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

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SCOPE AND PURPOSE OF THE SCIENTIFIC WORK.

The utility of scientific research and experiment in respect to all fishery matters has been fully demonstrated by the past experience of the U. S. Fish Commission, under the able management of Prof. Baird, whose efforts to promote the welfare of this important industry by accurate and painstaking observations have proved entirely successful. The measures taken in pursuance of this object and the results accomplished from year to year have been described in previous reports, but it seems advisable, in this connection, to briefly explain the character of this scientific work in order that its direct practical bearing upon the preservation and development of the fisheries may be better understood. Science, as applied to the industrial pursuits, has not only ceased to be a pastime, but affords the only basis for intelligent and secure advancement. Nowhere is its influence more appreciable, moreover, than in the branch now under consideration, and its effects are evident both in the increase of production and in the regulation and improvement of its methods.

In accordance with the subjects to which the same relate, the scientific inquiries now in progress may be classified under four headings, as follows: (1) The development of the fishing-grounds, (2) the decrease of food-fishes, (3) the increase and dissemination of food-fishes, (4) special investigations.

THE DEVELOPMENT OF FISHING-GROUNDS.

First in sequence comes the investigation of existing fishing-grounds, whether those grounds are known to the fishermen at present or still await discovery. The purpose of this inquiry is to aid in the development of the natural fishery resources by supplying information to the fishermen as to where their work may be carried on with most profit. Fishing-grounds are distributed along the seacoasts and occur in nearly all the lakes and rivers, thereby presenting a great diversity of char-

acteristics and conditions. The most important grounds, however, are located in the seas, in the lower courses of the large rivers, and in the great lakes, some fishes living upon the bottom and others at or near the surface. Assuming the bottom grounds to be most typical, we may summarize as follows the principal information essential to the fishermen which can be gained by proper scientific observations: The position, extent, and outline of the grounds; the depth of water upon them and the character of the bottom; the kinds of useful fishes which inhabit each, and their abundance, size, and utility; their breeding and feeding habits, affecting, to some extent, their quality for food at different times; their migratory habits, which explain the periodic shifting of the grounds from one locality to another; the character and abundance of the food, and certain physical conditions upon which the permanence of the grounds depends; the distance of the grounds from markets and the meteorological characteristics of the region, as determining the period and duration of the fishing season and suggesting the character of fishing vessels to be employed; the kinds of bait best suited to each fishery and the places where sufficient quantities may be obtained.

These inquiries belong to three different branches of research—hydrography, physics, and biology, although the two former may, in a measure, be combined. Hydrography, in its limited sense, deals with the topography of the bottom, the depth of water, and other matters upon which the charting of the grounds is based. Work of this character is performed by the Coast Survey and Hydrographic Office for the benefit of commerce, but the requirements of the fisheries in this respect have not been fully met by their investigations, necessitating that the Fish Commission vessels be well equipped for the same service. The physical observations relate to the temperature and density of the water, the character, direction, and force of currents, and to atmospheric conditions and other kindred subjects. These matters, in conjunction with hydrographic features, determine the limits of faunas, and thereby the distribution of useful as well as other fishes; they also regulate the movements of migratory species and the methods of the fishermen. The inquiries regarding them are most important with respect to the more active pelagic species, such as the mackerel, bluefish, and menhaden, and the anadromous species, like the shad and salmon, but they are essential to the solution of all fishery problems, whether these relate to the oyster beds between tides or to the greatest depths frequented by food-fishes, to the river systems or to the lakes and seacoasts. The biological investigations have reference to the products of the grounds and make known the different economic species which inhabit each region, their abundance, the purposes for which they can be utilized, and the seasons during which they may be found. The character and amount of the lower forms of life existing in each locality indicate the permanence of the grounds, and to a great extent the kinds of

fishes which resort to them. The methods of the fisheries are also largely dependent upon a knowledge of the habits of the useful species.

The manner of conducting the survey of the fishing-grounds is explained elsewhere. The information obtained is presented to the fishermen in the form of charts and descriptive text, the former enabling them to locate readily any desired spot, the latter describing its principal features. Until recently the discovery of fishing-grounds has chiefly been accidental, that is to say, not due to organized and well-directed efforts, and their resources have been ascertained only through their gradual development. The rapid increase of population necessitates, however, more active progress in this direction, and all the assistance that can be afforded by such comprehensive surveys as are now under way. The investigations of the steamer *Albatross* on the Pacific coast during the past year, described below, fully demonstrate the utility of such measures.

THE DECREASE OF FOOD-FISHES.

It was specifically for the study of this subject that the Fish Commission was established in 1871, the results of its first inquiry determining the later expansion of the work. Demanding in part the same method of treatment as the survey of the fishing-grounds, it requires a much more thorough execution and a closer attention to details. In the former instance the grounds were assumed to be in their normal or natural condition, but any marked decrease in productiveness is taken as an indication that the balance of life has in some way been disturbed. It then becomes essential to ascertain what changes have occurred, the causes producing them, and the measures necessary to restore the natural conditions, finally carrying out those measures so far as practicable.

Previous to the organization of the U. S. Fish Commission it was customary, in investigating matters of this kind, to rely mainly for evidence upon the testimony of persons dependent upon the fisheries for their support, and thereby prejudiced in one direction or another. We owe chiefly to Prof. Baird the inauguration of the natural method of inquiry now prevailing, not only in this country, but also to some extent abroad. The decrease of fishes may be due to natural causes, or to injudicious practices on the part of man. The existence of a decrease having been confirmed, its extent is generally difficult to determine, from the absence of concurrent observations, and while the causes may be evident on slight inspection, more often they are obscure. Among the human agencies instrumental in this respect are the large fixed appliances of capture along the shores, a too persistent fishing by other means, dams built across the streams, preventing the ascent and descent of fishes, and the pollution of waters by factory refuse. The natural causes are less well defined, such as the failure of the food supply, the ravages of predaceous fishes and other animals, changes in temperature

and perhaps in density, poisoned waters, excess of sediment, unusual storms, accumulations of shore ice, diseases, etc.

The deterioration in the inshore fisheries of New England and in the shad, salmon, and whitefish fisheries appears to have been the result principally of human agencies; if not in all cases directly, yet through the destruction of the food on which the several species lived. The naturally poisoned waters of the Gulf of Mexico have caused much injury, and physical disturbances along the inner edge of the Gulf Stream have been known to practically exterminate an abundant species. The oyster-grounds of southern New England and New York suffer severely through the depredations of drills and starfishes, and epidemics of disease are not uncommon among the food-fishes of the interior lakes.

