile-fish, respectively, were taken. On the 1st of September 78, weighing over 1,000 pounds, were caught and taken to Montauk Point, where they were distributed among the soldiers at Camp Wikoff. On the third trip, which terminated on October 2, the number taken was 203, weighing more than 3,000 pounds. The fishing was carried on between the sixty-ninth and seventieth meridians of west longitude—a section which the fish had not before been ascertained to inhabit. On each of these trips large fish were obtained in considerable numbers, and also a great many very small and immature specimens, weighing only 1 or 2 pounds, indicating that the species is actively breeding. The average weight was about 12 pounds.

While some additional investigations will be necessary in order to definitely determine the area of sea bottom over which the tile-fish ranges, it is now known that it has reestablished itself on a ground at least 175 miles long and 10 to 15 miles wide, at a depth varying from 60 to 120 fathoms. The proximity of this region to the great fishing centers and markets of the North Atlantic coast, and the abundance and excellent food qualities of the fish warrant a belief that a profitable fishery may be inaugurated. The trawl lines used by the *Grampus* were comparatively short, with few hooks, and were fished by only one dory;

it would therefore appear that vessels equipped as is usual for market fishing for "ground-fish" could obtain full cargoes in a few days.

The foregoing investigations were in charge of Dr. H. C. Bumpus, who gives an account of them in an article in the Fish Commission Bulletin for 1898, entitled "The reappearance of the tile-fish."

NARRAGANSETT BAY, RHODE ISLAND.

For a period of three weeks in October and November, 1898, the *Fish Hawk* was engaged in a special investigation of the waters of Narragansett Bay, for the purpose of determining the distribution of the star-fish in relation to the depth, temperature, and salinity of the water. Supplemental to this a study of the general biological conditions prevailing at different localities in the bay and in Block Island Sound was undertaken; 121 stations were selected for a careful examination of their biological and physical features, and extensive collections were made with the beam trawl. The inquiries show that the species of star-fish destructive to the oyster-beds occurs only within the bay; that there are certain localities in which the star-fish congregate and multiply with remarkable rapidity; that from these breeding stations the young are distributed to the oyster-grounds; that these nurseries might be destroyed at moderate expense; and that probably there is no invasion by star-fish from beyond the limits of the bay. The collections of invertebrates furnish data for a permanent record of the animal life at the present time, and will be of value in determining the effects of sewage and manufacturers' waste on the animals of the bay. The work was carried on at the request of the Rhode Island Commissioners of Inland Fisheries, and has been referred to in their report for 1898.

OYSTER-FATTENING EXPERIMENTS.

The experiments in the fattening of oysters at Lynnhaven River, Va., noticed in previous reports, were continued throughout the year under the direction of Dr. H. F. Moore, during whose absence in Puerto Rico Col. W. W. Blackford, of Lynnhaven, took charge of the observations.

By the end of the last fiscal year it had been fully determined that no advantage was to be gained by simply inclosing a pond, after the French method, and depending on the natural fertility of the water to produce the food essential for the rapid fattening of the oysters placed therein. A year's experience had shown that oysters under such conditions remained poor and lean, and were far inferior to those on the beds in the open waters of the river.

With these unfavorable conditions confronting the experiment, it was determined to attempt to increase the fertility of the inclosed water by adding fertilizer, in order to supply the pabulum required for the growth of the diatoms on which oysters feed. Accordingly, at intervals between June 28, 1898, and February 24, 1899, about 1,000 pounds of ordinary commercial fertilizer were put in the pond, which covers an area of 2 acres. The first lots were spread broadcast, while the last were deposited in marshy places at the head of the claire, so as to gradually leach into the pond, and thus approximate more closely the

natural conditions. A barrel of lime was spread around the edge of the claire, so as to be gradually washed into the water and furnish the material required by oysters in the fabrication of the shell.

Until October the oysters in the claire remained exceedingly poor, but during that month they began to improve, and in November were in better condition than those in the near-by beds in the open water. The improvement continued during December, and by January 60 per cent were as fat as oysters ever become, and the remainder were fair. These conditions remained unchanged until about the middle of April, when the proportion of fat oysters became much reduced. From November until the early part of March the claire oysters excelled those on the nearest outside beds, but in March all of the latter became fat, and soon after the former began to deteriorate. About this time the water in the claire, which had been of low density since June, 1898, became almost fresh, owing to an unusually heavy rainfall and the absence of tides high enough to flow over the crest of the claire. The salinity of the pond could have been maintained, but it was desired to study the effect of the excessive precipitation.

The reason why 40 per cent of the oysters under observation failed to attain the quality of their neighbors is not positively known, but it seems probable that it was in part owing to an irregular distribution of the food organisms. Under natural conditions the tides are the most important agent in this distribution; but the pond, being usually cut off from tidal influence, has no currents except the weak ones occasioned by winds and slight differences in temperature. It seems not unreasonable to expect that better results might be obtained by inducing stronger currents, and hence a more even dispersal of the oyster food. A plan for attaining this end is under consideration, and may be put into execution during the next year if a more uniform fattening of the oysters does not take place. These experiments promise to lead to improvements in methods that will place oyster-culture more nearly abreast of the best methods of agriculture.