Precise methods of investigation are, therefore, necessary to determine the actual cause of decrease and to furnish the proper information on which remedial measures may be based. The character of these inquiries must vary with that of the fishing-grounds, and in accordance with the habits of the several species which are concerned. The remedies may be effected in two general ways—by legislation or by artificial propagation. A judicious protection of the grounds might in many cases be sufficient, but the laws hitherto enacted have not generally been very beneficial, owing partly to their inefficiency and partly to the careless manner in which they have been enforced. Fish-culture has, however, proved a very effective means for improving the condition of many depleted grounds, and its utility has long ceased to be problematical.

THE INCREASE AND DISSEMINATION OF FISHES.

The objects of fish-culture are, first, the maintenance or increase of existing fisheries, and second, the formation of new fisheries. The former relates chiefly to depleted grounds, the latter to grounds which have never been sufficiently productive. In order to carry out these purposes effectively the aid of science must be invoked, and its assistance is required in nearly every step taken. The actual operations of propagation, the collecting and hatching of the eggs, and the rearing and distribution of the embryos are dependent for their success upon the close observance of natural laws. It is essential to know the breeding habits of the species, the spawning places and seasons, the character and number of the eggs, the manner in which the latter can be fecundated and incubated artificially, the duration of the period of incubation, the developmental history of the embryo and the length of time it should be kept in captivity, the kind of food adapted to the young, and the proper localities for its planting, where it may find nourishment and freedom from its enemies.

In case the object of propagation is to replenish depleted grounds with a species native to them, the chief precaution to be taken is to

ascertain that the physical and, to a certain extent, the biological features of the region have not materially changed. The conditions of environment must remain congenial to the species, and it must have an abundance of proper food. If, on the other hand, fishes are being transplanted into new regions, it becomes necessary to study all the conditions of the latter with respect to their suitability for the forms in question. Are the temperature and density of the water and the character of the bottom adapted to them? Does the coast or river afford the necessary facilities for their spawning? Is there sufficient food for the young and adult, and is the region free from predaceous species which may destroy the eggs and embryos? Fishway methods, enabling the anadromous species to overcome obstructions to their ascent to spawning-grounds, must also be based upon scientific principles to insure their complete utility.

SPECIAL INVESTIGATIONS.

Among scientific problems which do not pertain directly to the above subjects, but which are sometimes of great importance, are such as relate to the deterioration of fishery products, methods of preservation of fish for food and bait, and the comparative value of the different species for food and other purposes.

FACILITIES FOR SCIENTIFIC INVESTIGATIONS.

The wide scope given to the scientific work makes it necessary to provide for a great diversity of observations. At the outset Prof. Baird found a steam launch and small sailboat entirely adequate to the conduct of his seacoast investigations. Two years later a naval tug was added to the fleet, and in 1877 this gave place to a larger naval vessel of the same type. With slight changes these two vessels were readily adapted to the explorations, and the experience acquired by their use led subsequently to the building of the fishery steamers *Fish Hawk* and *Albatross*. The schooner *Grampus* was afterwards constructed to meet certain requirements of the practical fisheries, but she is also fitted to participate in the study of scientific problems.

At present, therefore, the Fish Commission is provided with three vessels suited to the inquiries along the coast. The *Albatross* is a thoroughly sea-going steamer, built of iron, measuring 1,074 tons displacement, and propelled by twin screws. In her construction everything was sacrificed to strength and durability, to arrangements for easy working in a sea way, and to accommodations for scientific research. The heavy apparatus is operated from the forward deck, but the laboratories are amidship, being large and well equipped. Her outfit is the most perfect that has ever been supplied to any surveying vessel, and comprises every necessary device for sounding, dredging, and

fishing, as well as for physical observations, whether along the seacoasts or in the deepest parts of the ocean.

The steamer *Fish Hawk*, of 205 tons burden, was built when fish-cultural work along the coast was still regarded as experimental, and before the establishment of permanent hatching stations. She was designed, therefore, both as a floating hatchery and as a means for investigating fishery problems. To enable her to enter the shallow bays and river mouths in connection with the former service, her draft was made as light as possible, with a corresponding decrease in her seagoing qualities, but she is nevertheless well adapted for explorations, and her early trips to the offshore fishing-banks first demonstrated the expediency of having a steamer entirely suited to that class of work. The equipment of the *Fish Hawk* is similar in character to that provided on the *Albatross*, and equally efficient for use in shallow water. With the increase in number of hatching stations her services have been diverted more and more to the requirements of this division, and during the past year she has been largely occupied with the oyster and other scientific surveys.

The schooner *Grampus* is a modern fishing vessel of 83 tons burden, combining the best features of the American and English types. While serving primarily as a pattern for the improvement of the offshore fishing smacks, in which she has been entirely successful, she is also provided with the means of sounding and dredging in moderate depths of water, and of using all kinds of fishing apparatus. Her investigations have had reference chiefly to the migrations of the mackerel and to the conditions of the red-snapper banks in the Gulf of Mexico.

Facilities for special researches respecting the structure, life history, and habits of useful fishes and other kindred subjects are afforded by the several vessels, but more particularly by the large and well-equipped laboratory at the Wood's Holl Station, one of the most important of its character in the world. The aquaria at Washington also furnish the means for similar observations on a smaller scale, and temporary stations may readily be established anywhere along the seacoast or on the interior waters when such a course is necessary. The inland work, relating to the lakes and rivers, is at present chiefly carried on by temporary parties of volunteers, who make such observations as are possible in the field and conclude their examination of the specimens at convenient stations. The University of Indiana, at Bloomington, has been the headquarters for the surveys conducted under the direction of Dr. David S. Jordan, the remainder centering at Washington, where opportunities for investigations are provided by both the Fish Commission and the National Museum. The Commission is still dependent upon volunteers and temporary assistants for much of its scientific work, but it is hoped that the means for employing a larger permanent staff may soon be furnished.

THE PACIFIC COAST.

The development of the ocean fishing-grounds along the Pacific coast of the United States was taken up for the first time during the past year, the work being vigorously prosecuted and yielding results of great importance. The surveys were made by the steamer *Albatross*, Lieut. Commander Z. L. Tanner, U. S. Navy, commanding, and while the methods of inquiry were essentially the same that had been followed on the Atlantic coast, the operations were restricted chiefly to obtaining information of direct utility to the fishermen. The only extensive fishery investigations previously made in that region were conducted during the years 1879 and 1880, in connection with the fishery census, by Dr. T. H. Bean, for Alaska, and by Dr. David S. Jordan and Prof. Charles H. Gilbert, for Washington, Oregon, and California. Dr. Bean accompanied an expedition of the Coast Survey, and his personal observations were limited by the movements of the vessel and by the lack of proper facilities for offshore examinations. The inquiries of Profs. Jordan and Gilbert were principally confined to the use of seines along the shores and to the material obtainable from the small fishing boats and the local markets. However, the work of both these parties was performed in a most careful and painstaking manner, and the results accomplished were of great interest and value, especially as regards the inshore resources and the fisheries then existing. A full account of their discoveries and observations will be found in "The Fisheries and Fishery Industries of the United States," published by the U. S. Fish Commission between 1884 and 1887.

Respecting the region which he examined, Dr. Jordan explains that, "except the salmon fisheries of the Sacramento and the Columbia and the ocean fisheries in the immediate neighborhood of San Francisco, the fisheries of the Pacific coast exist only as possibilities; for the most part only shore fishing on the smallest scale is done, and no attempt is made to discover offshore banks or to develop them when discovered." He refers, however, to an extensive halibut bank, about 8 miles northwest of Cape Flattery, off the mouth of the Straits of Fuca, where the Indians take halibut in large numbers, and which, he adds, may sometime become of importance to the white people.

Dr. Bean's report contains a detailed summary of all that was known at the time of his visit concerning the fishing-grounds, the fishes, and fisheries of Alaska, except those for the marine mammalia, his information being drawn in part from the publications of Dall, Davidson, and other Alaskan explorers. After describing the inshore cod-fishing grounds occurring along certain portions of the coast, he states that "extended areas of soundings on which cod assemble in great masses are present in the Gulf of Alaska, but they have been but little investigated, and their limits and characteristics are imperfectly known." Four offshore banks are cited by name—Portlock, Shumagin, Sannak,

and Davidson—but they had been located by only a few isolated soundings, and their extent and boundaries were undetermined.

The only commercial marine fisheries which have been developed in Alaskan waters are those for the cod, and for the seal and other aquatic mammals. The first cod brought to San Francisco from the North Pacific region were said to have been taken in 1863 in the Gulf of Tartary and in the Ochotsk Sea. Two years later six vessels were engaged in this fishery, and in the same year they began to fish for cod in the neighborhood of the Shumagin Islands, off the Alaskan coast. Twenty-four vessels participated in this industry in 1870, but only eight in 1880, and the same number in 1888. The places most frequented for this purpose were in the vicinity of the Shumagin Islands and Kadiak, a few vessels also entering Bristol Bay to the north of the peninsula. Besides the cod, many other valuable food-fishes, including the halibut, are very abundant on the Alaskan coast; but owing to the distance from markets and the unsettled condition of the region these resources have not been utilized hitherto except by the natives. Even on the coasts of Washington, Oregon and California, where a great variety and abundance of marine fishes exist, the difficulty of disposing of a large catch has been the chief cause of the slow development of the fishing-grounds. The Alaskan products are chiefly marketed through San Francisco, which has also been the center of the only extensive local sea-fishery on the western coast. With the recent completion of several transcontinental railroads, affording the means of rapid transportation for fresh produce into the interior of the country, and with the prospect of greatly increasing the trade in salt cod and other prepared fishes with Central and South America, as well as Asia, a renewed interest has sprung up in relation to the western fisheries, which seems destined before long to exert a marked influence upon the welfare of the Pacific States. It was an expression of this interest that led Prof. Baird, shortly before his death, to prepare for the extensive investigations now in progress, which should determine, for the benefit of the fishermen, the varieties of fishes distributed along the coast, and the places where they occur in greatest abundance.

The steamer *Albatross* arrived at San Francisco from the Atlantic coast in May, 1888, at which time the general scheme of operations had been perfected by Commissioner McDonald. This provided primarily for a somewhat rapid yet comprehensive survey of all the waters adjacent to the western coast of the United States from the Mexican boundary line to the northern part of Bering Sea, the same to be restricted mainly to the submerged continental platform or between the shore line and a depth of 200 to 300 fathoms, as the principal bottom fisheries occur within those limits. As the characteristics of the bottom in this region are but little known, it was necessary to arrange for a very complete hydrographic as well as natural-history investigation, for both of which the *Albatross* is well adapted. Subsequently it is

proposed to engage in the study of special subjects, and, by careful observations upon the more important fishes, to collect data which can be utilized in the development of individual fisheries. Owing to the diversity of climate resulting from the great extent of coast line, the field work can be kept up during nearly the entire year and, therefore, with little loss of time.

A month and a half were spent at San Francisco in preparation for the first cruise, and on July 4, 1888, the *Albatross* started north, under instructions to explore the region south of the Alaska Peninsula between Unalaska and Middleton Islands. Completing this survey the last of August, she arrived at Seattle September 6, and continued operations on the coasts of Washington and Oregon, returning to San Francisco October 21. The winter cruise began January 3, 1889, the field of work lying between Point Conception and the Mexican boundary line, a trip also being made to the upper part of the Gulf of California for the purpose of determining the relations of that body of water to the Colorado River. The *Albatross* was back in San Francisco on April 25, but left again on May 21 to renew the investigations on the coasts of Washington and Oregon, which were still in progress at the close of the fiscal year. No fishery explorations were ever started under more auspicious circumstances, and none have been productive of more thoroughly practical results. For the successful execution of these plans credit is chiefly due to Lieut. Commander Tanner, who, with a full appreciation of the objects of the survey, has pressed the work with all his customary zeal and energy. Mr. Charles H. Townsend, an experienced collector, acted as permanent naturalist, and fishery matters were in charge of Mr. A. B. Alexander, formerly of the schooner *Grampus*. During the winter Prof. Charles H. Gilbert, of the University of Indiana, also joined the steamer as chief naturalist and ichthyologist. A narrative account of the year's operations is published in Appendix 4 to this volume (pp. 395–512), while the summer's cruise has been described in the Fish Commission Bulletin for 1888, pp. 1–95. The principal results may be summarized as follows:

ALASKA.