The oyster business of the Lynnhaven region was better during the season of 1898–99 than for several years. The green coloration of the oysters which had prevailed disappeared by July, 1898, and, as frequently happens after such a visitation, the oysters in many parts of the bay became quite fat in the following season. The prompt disappearance of the greenness was probably due to excessive rainfall during the summer and autumn of 1898, for it seems that this peculiar affection is in some way correlated with a deficient rainfall.

FISHES OF THE COAST OF LONG ISLAND, NEW YORK.

In September and October, 1898, the Commission had the services of the well-known ichthyologist, Dr. Tarleton H. Bean, in studying and collecting the fishes of the southern shore of Long Island, New York. For about two months before his work for the Commission began, Dr. Bean was engaged in this locality in obtaining specimens for the New York State Museum. This coast has a very rich fish fauna, and about half

the salt-water and fresh-water species recorded from New York have been taken along this shore. The number of species found by Dr. Bean in the year 1898 was 84; to these may be added 79 others observed by him during previous visits, giving 163 as the present known number of species detected on this shore. A noteworthy feature of the fauna in 1898 was the absence of many fish that had been found during summer and fall in other years. Several species were recorded from Long Island for the first time, among them the rough silverside (*Kirtlandia laciniata*) and the red mullet (*Mullus auratus*). A finely-preserved series of specimens was forwarded to Washington at the close of the work, and a notice of the results of the investigation was published in *Science* for January 13, 1899.

EXPLORATION OF PUERTO RICAN WATERS.

Immediately after the acquisition of Puerto Rico by the United States plans were made by this division for an examination of the coastal and interior waters of the island for the purpose of determining the aquatic resources, about which practically nothing was known. The steamer *Fish Hawk* was assigned to the work, and sailed for Puerto Rico in December, 1898, having on board a party from the Fish Commission, Department of Agriculture, and Smithsonian Institution. Prof. B. W. Evermann was in charge of the general scientific investigations, and was assisted by Dr. H. F. Moore, Mr. M. C. Marsh, and Mr. A. H. Baldwin. Mr. August Busck represented the Department of Agriculture, and accompanied the expedition, at the request of the Department, for the purpose of studying the insects, particular attention being given to the scale insects which are liable to be introduced and become pests in the United States. Mr. A. B. Baker, of the National Zoological Park, joined the party to obtain live animals for the park and general natural-history collections for the Smithsonian Institution. The inquiries as to the economic fisheries of the island were intrusted to Mr. W. A. Wilcox, of the Commission. The *Fish Hawk* returned to the United States about the end of February, 1899.

The time allotted for the cruise was not sufficient for a thorough investigation, but the expedition was, as a whole, very successful. Although the vessel was fully equipped for all branches of marine research, the opportunity for deep-water dredging and trawling was limited, owing to the configuration of the bottom, and most of the efforts were devoted to the shores, outlying coral reefs, and short fresh-water streams. The vessel proceeded first to San Juan and thence circumnavigated the island, stopping at all places where there was safe anchorage, including Aguadilla, Mayaguez, Ponce, Arroyo, Hucares, Fajardo, and the islands of Culebra and Vieques. Frequent trips were made by members of the party to the interior, to examine the upper courses of streams, the most important being to Bayamon, Arecibo, Caguas, and El Yunque Mountain. Large collections of fishes, mollusks, crustaceans, corals, and other marine animals were obtained, and many new forms were taken. The fishes were very abundant, and over 200 species

were noted, including numerous food-fishes. Important additions to our knowledge of the fauna of the Antilles were made, and valuable data concerning the fishery possibilities of the island were gathered.

As soon as the vessel returned, the collections were sorted and distributed for study to prominent specialists, a number of important groups being assigned to assistants of the U. S. National Museum. Collections of birds, plants, and land forms generally, incidentally obtained by members of the Commission, were transmitted to the National Museum. It is the intention to bring together in one volume the scientific results of the expedition, and it is expected that the work will be a valuable contribution to the knowledge of the aquatic fauna and flora of Puerto Rico and the West Indies.

STUDIES OF SPECIAL FISHES.

VARIATIONS OF MACKEREL.

Recent investigations by Mr. Walter Garstang, of the marine biological laboratory at Plymouth, England, have shown that not only do the mackerel (*Scomber scombrus*) inhabiting our coastal waters differ strikingly in structural details and color from those found on the shores of Great Britain and Ireland, but also that the mackerel of the British coast have peculiarities among themselves by which the fish from one section may be distinguished from those of another.* Similar investigations as to the mackerel of the western Atlantic would be of great scientific value and would have an important bearing on the problems connected with artificial propagation, commercial fishing, and the international relations of the fishery.

Mr. M. C. Marsh, scientific assistant in this division, was assigned to this investigation, and spent a part of May and June, 1899, in the examination of fresh mackerel in the New York markets. Owing to the almost complete failure of the southern spring mackerel fishery, it was impossible to secure for this inquiry more than a few fish from the southern grounds, but satisfactory series of mackerel from the New York and southern New England shores were obtained for examination. Hon. E. G. Blackford, of New York, extended the facilities of his Fulton Market office to the Commission's representative, and in other ways showed his interest in the work. The inquiry will be actively pushed during the next fiscal year, although several seasons may be required to collect sufficient data from all parts of the United States and Canadian coasts.

VARIATIONS OF SHAD.

From an economic and fish-cultural point of view, as well as from a purely biological standpoint, it is of interest to determine whether the shad which frequent the waters of the entire east coast of the United States belong to one race or whether different hydrographic areas have runs of shad which may be distinguished by structural and color features. Fishermen and fish-dealers often profess to distinguish by super-

* Journal of the Marine Biological Association, 1898.

ficial characters the shad from various streams, and biologists have called attention to slight anatomical peculiarities, but the examinations have not been sufficiently extensive to establish the existence of tangible differences in shad inhabiting particular waters.

For the purpose of settling this question, so far as possible, arrangements were made to obtain series of specimens of shad from the principal streams from Florida to Maine, and a personal examination of large numbers of shad in Albemarle Sound and the Potomac River was made by the chief of the division in the spring of 1899. Considerable material for study and much information have already been collected, but more will be required before the matter can be satisfactorily settled. Detailed data for at least 100 shad from each stream are required.

HERRING OF PASSAMAQUODDY BAY.

At the extreme northeastern part of the coast of Maine the fisheries for herring (*Clupea harengus*) are more extensive than in any other locality in the State. The chief fishing-centers are Eastport and Lubec, and the principal fishing-ground is Passamaquoddy Bay and its tributaries, lying partly in Maine and partly in New Brunswick. This fish is caught almost exclusively in brush weirs and is used principally for canning and smoking. It is not only the object of the most important fishery in the Passamaquoddy region, but is of great value as bait in the line fisheries for several members of the cod family, and also furnishes food for the fish. In the interests of the fishing industry, it is of great practical consequence to have a better understanding of the general natural history of the herring, especially the relations and movements of the several distinct schools which annually visit those waters.

In the Report of the Commission for 1896 is a paper * by Dr. H. F. Moore, in which was brought together practically all that was known concerning this subject. Reference to this article will show that in many respects our knowledge of the habits of the herring is meager and unsatisfactory, particularly as regards the migrations of the fish and the relations existing between the spring-spawning and fall-spawning schools, both of which subjects have been largely matters of speculation. It is, of course, known that schools of herring appear on different parts of the shore with more or less regularity each year, sometimes to spawn and sometimes for other purposes, but it is undetermined whence they come or whither they go and whether they are the same or different bodies of fish. To successfully and intelligently deal with several problems presented by the fishery, such as the cause of the disappearance of winter herring, it is essential that these subjects be understood.

In August and September, 1898, Dr. Moore devoted about a month to a general study of the abundance and distribution of the herring in the vicinity of Eastport and Grand Manan as compared with former seasons. Particular attention was given to the critical examination of

*Observations upon the herring and herring fisheries of the northeast coast, with special reference to the vicinity of Passamaquoddy Bay. Report U. S. Fish Commission 1896, XXII, pp. 387–442, plates 60–62.

the herring from different localities with reference to their structural peculiarities and variations. Although it is impossible to keep the erratically moving fish under direct or continuous observation, by indirect methods conclusive information may be gained as to the composition of the schools. If, for example, the school which spawns in spring has for a long time been quite distinct in its membership from the school which spawns in summer and autumn, the individuals of one school would show more or less constant minor structural differences from those of the others. The distinctness of the schools could thus be demonstrated by the detailed examination of fish taken at different seasons and places. Over 5,000 accurate measurements were made by Dr. Moore, but many more will be necessary to furnish material for final discussion.

NATURAL HISTORY OF PACIFIC SALMON.

The inquiries of Mr. Cloudsley Rutter and Mr. F. M. Chamberlain regarding the habits, movements, growth, food, etc., of the salmon of the Sacramento River, referred to in previous reports, were continued during the present year, beginning July 6, 1898, and extending without material interruption to May 13, 1899. In May and June of the previous fiscal year, when all parts of the Sacramento had been visited and seining stations established at intervals of about 17 miles between Redding and Sacramento, the last of the regular downstream migration of the fry was found.

On the resumption of the investigation the same ground was again gone over, and, in addition, the lakes at the source of the Sacramento were visited and the Pitt River basin was explored, the distribution of the salmon therein being determined. One station favorable for observation, located at Sims, on the Upper Sacramento, was visited monthly from April to December in order to ascertain the relative numbers and growth of the young salmon remaining in that part of the stream.

During October and November a trap arranged for catching even the smallest salmon fry—set in Battle Creek and tended by Mr. Rutter—yielded some noteworthy results. Another trap in an adjacent part of the Sacramento River was visited regularly by Mr. Chamberlain from January to April. A third, placed in Georgianna Slough at Walnut Grove, in the lower course of the river, was tended by Mr. N. B. Scofield and Mr. Rutter from January to May.