While approaching the Alaskan coast, soundings were begun in a depth of 2,550 fathoms, latitude 52° 15′ N., longitude 156° 37′ W., and were continued thence to Kiliuluk Bay on the south side of Unalaska Island. From this point the investigations were carried northeastward parallel with the coast line as far as Middleton Island, the most time being spent in those localities where banks had been reported by the fishermen, or where their existence was conjectured from other evidence. The results in a general way indicate that the entire submerged plateau in this region is one immense fishing-ground of irregular outline, not usually separated from the adjacent shores by deep water, but limited on the outer side by the abrupt slope beginning in about 100

fathoms. Although of much less extent, this important tract can best be compared with the eastern offshore banks extending from Massachusetts to Newfoundland, and, as with the latter, equally good fishing does not exist in all places, some localities being much more favorable in that respect than others. Whenever the ship was detained in port by stormy weather or for the purpose of coaling, attention was paid to inshore fishery matters.

Three lines of soundings were made off the south side of Unalaska Island, and while they were not sufficient to demonstrate the existence of a defined bank, it was estimated that an area of about 2,000 square miles in that region is suitable for fishing. The outlines and surface contours of Davidson Bank, discovered about 20 years ago by Prof. George Davidson, of the U. S. Coast Survey, were established with considerable accuracy. This bank lies south of Unimak Island, extending eastward from off the southern entrance to Unimak Pass as far as the shoal water surrounding Sannak Islands, and has an estimated area of 1,600 square miles. Sannak Bank lies to the east and southeast of the islands of the same name, and is elongate in shape, trending in a general way northeast and southwest. Its total extent is about 1,300 square miles. Between Sannak Bank and the Shumagin Islands, an area of about 1,800 square miles, more or less adapted to fishing, was partly surveyed, the depths ranging from 38 to 74 fathoms.

Directly to the south and southeast of the Shumagin Islands is an important bank, to which the same name has been given. Its outer margin was ascertained to follow approximately the trend of the coast line as formed by the adjacent islands, but its eastern limit was not determined. The part examined has a width of 15 to 35 miles and an area of about 1,800 square miles. Between there and Kadiak Island an extent of over 4,000 square miles was also partly developed, although not many fishing trials were made upon it.

Albatross Bank, named after the Fish Commission steamer, lies off the southeastern side of Kadiak Island, extending its entire length, and also in front of the Trinity Islands. Its eastern end is practically continuous with Portlock Bank, and its total area was found to be about 3,700 square miles, the 100-fathom curve being distant 25 to 45 miles from land. Portlock Bank is the largest single bank that has yet been discovered on the Alaskan coast, having an area inside of the 100-fathom curve of about 6,800 square miles, or only about 1,600 miles less than Georges Bank, the second in size in the western Atlantic Ocean. It extends northeastward from Kadiak Island in the direction of Middleton Island a distance of about 120 miles, and is very irregular in shape. From Portlock Bank the soundings were carried to Middleton Island, and thence to certain positions reported for the Pamplona Rocks, but without finding the latter.

The total area of the fishing-grounds on the Alaskan coast examined by the *Albatross* during this short season amounted to over 23,000

square geographical miles. The beam trawl and naturalist's dredge were frequently used upon all the banks for the purpose of determining the characteristics and conditions of the bottom as feeding-ground and its comparative richness in different places. The assemblage of animals collected strongly recalls the fauna of the great fishing-banks of eastern North America, and many of the species from both regions will probably prove to be identical. The more conspicuous features of the hauls were the fishes, crustaceans, mollusks, and echinoderms. Edible fishes, crabs, and shrimps were frequently taken, the last mentioned often in great numbers. The regular trials for fishes were made entirely with hand lines, cod and halibut being the principal species taken. Six to nine lines were generally used at each trial, which occupied from fifteen minutes to an hour or more, according to circumstances. Salt clams and salmon were chiefly employed as bait, and pollock, sculpins, and cod occasionally. The depths in which the fishing was done ranged from 27 to 84 fathoms, and every variety of bottom observed upon the banks was tried. A careful record was kept of the number of cod and halibut captured at each trial, and of their weight and size. The trials were usually made during the progress of, or subsequent to, a sounding or dredge haul, the steamer often drifting with the tide and changing its location before the hooks had touched bottom. The results were, therefore, not as satisfactory as they would have been had the steamer anchored and remained for some time in each position, as the fishermen consider that the large cod, as a rule, are the last to be attracted by the bait. In conducting lines of soundings, however, it is inexpedient to make long detentions, and it was regarded as most important that the hydrographic work should be completed first.

The cod taken off Unalaska averaged from 21 to 28¾ inches in length; on Davidson Bank, 24½ to 28 inches; on Samnak Bank, 23½ to 25 inches; off Unga, one of the Shumagin Islands, 30 inches; on Shumagin Bank, 26½ inches; and near the Chirikoff Islands, 23½ inches. The best captures were made, however, on Albatross and Portlock banks. On the former, 47 cod, averaging 28½ inches, were caught in the space of thirty-eight minutes off Tugidak Island, and 69 cod, averaging 30¾ inches, in fifty minutes off Dangerous Cape. In a depth of 36 fathoms, on Portlock Bank, 30 cod, averaging 27 inches, were secured in eighteen minutes. The bait question presents no difficulties on the Alaskan coast, and the fishermen generally have no trouble in obtaining what they need during the progress of their work.

While the *Albatross* made no investigations in Bering Sea, sufficient information was obtained from the fishermen to prove the advisability of extending the inquiries into that region.

WASHINGTON AND OREGON.

Investigations were conducted along the coasts of these two States during September and October, 1888, and June, 1889. In May, 1889, the *Albatross* was placed at the disposition of the Senate Committee

on Relations with Canada, for the purpose of visiting southeastern Alaska, and, her services being accepted, arrangements were made accordingly. The steamer proceeded to Victoria, British Columbia, to meet the members of the committee, but a change in their plans becoming necessary, the trip was finally abandoned. The surveys off Washington and Oregon were at once taken up, however, where they had been stopped the previous fall, and were still in progress at the close of the year. During both seasons the operations were mainly restricted to the outer seacoast, although the inshore fisheries received due attention while the steamer was in port.