The inquiries are now practically complete, and a comprehensive report on the natural history of the salmon is being prepared by Mr. Rutter. The following are some of the facts regarding the life of the salmon in the Sacramento River established by the investigation:

(1) Adult salmon may be found in the Sacramento at almost any time of the year; the smallest numbers are observed in the lower river during winter.

(2) There are two main runs of salmon, known as the spring and summer runs in the lower part of the river, and as the summer and fall runs in the upper waters. The fish in the early run ascend to the headwaters because the water is high and suitable spawning-grounds

can not be found in the main stream. By the time the later run reaches the middle section of the river, that is to say, from Chico to Redding, the water is so low that many fish are obliged to spawn in the main river, where numerous spawning-beds are found. The salmon of the later run, therefore, rarely go beyond Redding.

(3) The spawning period of the early run is between July and September, of the later run during November and December, though occasional spawning fish may be found any time from April to January.

(4) Shallow water with gravelly bottom and swift current is usually selected for the spawning-beds. The female selects a place, extrudes a few eggs, and moves away; the male immediately takes the same position, or sometimes a few feet farther downstream, and emits a small quantity of milt. These acts are repeated at short intervals for 10 days or 2 weeks, continuing day and night. The few eggs that are not at once devoured by small fishes float several feet or yards downstream and lodge among the gravel, where they hatch in 40 to 70 days, according to the temperature.

(5) The so-called "nests" of spawning salmon are not nests in any sense of the word, as they are not intended for eggs and do not receive eggs. These excavations, several feet in diameter and often 6 or 8 inches deep, are made by the female turning on her side and digging her tail in the gravelly bottom; the movement is probably for the purpose of loosening the eggs from the ovarian sac. Incidentally, some of the eggs may thus be covered by fine sediment, which drifts downstream.

(6) The alevins hide among the rocks about six weeks. As soon as they are able to swim, they begin feeding and moving downstream. At first they travel more at night, but as they get older and reach the lower part of the river, they migrate mostly by day. They require about three months to pass from Redding to San Francisco Bay.

(7) There are two runs of salmon fry down the river, one passing the vicinity of Redding during October, November, and December, the other during the latter part of January, February, and March. Practically all the young salmon have left the region by the 1st of April, although a few remain in the headwaters all summer.

(8) Most of the salmon return to fresh water at the age of 2½ years, and spawn 36 months after the spawning of the parents. Some, however, are a year older when they leave the sea.

The planting of salmon fry near the ocean, in order that they may not have to run the gauntlet of enemies in their long journey to the salt water, has from time to time been suggested. To test the feasibility of this project, Mr. Rutter took 50,000 salmon eggs from Battle Creek to Pacific Grove, on Monterey Bay; the eggs reached the coast on December 12 and were hatched December 19. The experiments concluded February 15. It was shown that salmon fry can not go directly from fresh to salt water, but need to pass through an estuary of brackish water. An alternation of density, such as is secured by the tides, appears to be beneficial. It was further shown that under the age of two months salmon can not live in pure salt water.

BIOLOGICAL LABORATORIES.

WOODS HOLE, MASSACHUSETTS.

Announcement was made in the last report of the appointment of Dr. H. C. Bumpus as director of the laboratory and of the intention of the Commission to keep the laboratory open throughout the year for the accommodation of those persons who might desire to carry on investigations in fall, winter, and spring. The year ending June 30, 1899, was one of the most successful in the history of the laboratory, and the investigations were much encouraged by the Commissioner, who was present at the station during a large part of the summer. The laboratory assistants were Prof. R. W. Tower, Mr. G. H. Sherwood, Mr. E. E. Tyzzer, and Mr. Vinal N. Edwards. The regular employees of the station, under the direction of Mr. E. F. Locke, rendered frequent and valuable assistance. The following abstract of the investigations and of the incidental work carried on at the laboratory is taken chiefly from the report of the director.

The already large equipment of the laboratory was supplemented by new apparatus, instruments, glassware, etc., and a stock of chemicals for carrying on physiological, histological, and microscopical research; additional rooms were provided for investigators; an excellent camera, especially adapted for taking life-size photographs of water animals, was provided, and the photographic room was replenished. The apparatus for the collecting of fishes and other animals was increased by a 250-foot purse seine, a 5-foot beam-trawl, 10 deep-sea traps, and 3 complete sets of trawl lines. One of the most important adjuncts of the laboratory was a fish-trap or pound net. In previous years the fish-traps in Buzzards Bay had furnished valuable data relative to the migrations, breeding, and abundance of fish, besides providing material for laboratory work; but in 1898 the laws of Massachusetts prohibited the operation of these traps. In order that the interests of the laboratory might not be curtailed, and the important record of the movements of fish might not be broken, the Commission in 1898 purchased one of the largest of the traps and obtained permission to operate it from the State Fisheries Commission. In the spring of 1899 a similar trap was secured for use in Vineyard Sound.

During the year the steamer *Fish Hawk* and the schooner *Grampus*, together with several steam launches and the various small boats at the station, were available for use in connection with the laboratory. The trustees of the Marine Biological Laboratory again placed their launch at the disposal of the Commission at a time when it was much needed.

An essential part of a biological laboratory is a library, and the director has taken special interest in the establishment of a creditable collection of works of reference and technical papers relating to biology. For the purpose of increasing the usefulness of the library, the Fish Commission sent circular letters to men of science, both in this country and abroad, asking them to contribute reprints of the papers they had published, or to exchange such reprints for publications of the Com-

mission. The response to this appeal has been most gratifying, and by the close of the year the catalogue of the library contained nearly 2,000 titles. Besides a full set of the *Challenger* reports and other works from the Washington office of the Commission, the more valuable donations included a nearly complete set of Bulletins and Memoirs of the Museum of Comparative Zoology from Mr. Alexander Agassiz, and a complete series of the publications of the Prince of Monaco. During the summer of 1898, several hundred bound volumes, together with files of scientific journals, were loaned from the laboratory of Brown University. The Boston Society of Natural History also loaned works on request.

Following is a list of the persons who pursued investigations at the laboratory during the year: Frank W. Bancroft, Ph. D., Harvard University; H. G. Barber, A. B., Harvard University; C. R. Bardeen, M. D., Johns Hopkins University; John Barlow, A. M., Rhode Island Agricultural College; Edward W. Berger, A. B., Johns Hopkins University; H. C. Bumpus, Ph. D., Brown University; T. J. Burrage, A. M., Brown University; Hubert L. Clark, Ph. D., Amherst College; Wesley R. Coe, Ph. D., Yale University; Ulric Dahlgren, Ph. D., Princeton University; William H. Dudley, Wisconsin State Normal School; Alexander W. Evans, M. D., Yale University; J. W. Galloway, Harvard University; S. P. Goodhart, M. D., Columbia University; F. P. Gorham, A. M., Brown University; Caswell Grave, B. S., Johns Hopkins University; L. E. Griffin, Ph. B., Johns Hopkins University; Robert W. Hall, Ph. B., Harvard University; C. W. Hargitt, Ph. D., Syracuse University; C. Judson Herrick, Ph. D., Denison University; Roswell H. Johnson, Harvard University; J. L. Kellogg, Ph. D., Olivet College; Harry M. Kelly, A. M., Cornell College; Edwin Linton, Ph. D., Washington and Jefferson College; Albert D. Mead, Ph. D., Brown University; A. E. Ortmann, Ph. D., Princeton University; George H. Parker, Ph. D., Harvard University; William Patten, Ph. D., Dartmouth College; Raymond Pearl, Dartmouth College; C. W. Prentiss, A. M., Harvard University; Herbert W. Rand, A. B., Harvard University; Albert M. Reese, A. B., Johns Hopkins University; Porter E. Sargent, A. M., Harvard University; G. H. Sherwood, A. B., Brown University; Boris Sidis, Ph. D., Pathological Institute of the New York State Hospitals; C. F. Silvester, Princeton University; Hugh M. Smith, M. D., U. S. Fish Commission, Washington; Oliver S. Strong, Ph. D., Columbia University; Frederick H. Thompson, jr., A. B., Harvard University; Millet T. Thompson, A. B., Brown University; R. W. Tower, A. M., Brown University; E. E. Tyzzer, A. M., Brown University; Ira van Gieson, M. D., Pathological Institute of the New York State Hospitals; Herbert E. Walter, North Division High School, Chicago; F. E. Watson, A. M., Brown University; Stephen R. Williams, A. M., Harvard University.

Although the Commission places no restrictions on the problems that are selected for investigation, a very large proportion of the work is of immediate or indirect practical and economic value. Dr. Bumpus

gave special attention to the rearing of newly hatched lobsters. No branch of our fisheries seems to be more in need of intelligent treatment at the present time than the lobster industry. Notwithstanding stringent protection laws and extensive fish-cultural operations, the supply of lobsters along the entire coast is steadily diminishing, and during the past three or four years has been especially limited. It is apparent that, unless active measures are taken to increase production, the animal will, in a few years, become practically exterminated. The eggs stripped from the female readily develop and hatch in McDonald jars with little loss, but the young quickly perish under the unnatural conditions in the hatchery. Therefore, the planting of the young as soon as possible after hatching has heretofore been necessary, owing to repeated failures to carry them through the early molts. If, however, the young could be artificially reared until they reach the fourth stage, when in structure and habits they are similar to the adults, they would be much more likely to flourish after their liberation, and the chances of rehabilitating the industry would be greatly improved. Before the close of the year a food was found which the young lobsters readily devour, inclosures were designed within which they seemed to flourish, and a larger number of young were carried to advanced stages of development than ever before. The problem, however, of rearing lobsters on a large scale still remains unsolved, although Dr. Bumpus believes that investigation along the lines recently followed will result in perfecting a practical method of lobster-culture.