No soundings were made north of Cape Flattery, as the contour of the bottom at the mouth of the Straits of Fuca had previously been determined with sufficient accuracy for fishery purposes. The dredging and fishing appliances, however, were used in several places on the halibut bank described below. Hydrographic observations were carried southward from Cape Flattery, the bottom being uniform and consisting chiefly of gray sand as far as Gray's Harbor, off which place a small bank was discovered and surveyed. Rock-cod and other food-fishes were taken there in abundance, but no specimens of the true cod or halibut were secured. The coast of Oregon was examined as far south as Heceta Bank, the only distinctive offshore fishing-ground thus far detected in that region. A few fishing-spots occur along the shore, however, the most important one being adjacent to Tillamook Rock, a short distance south of the mouth of the Columbia River. Heceta Bank has a length of about 20 miles and a width of about 10 miles. The bottom is very uneven and supports an exceedingly rich growth of animal life, affording abundant food for fishes. Several varieties of rock-cod were very plentiful, and other valuable species were not uncommon, one small halibut also being captured there. The Tillamook Rock ground is only adapted to boat fishing, but in June four halibut were taken upon it, while an abundance of flounders, rock-cod, and other species were secured by means of the beam trawl, both in the vicinity of the rock and elsewhere along the coast. The investigations of the *Albatross* indicate, however, that the halibut fishery as a separate industry could not profitably be carried on in this region.

A halibut bank, resorted to by the Indians, begins close to the shore in the vicinity of Cape Flattery and extends thence northwestward about 15 miles with depths of 35 to 75 fathoms. Halibut are said to be abundant there from early in the spring until the middle of June, when the bank becomes infested with dogfish and sharks. The bottom is exceedingly variable and was found to be very rich in life. North of this bank as far as Barclay Sound, Vancouver Island, the bottom is smoother and less promising in every respect. A second halibut bank occurs off Flattery Rocks and extends in the direction of Cape Flattery, but it is smaller and much less important than the first. In the course of the fishing trials made by the *Albatross*, during the fall of 1888, it

became evident that the sharks and dogfish had taken possession of the grounds almost to the entire exclusion of edible fishes. On the principal bank halibut were taken in two localities, six specimens in all, averaging in one case 47¾ pounds each, and in the other 55 pounds each. Five halibut were secured north of this ground, but only one, weighing 140 pounds, on the bank off Flattery Rocks. In June, 1889, three days only were spent in this locality, and they were chiefly occupied with determining the contour of the outer edge of the larger bank. In one short trial with the trawl line eight halibut, averaging 35 pounds in weight, and several other food species were captured, dogfish being scarce. According to the testimony of fishermen who have recently operated in this region, halibut are abundant from March until into June, and vessel fishing may be considered advisable only between March 1 and September 1.

Beginning early in 1888, a number of trips for fresh halibut were made from different ports in the State of Washington. Some proved very successful, while on others poor fares were obtained or the vessels were absent a long time. Difficulties have also been encountered in the maintenance of this fishery through the competition of eastern markets, the cost of transportation, and the price of ice. The Gloucester schooner *Mollie Adams* secured its first fares of halibut on the bank off Cape Flattery, and the same vessel, fishing nineteen days off the southern extremity of the Queen Charlotte Islands, obtained 150,000 pounds of halibut, of which one-half were large enough for fletching. The crew shared about $9 apiece for each fishing day. The yacht *C. H. White* has made three trips to Flattery Bank since the fall of 1888, taking in all about 100,000 pounds of halibut, of which 60,000 were shipped fresh to New York, the remainder being smoked. The schooner *Rosie Olsen* took 15,000 pounds off Cape Scott, during a trip of about five weeks in the spring, while the schooner *Oscar and Hattie* had a long experience off the southeastern coast of Alaska and off British Columbia, lasting from January to June, 1889, a fare of 140,000 pounds, the fish averaging 65 pounds in weight, being finally secured.

SOUTHERN CALIFORNIA.

The examination of this region between Point Conception and the Mexican boundary line occupied the months of January and February, 1889. Some of the best fishing-grounds adjacent to the western coast were found in this district, and only the lack of markets prevents their immediate development. The continental plateau is wider here than to the north of Point Conception, and the area available for fishing is therefore much greater. Moreover several large islands, the Santa Barbara group, San Nicolas, Santa Catalina, and San Clemente are located near the coast, affording good anchorage and protection against storms. Two small but important banks, called Cortez and Tanner

banks, also exist directly off San Diego, at a distance of about 95 miles; the former has been known to navigators for a long time, but the latter was first discovered by the *Albatross*. Cortez Bank was found to be the most promising fishing-ground south of San Francisco; it has an area of 51 square miles with depths less than 50 fathoms, but good fishing can also be obtained in the slightly deeper water surrounding it on all sides. Many varieties of fishes were taken on the lines, the most abundant being several species of the rock-cod (*Sebastodes*), fat-heads (*Trochocopus pulcher*), sea bass (*Serranus clathratus*), and whitefish (*Caulolatilus princeps*). Tanner Bank is separated from Cortez Bank by depths of 150 to 250 fathoms, and has a shoal area about 17 square miles in extent. The fishes are identical on the two banks.

Lines of observing stations were run over the entire region, and all suitable localities were carefully tested with the fishing apparatus. The methods of existing fisheries were also studied, and much information was obtained respecting the habits and distribution of the food-fishes. The range of the black-cod or beshow, so abundant on the coast of Washington and farther north, was found to extend as far as the Santa Barbara Channel, where several specimens were secured by means both of hand lines and of the beam trawl.

GULF OF CALIFORNIA AND LOWER CALIFORNIA.

The *Albatross* left San Diego for the Gulf of California February 26, but taking advantage of the opportunity to examine certain reported dangers to navigation off the coast of Lower California, the cruise was not made direct. A line of soundings was carried first to the island of Guadeloupe, and thence to the Alijos Rocks, in latitude 24° 58′ N., longitude 115° 52′ 36″ W., and to the Revillagigedo group, of which Clarion, Socorro, and San Benedicto islands were visited in the order named. Besides obtaining very satisfactory hydrographic results, important collections of fishes and other marine animals were made. The investigations in the Gulf, beginning at La Paz, were carried northward to the mouth of the Colorado River, touching at San Josef Island, Carmen Island, Conception Bay, Guaymas, and other places. On the return trip the steamer again stopped at Guaymas and La Paz. The shallow waters at the mouth of the Colorado River were found to be very barren of life, and the conditions generally seemed unfavorable to the stocking of that river with the shad or other anadromous species.