For several years the aquaria at the station had apparently been infected with a parasitic organism which attacked the fish, produced bubbles of gas, around which the tissues wasted away, and ultimately caused death. This is not an uncommon affection in aquarium specimens. Prof. F. P. Gorham made a careful bacteriological examination of the water of the aquaria and of the tissues of the fishes, but found no organism that could be held responsible for the disease. Further observations convinced him that the condition was due to diminution in the pressure to which the fish were subjected when transferred from the deep water of the bay and sound to the shallow water of the tanks. He was able to produce and cure the disease experimentally by using small closed receptacles in which the pressure could be regulated. His observations are published in the Bulletin of the Commission for 1899.

Mr. L. E. Griffin began a study of the life-history of the squid (*Loligo pealii*), an article of great importance as bait in the commercial fisheries. The eggs of the squid are easily fertilized artificially, and the young appear to flourish in the hatchery.

The laboratory furnished Prof. C. J. Herrick with the material and facilities that enabled him to trace the origin and distribution of the cranial nerves, and Dr. Ira van Gieson was provided with material for use in elucidating certain problems relative to the structure and functions of nerve cells. While these neurological researches and other similar investigations carried on at the laboratory have no immediate

bearing on the practical work of the Commission, they are nevertheless worthy of encouragement, because of their important bearing on the physiology and pathology of man; and the Commission considers it not irrelevant to its functions to thus aid in the increase of knowledge by furnishing for such inquiries a part of the wealth of marine life that is obtainable at the laboratory.

The clam industry of the northeast coast has for several years shown an unmistakably downward tendency, and, next to the lobster, the clam is perhaps the most important animal obtained in the shore fisheries now demanding consideration. An essential step preliminary to the measures for increasing the clam supply is a thorough knowledge of the breeding habits of the clam, its rate of growth, time of sexual maturity, food, enemies, etc., on all of which subjects a survey of the literature reveals a deplorable lack of information. In the summer of 1898 Prof. J. L. Kellogg was engaged by the Commission to give special attention to this subject, and he has carefully examined the clam beds in the Woods Hole region, at Essex, Mass., and in Narragansett Bay. His studies have shown among other things (1) that there is an abundance of young clams, the shores in July being literally covered; (2) that these young clams are destroyed by young star-fish, which make their advent on the shores at about the same time the clams appear; (3) that young clams are easily susceptible of artificial rearing; and (4) that their rate of growth is rapid. With these data, the Commission has undertaken artificial clam-culture on an experimental but nevertheless rather extensive scale, and the results so far obtained fully warrant the effort.

Prof. Edwin Linton, whose investigations at Woods Hole have greatly increased our knowledge of parasitology, continued his studies of the entozoa of marine fishes. The large trap operated by the Commission furnished abundant material for this work. It is important that the fish-culturist should be acquainted with the fish parasites that may invade the hatchery, but it is more important that the Commission should have a knowledge of the life-history of all animals that spend a portion of their lives in fishes and may finally infect man.

Dr. A. D. Mead pursued several important lines of inquiry. In the summer of 1898 he continued his observations on the star-fish begun at the laboratory in the spring in the interests of the Rhode Island Fish Commission. His work related especially to the habits, rate of growth, powers of regeneration, and methods of breeding of the star-fish, which ravages the oyster-beds of southern New England and New York and extends its depredations to the clam and mussel beds. A feature of these investigations, which showed a positive relation between the menhaden fishery and the oyster industry, was most instructive. That the wholesale seining of menhaden, more especially in the inshore waters, has a direct bearing on these ravages of the star-fish was not suspected until the researches of Dr. Mead, carried on at Woods Hole and in Narragansett Bay, proved beyond a doubt that the young of the star-fish, at times so abundant that they actually color the water, are

the natural food of the menhaden, the schools of which form veritable living skimming-nets often a mile in breadth. This investigation indicates that it is perfectly justifiable to ascribe the rapid increase in the number of star-fish to the extensive capture of their natural enemies at a time when the latter are known to be feeding on young star-fish. Dr. Mead's very interesting report on this subject, which is printed in the annual report of the Rhode Island Commission for 1898, will appear in somewhat modified form in the Bulletin of the Commission for 1899.

In the fall of 1898 the waters of Narragansett Bay suddenly became a deep red color and emitted a very offensive odor. The fish were killed, even the hardy eels sought the shores, and dead shrimp were washed ashore in windrows. The cause of the "blood water" was entirely unknown, and Dr. Mead was engaged to investigate the matter. A species of the infusorian *Peridinium* was found to be the cause of the phenomenon. The Commission was advised that the trouble probably would be only temporary; and manufacturers, who were accustomed to pour waste dye materials into the bay and who were at first accused of causing the trouble, were exonerated.

Some very practical observations on the causes of decay in fish and the methods of arresting decay without the use of ice were made by Prof. R. W. Tower, the fish-trap providing the material necessary for the experiments. The work was undertaken by Professor Tower as the representative of the Rhode Island Fish Commission. It was shown conclusively that fish properly handled will keep absolutely fresh for 24 hours, even under the most trying climatic conditions, without the use of ice. In view of the large sums of money spent by the commercial fishermen for ice, the increased express charges on fish thus packed, and the unsatisfactory results of its use as ordinarily applied, these investigations have great importance.

The several trips of the *Grampus* in 1898, which resulted in the finding of the tile-fish in abundance off the southern New England coast, are referred to elsewhere in this report. These expeditions, however, may properly be regarded as a part of the operations of the laboratory, the vessel sailing from Woods Hole and being attended by a corps of laboratory investigators.

BEAUFORT, NORTH CAROLINA.

In conjunction with the fresh-water fish-cultural operations to be carried on at its new station at Edenton, N. C., on Albemarle Sound, the Commission contemplates the artificial propagation of the important salt-water fishes which spawn in the coastal waters of North Carolina and the other South Atlantic States. An essential preliminary to this work is the study of the habits, abundance, and distribution of the food-fishes, and also the determination of the non-economic fishes and other animals which are related to the food-fishes as food, enemies, etc. After consultation with Prof. J. A. Holmes, of the North Carolina Geological and Natural History Survey, Dr. H. V. Wilson, professor of biology in the State University, and other persons interested in the

development of the fishery resources of the region, it was decided that the best place for the prosecution of marine fish-cultural operations and the conjoint scientific investigations was Beaufort harbor. The harbor and the adjacent waters teem with animals in great variety and abundance. Many naturalists have from time to time resorted to the region for the study of special problems, the advantages of the locality having been especially demonstrated by Professor Brooks and other members of Johns Hopkins University, who maintained a laboratory at Beaufort during a period of ten years.

The consensus of opinion was that the Beaufort region was not only favorable for the study of the comparatively local problems of the North Carolina waters, but also for the investigation of the fauna of the southeastern coast in general, from the combined economic and scientific standpoints. Accordingly, in May, 1899, the Commission announced that it would maintain, during the succeeding summer, at Beaufort, N. C., a laboratory for the study of questions pertaining to fish-culture, fisheries, and marine biology, and placed Prof. H. V. Wilson in charge. Beaufort is situated on Beaufort Harbor, near one of the great ocean inlets, and is reached by boat from Morehead City, the nearest railroad terminus. The use of a commodious building on the water front was acquired at a nominal rental; a suitable equipment was provided; a small working library was installed; a steam launch was assigned from another station, and on June 1 the laboratory was opened to a limited number of investigators. By the close of the year the following persons had taken tables in the laboratory, and a number of others had applied for accommodations later in the season: Dr. D. S. Johnson, Dr. Gilman A. Drew, Dr. Caswell Grave, and Mr. W. C. Coker, all of Johns Hopkins University; Prof. J. I. Hamaker, of Trinity College, N. C.; Prof. T. G. Pearson, of Guilford College, N. C.; Prof. E. W. Berger, of Baldwin University, Ohio, and Prof. H. V. Wilson, of the University of North Carolina.

The special investigations carried on at the laboratory in June included the following: Dr. Johnson and Mr. Coker studied from a systematic and œcological standpoint the marine algæ of the harbor and the flora of the banks. Dr. Drew considered the habits of the clam (*Solenomya velum*), investigated the breeding condition of the round clams (*Venus mercenaria* and *V. elevata*) and other bivalve mollusks, and reared the eggs of *Venus elevata*. Dr. Grave studied the embryology of certain ophiurans, and made a number of valuable observations on the breeding time and general life-history of other echinoderms. Professor Wilson's work included observations on the breeding condition of the sponges and of certain edible fish. All the members of the laboratory cooperated in the effort to determine the animals and plants in and near the harbor, their abundance, local distribution, breeding times, habits, etc. The foundation of a museum collection illustrating the fauna and the flora of the region was laid, and a record book was opened, in which full notes on each species observed were entered.

MISCELLANEOUS MATTERS.

Fish ova for educational purposes.—The Commission has from time to time received requests for fertilized fish eggs for use in biological courses of schools and colleges. Such eggs are very acceptable objects of study, especially during the colder months, when other material is scarce; and as they can be furnished at an inappreciable expense, the Commission has been pleased to accommodate applicants. With a view to increase the aid that might thus be given to biological work, it was decided, in the fall of 1898, to make the fact more generally known among educational institutions that living fish-eggs, in small quantities, would be supplied on request. Accordingly, a notice was published in *Science*, stating the conditions under which eggs would be sent, the stations at which they were incubated, the kinds of eggs at each station, and the season when available. A number of universities and schools took this opportunity to obtain class material.

Investigation of trout epidemic at Northville, Mich.—About the middle of October, 1898, a very disastrous epidemic broke out among the yearling brook trout (*Salvelinus fontinalis*) at the Commission's station at Northville, Mich., and continued for three months, during which time upward of 3,000 fish died, or about 32 per cent of the total number in the affected ponds. The epidemic was first investigated by Mr. M. C. Marsh; later, when it became necessary to assign Mr. Marsh to other duties, Dr. C. M. Blackford, jr., took up the inquiry.

The affected fish had been hatched in the preceding spring and were previously in good condition. The earliest symptoms of the disease are sluggish movements and inability to keep up with the other fish of the school. Later, they remain close to the bottom and are almost motionless, a slight fanning movement of the pectoral fins being the chief indication of life. As the disease progresses the gills are involved in a large proportion of cases and breathing becomes difficult, the fish going to the surface and gasping for air. The power of maintaining equilibrium is gradually lost, and the fish turns on its side, and the effort to regain the upright position may carry it past the center and cause it to roll over and over as it swims.