While in the neighborhood of Guaymas an examination was made of the extensive oyster beds at the mouth of the Yaqui River. Oysters from this locality were formerly sent to the San Francisco market, and their introduction for stocking purposes into the bays of southern California has been suggested. The tropical conditions which seem necessary to their welfare, however, precludes their being used successfully for that purpose.

During the year the *Albatross* was at sea 168 days, the distance traversed during that time being 17,124.6 nautical miles. The total number of soundings made was 965, and of dredgings and trawlings 237. This record is much higher than for any previous year.

INTRODUCTION OF OYSTERS.

The native oyster of the Pacific coast is inferior in quality, and efforts have been made to introduce the eastern species, but as regards the establishment of self-sustaining beds it is reported that they have been entirely unsuccessful. Large quantities of the Atlantic oyster are carried overland and planted in San Francisco Bay, where they grow and remain in good condition for the market, but they are said not to reproduce to an appreciable extent, owing, it has been supposed, to the low temperature of the water during the breeding season. The study of the oyster problem on the western coast has been taken up by the Fish Commission during the past year, and while it has not the means to place a special party in the field for that purpose, the naturalists of the steamer *Albatross* have been instructed to make suitable observations whenever possible. Several opportunities occurred during last winter, and the facts obtained were presented in a report by Prof. Charles H. Gilbert, published in the Fish Commission Bulletin for 1889, pages 95–98.

According to Prof. Gilbert, the coast of southern California contains few harbors or river mouths which might prove suitable for oyster-culture. The proximity of the Coast Range of mountains and the limited rainfall conspire to produce small rivers, which are dry during the greater part of the year, and at other times commonly reach the sea by filtering through the sands thrown up across their mouths. Two of the most promising estuaries, Alamitos Bay and Newport Bay, were examined by Prof. Gilbert, and their characteristics are described in his report. The only other localities in the southern part of the State which might offer favorable conditions are Anaheim Bay and the mouth of Los Bolsos Creek, between Alamitos and Newport bays, and False Bay, near San Diego. All of these areas are very small, however, and observations during the dry season are required before reaching definite conclusions. The oyster beds near Guaymas, referred to above, are also discussed by Prof. Gilbert, who concludes that the Mexican oyster, living naturally under tropical conditions, is unsuited to the coast of California. It is proposed during the ensuing year to begin an investigation of San Francisco Bay with respect to its adaptability for oyster-raising.

TRANSPLANTING OF LOBSTERS.

Two large shipments of lobsters have been made to the Pacific coast within the past thirteen months, the plants being distributed between Monterey Bay and the Straits of Fuca, a distance of 11 degrees of latitude,

in order that the experiment might have the benefit of as wide a range of temperature and conditions as possible. The specimens were brought from the southern New England coast, where the water temperature, although much less equable, coincides in part with that of northern California. This subject is fully discussed under the special heading of "Lobster."

THE GULF OF MEXICO.

The red-snapper banks.—The red-snapper and grouper fisheries of the Gulf of Mexico were first investigated for the Fish Commission in 1880 by the late Silas Stearns, of Pensacola, Florida, whose report upon that subject was printed in the "Fisheries and Fishery Industries of the United States." Chart No. 16 of Section III of that publication represents the distribution of the fishing-grounds for those species between the mouth of the Mississippi River and the southern extremity of Florida. Most of the submerged continental platform along that portion of the coast, in depths less than 50 fathoms, was designated by Mr. Stearns as a more or less continuous fishing-bank, of which the principal commercial resources are the red snapper (*Lutjanus blackfordi*), red grouper (*Epinephelus morio*), and black grouper (*Epinephelus nigritus*). Although dependent upon the fishing vessels for the means of making his observations, he was able to describe the grounds in considerable detail, and to designate the general distribution of their commoner inhabitants. On the more southern grounds, he states, the majority of the edible fishes taken are groupers, while on the northern ones red snappers are more numerous and the groupers less common.

During the early part of 1885 the steamer *Albatross* made extensive explorations in the eastern part of the Gulf of Mexico, the fishing-grounds and fisheries examined being discussed by Capt. J. W. Collins in the annual report of the Fish Commission for the same year. With respect to the red-snapper banks, Capt. Collins explains that the grounds then generally visited in winter are embraced in a somewhat narrow belt along what is termed the outer edge of the shore soundings between the meridians of Cape San Blas and Mobile. So far as is known, the red snapper during the winter occurs in greater abundance along this stretch of bottom than elsewhere. The grounds lying between Cape San Blas and the Tortugas have been thoroughly worked over by the Key West smackmen, chiefly in depths of 5 to 15 fathoms, but outside of the 15-fathom line little fishing has probably been done south of Tampa Bay. The red snapper may, however, occur there in abundance, and should that fact be established this region would undoubtedly be resorted to whenever the supply diminished on the grounds nearest the fishing ports.

With the object of determining the characteristics and resources of the southern deep-water extension of this large bank, and bringing the same to the attention of the fishermen, the schooner *Grampus*, Capt. A.

C. Adams commanding, was dispatched to the west coast of Florida, leaving Wood's Holl, Mass., January 14, 1889, and reaching Key West on the 27th of the same month. Mr. W. C. Kendall acted as naturalist on the schooner, while Dr. James A. Henshall, secretary of the Cincinnati Society of Natural History, was detailed to make an investigation of the adjacent shores, as explained farther on. The work was conducted in a thorough and systematic manner and upon a somewhat different plan from any previous survey. The examination was begun about 20 miles north of the Tortugas Islands, with instructions to carry it as far northward as the time would permit, between the depths of 15 and 50 fathoms, or outside of the area now resorted to for fishing purposes. The bank in this region has practically a north and south trend and it was deemed most advantageous to run east and west lines of observations entirely across it, at regular intervals of 10 miles. Dredgings to determine the character of the bottom were to be made 10 miles apart on each line, while the fishing trials with hand lines were to be continued with as few interruptions as possible both while under way and while at anchor. The first line was started February 14, and the work closed March 27. Unfortunately, stormy weather prevailed during most of the season and prevented the extension of the survey north of the latitude of Charlotte Harbor, a distance of 100 miles from the starting-point. The instructions, however, were closely followed, and ten lines, averaging about 65 miles each in length, were run, the total area covered being, therefore, about 6,500 square miles. Had the time and weather permitted, the good fishing-places could have been more accurately located and their limits better defined, but as it is the results are interesting and instructive, the relative abundance and distribution of the several species having been ascertained with sufficient accuracy for all immediate purposes. It would, however, be important to determine to what extent these conditions vary with the seasons.