The characteristic lesions are effusions of blood in the subcutaneous tissues and between the muscles; and frequently, but not constantly, an inflammation of the gills leading to bulging of the opercles, and inflammation and softening of the heart and large blood vessels. The areas of extravasated blood occur upon all parts of the body, but most commonly at the bases of the fins, varying in size from a mere speck to three-fourths of an inch, larger spots sometimes being formed by the confluence of several small ones. Should the fish live long enough these effusions undergo degenerative change, with the formation of pus and an abscess cavity. In time the abscesses reach the surface and discharge, leaving a deep ulcer with pockets and sinuses extending in various

directions under the skin and muscles. Changes in the blood are present, most marked in the colored corpuscles, which, instead of having the regular elliptical outline, present irregular and bizarre shapes, constituting poikilocytosis. The blood is found to be teeming with bacteria, chiefly streptococci, which appear to explain the condition of the corpuscles; the tissues and viscera also contain large numbers of bacteria.

Microscopic examination of the tissues, with the usual culture experiments, indicates that the disease is a septicæmia, caused by infection by a streptococcus. The disorganization of the blood leads to malnutrition of the tissues, followed by softening and rupture of the vessel walls and the escape of blood into the tissues. The extravasation becomes purulent, with the results stated.

The disease originated in one pond and spread thence to two other ponds into which the first pond discharged. The fact that other ponds supplied by the same (spring) water escaped the epidemic shows a local source of infection, and acquits the water of any responsibility. This was further demonstrated by a careful examination of the water. By drawing off the water in the first pond it was found that planks which formed the sides of the pond were rotten below the level of the gravel bottom of the pond, and that the cracks and softened spots therein were filled with organic débris. From cultures made from the rotting wood, and the vegetable and animal matter thereon, streptococci and staphylococci developed in great numbers, those most prevalent being *Streptococcus pyogenes*, *Staphylococcus pyogenes aureus*, and *Staphylococcus pyogenes albus*. The removal of the woodwork of the ponds and the substitution of cement or stone linings have been recommended.

Cod-tagging experiment.—The tagging of adult cod at the Woods Hole station, referred to in the last division report, was continued during the winter of 1898–99. The number of cod tagged was 593, which, with those previously liberated, make 1,155 tagged fish released in the adjacent waters. The number of tags thus far recovered from the first lot is 34; by June 30, 1899, the number returned from the second season's plant was 23. The recaptured fish furnish information regarding the movements, rate of travel, growth, etc., of the cod. The tagging will be carried on during another season.

Aquatic fauna in vicinity of hatching-stations.—The hatcheries of the Commission are annually visited by large numbers of persons, some of whom are merely sight-seers, while others are in search of information. The stations, in their respective communities, are regarded as centers of information on all matters pertaining to fishes and aquatic animals in general, in addition to purely fish-cultural subjects. In order to increase the usefulness of hatcheries in this respect arrangements are being made to provide for each station a series of labeled specimens representing all the species of fishes and other water animals found in the vicinity. As a preliminary step, this division supplied a collecting seine and preserving media to the various superintendents, some of whom have already obtained very complete collections.

Distribution of collections.—Large collections of fishes, mollusks, crustaceans, reptiles, and other objects of natural history obtained by the field assistants and vessels of the Commission have been transferred to the U. S. National Museum, in accordance with established custom. In response to requests, a number of series of fresh-water and marine fishes, preserved in alcohol, were prepared from duplicate material on hand and sent to various leading educational institutions.

Educational exhibit at Washington, D. C.—During the meeting of the National Educational Association at Washington, July 7 to 12, 1898, the various departments of the Government united in making an exhibit in the Central High School building for the information and instruction of the teachers in attendance. The main object of the exhibit was to acquaint instructors with the functions of the different Government bureaus, their methods of work, and the ways in which the results may be made available in our system of public instruction. The exhibits were largely geographical in character. The exhibit of the Fish Commission, which was installed by Dr. B. W. Evermann and Mr. M. C. Marsh, attracted much attention; it embraced the following: Samples of seines and other collecting appliances used by the Commission in its field work; thermometers, salinometers, sounding apparatus, etc.; microscopes and other laboratory instruments; apparatus used in handling eggs of different fishes propagated by the Commission and in shipping live fish and eggs; series of alcoholic fishes illustrating the species propagated; series of alcoholic fishes illustrating the geographical distribution of the genera of American fresh-water fishes; a series of aquatic invertebrates, such as are collected by the Commission and furnished by the United States National Museum to high schools and colleges for exhibition purposes; series of drawings illustrating one species in each of the more important families of North American fishes; maps showing the location of United States fish-cultural stations, the streams and lakes which have been investigated by the Commission, geographical distribution of certain important fishes; charts showing surveys made of oyster-grounds, etc., and a complete set of Fish Commission publications.