Three times as many red snappers as groupers were secured over the entire area, indicating that the former species is the most abundant one during at least the season when the inquiry was conducted. Red snappers were found in all depths from 15 to 48 fathoms, but the largest catches were made in depths of 15 to 25 fathoms, comparatively few being taken in over 30 fathoms. The red grouper ranged through depths of 15 to 37 fathoms, and the black grouper through depths of 19½ to 48 fathoms. On the more southern lines the red snappers and both species of groupers were found as far out as depths of 35 to 40 fathoms, becoming less abundant but increasing in size as the water deepened. As the work progressed northward, the fish were chiefly obtained on the inner parts of the lines, the red groupers also taking the place of the red snappers, which were rarely seen. In the deeper waters the black groupers predominated over the red groupers, the latter becoming relatively more common as the water shoaled toward the coast.

A detailed account of these investigations will be found in the Bulletin of the Fish Commission for 1889 (pp. 289–312), which also contains lists of the fishes, mollusks, and higher crustaceans collected during the cruise. It had been intended to extend the inquiry to Campeche Bank, where it is expected important fisheries can be established, but for reasons previously explained this matter was necessarily deferred until some future occasion.

Fishes of southern Florida.—The examination of the coast waters of southern Florida by Dr. Henshall, previously referred to, was carried on while the schooner *Grampus* was at work upon the offshore grounds. The object of his inquiry was to collect and study the fishes and other marine animals between Biscayne Bay and Tampa, paying particular attention to the abundance, distribution, and habits of those species which are of economic importance. He was provided with a seine boat and a dory belonging to the *Grampus*, together with the necessary fishing and camping equipment, and was accompanied by a local pilot and a seaman and cabin boy from the schooner. The party was conveyed by the *Grampus* as far as Indian Key on February 11, thence making its way through the reefs to Card Sound. From this point Dr. Henshall worked along the coast to Charlotte Harbor and Tampa Bay, concluding the investigation on April 4. Nearly all the work was limited to salt water, on account of the remoteness of the fresh-water streams from the shores and their inaccessibility, but a few isolated fresh-water ponds were reached by carrying the collecting outfit overland. Between Biscayne Bay and Charlotte Harbor practically no fisheries are carried on. From Cape Sable to Pavilion Key the coast consists of mangrove shores and islands, unsuited to the hauling of large seines. There is a small fishing ranch on Estero Bay, just below Charlotte Harbor, and at Gordon Pass and Marco a little fishing is done to supply the local demand, but at none of these places is the catch sufficient to entitle it to recognition from a commercial standpoint. In his report on the results of the exploration* Dr. Henshall gives a complete list of all the fishes collected, with notes upon their habits, distribution, abundance, and uses.

Propagation of the mullet and other fishes.—The steamer *Fish Hawk* left Washington January 6, 1889, to investigate the hatching of the mullet and of other fishes on the west coast of Florida. A few stops were made along the Atlantic coast, on the way south, in order to gather information regarding certain fisheries, and a brief examination was also made of the Blackfish Banks off Cape Fear, North Carolina. Reaching Charlotte Harbor, February 7, operations were immediately begun at that place and were subsequently continued at Boca Grande and Punta Rassa until about April 1. The spawning season of the mullet in this region had closed before the arrival of the *Fish Hawk*, but large numbers of the adults and of the fry were obtained in both fresh

* Bulletin of the U. S. Fish Commission for 1889, pp. 371–389.

and brackish water, the latter, measuring from half an inch to 3 inches long, having been found especially abundant in the headwaters of Alligator River, which are entirely fresh. According to the information collected, spawn might be secured in Charlotte Harbor and San Carlos Bay through a long period, beginning in September and continuing until early in January, but it was ascertained that the mullets have not decreased on the west coast of Florida to the same extent as along the south Atlantic coast. Lieut. Platt recommends as a site for a hatching station a place near Sinnable Point, in San Carlos Bay, about a quarter of a mile from the light-house. There is a good wharf belonging to the Light-House Service in that locality, and a steamer leaves there every alternate day for the railroad terminus at Punta Gorda.

Sheepshead (*Archosargus probatocephalus*) with ripe spawn were first taken by the *Fish Hawk* March 19, at the entrance to Charlotte Harbor, about 2,000,000 eggs being secured from 10 females and being impregnated with the milt of 4 males. Subsequently over 20,000,000 more of the same eggs were obtained. They are transparent, buoyant and very small, numbering about 50,000 to the fluid ounce. The tidal hatching box answered satisfactorily for their incubation, which requires from thirty-six to forty hours. The embryos can be planted when from seventy-two to eighty hours old; they are small, but hardy and active. The spawning fish can best be taken just before sundown, as the flood tide begins to make. They swim in schools, but not near the surface, and the seine would sometimes contain more than could be landed.

Of the spotted weakfish (*Cynoscion maculatum*) about 1,450,000 eggs were obtained, April 1, from 4 females and were impregnated with the milt from 4 males. The eggs are said to be of about the same size as those of the sheepshead and are also buoyant, hatching in about forty hours. About 350,000 healthy embryos were obtained from the above lot. Large numbers of pompano and Spanish mackerel were captured at different times. The former were not in spawn, but in the latter the roe seemed to be somewhat advanced.

THE ATLANTIC COAST.

During the past year the general exploration of the fishing-grounds, hitherto the most prominent feature of the work along the Atlantic coast, was discontinued in that region, as explained above, and in its place special investigations relating chiefly to the oyster fishery were taken up. The latter industry is greatly in need of such assistance as might be afforded by careful study and experiment, and the time seems opportune for utilizing in that direction the information which has been collected during the past eighteen years. The oyster (*Ostrea virginica*) is native to all parts of both the Atlantic and Gulf coasts of the United States, and small colonies occur even as far north as the Gulf of St. Lawrence. Only a few small natural beds now exist, however, in waters

tributary to the Gulf of Maine, and the fishery first becomes important on the southern New England coast, where the beds have been greatly enlarged by the planting of both native and Southern seed. New York has shared with Connecticut in the impetus recently given to this ready system of oyster-culture; in New Jersey the fishery is extensive, and in Maryland and Virginia the natural resources have afforded advantages superior to those of any other States. Farther south, however, while important fisheries exist in some localities, the industry may be said still to await development. The natural conditions are favorable nearly everywhere, and the thick growths of "coon" or wild oysters, forming a broad fringe along the coast, constitute a supply of seed which appears to be inexhaustible.

In spite of the great prosperity of the oyster fishery at the north, resulting from the recent enactment of judicious laws, it has certain serious drawbacks, which tend to reduce the profits and threaten to some extent its future welfare. In the salt waters of New England and New York the drills and starfish are most persistent and destructive enemies of the oyster, doing an amount of damage to the beds which it is difficult to calculate. Enemies of this character give practically little trouble in Chesapeake Bay, but under the present system of administering upon the fishery there the production of the grounds is rapidly falling off from year to year, sufficient inducements not being offered to supplement the natural supply by the artificial extension of the beds. Oyster-culture, properly so called, the production of spat by aid of artificial methods, has, moreover, never been resorted to in this country, in consequence of the fact that the practical utility and economy of any proposed system has yet to be established. As the scarcity of seed is one of the greatest difficulties now encountered by the oyster-planter, this subject offers an interesting field for investigation.

The above statements plainly indicate in what channels the inquiry may be directed to best advantage for the oyster fishery. The oystermen of New England and New York desire to learn by what means, if any, their beds may be preserved from the attacks of drills and starfishes; in the Chesapeake, the wisdom of some system of individual responsibility for the condition and abundance of the crop must be demonstrated practically; in more southern waters, the best manner of utilizing the wild stock should be determined and a system of oyster-culture applicable to all parts of the coast should be developed.

For the prosecution of these inquiries the several States have looked to the General Government as being the best equipped for that purpose, and also in view of the fact that the questions at issue are not limited in their application to any one State. Experiments respecting oyster-culture were conducted by the Fish Commission in Chesapeake Bay during several years, but they were temporarily discontinued before a final solution of the matter had been reached. Outside of these researches and the methods and statistics of the business, the Fish Com-

mission has paid but little attention to the oyster question, its limited resources for investigation being utilized for the benefit of other fisheries whose demands seemed more urgent. The present Commissioner, however, has considered it expedient to begin at once upon the study of this subject, applying to it such means as are now available, special provisions not having been made by Congress for this branch of work. The steamer *Fish Hawk* is well adapted to this inquiry, but being also required for certain fish-cultural operations she is available during only a few months of each year, and considering the great extent of seacoast to be covered, her progress must necessarily be slow. It was not until September, 1888, that she could be detailed for this purpose, the two months remaining, suitable for investigation, being spent upon the southern New England coast.

While the oyster beds in this region are subject to injury from several causes, by far the greatest amount of damage is effected by the drills and starfishes, and these two animals, harmless as they appear, are particularly dreaded by the oyster-planters. The former, a small gastropod or snail-shaped mollusk, whose mouth is provided with a ribbon-like tongue, armed with several rows of minute but relatively strong and very sharp teeth, pierces the upper valve with a small hole, through which the soft parts are subsequently extracted. It feeds principally upon the young oysters, preferring those from a few weeks to a few months old, in which the shell is still thin and quickly bored. It is also most abundant in shallow water, and comparatively few individuals are capable of doing widespread damage. The starfish is more widely distributed as regards the depth of water and, often attaining a comparatively large size, is not limited in its diet to the smaller oysters. Placing its five arms about the shell and extruding its capacious stomach, it causes the two valves to open and, without appreciable injury to the stony covering, absorbs the inclosed tissues. These two enemies, however unwelcome they may be, are natural associates of the oyster, finding congenial to them the same temperatures and the same densities of water which prevail in that region. Here they reproduce and complete their life history. Whatever privileges the one enjoys, the others are equally entitled to by nature, and this circumstance renders the question of protection an especially difficult and perplexing one. While the drill and starfish do not confine their depredations to the oyster, the latter seems to be their particular favorite, and with the enlargement of the beds by planting, the number of these two pests appears to increase proportionally. The oystermen have no other remedy than the forcible removal of these animals after the grounds have been invaded, generally necessitating the taking up of many of the oysters with them and often the entire stock. Special dredges and tangles have been devised for the capture of the starfishes, but none of these have proved of much utility.

Considering the amount of damage done by the drills and starfishes,

and the cost of their removal, usually not until a large percentage of the crop has been destroyed, it may be realized with what anxiety the oystermen regard their presence and how desirous they have become to ascertain if any precautions can be taken to anticipate and prevent their inroads. However impracticable this question may appear from our present knowledge of the habits of those species, the matter is sufficiently important to warrant its careful study, and even should the inquiry not prove entirely satisfactory in that respect, it will undoubtedly lead to other improvements in the oyster fishery of that region. The scheme of work proposed has been prepared upon a basis broad enough to meet all the present requirements of the industry.

Mate James A. Smith, U. S. N., commanding the steamer *Fish Hawk*, was in charge of operations during 1888, with Mr. C. F. Hodge, of Johns Hopkins University, as naturalist. A visit was first made to New Haven, to enable Mr. Smith to confer with the shellfish commissioners of Connecticut and the oyster-growers in that vicinity, after which a month was spent in Narragansett Bay and Providence River, the steamer returning to New Haven later in the season for a brief reconnaissance.

The plans for the investigation of Rhode Island waters contemplated a thorough survey of the upper part of Narragansett Bay and of all of Providence River as far up as the city of Providence, and provided for the following character of inquiries, namely: An examination respecting the physical characteristics and condition of the bottom and of the water, with density and temperature observations at many places during different stages of the tide; a systematic series of dredgings to determine the present condition of the oyster beds, the distribution and abundance of drills and starfishes, and the character and extent of the damage they are doing; the plotting of the principal existing oyster beds on charts, and a comparison of the same with the beds known in 1880, in order to ascertain if any and what changes have taken place between those dates, and their probable causes; a study of the life history and habits of the starfishes in this region, the latter with special reference to their movements and distribution at different seasons of the year; conferences with the oystermen respecting all matters pertaining to the damage done the beds by their natural enemies at different periods and the means taken to remove the latter or to protect the beds. As no scientific examination of this region had previously been made, and no information was obtainable as a basis for comparison, the difficulty of reaching positive conclusions in the course of a single season's operations was soon made evident. The oyster beds were last chartered by the State shellfish commission in 1880, their delineation furnishing the positions and outlines of the grounds, but nothing regarding their conditions at that time.

The *Fish Hawk* began the investigation by running a line of density observations through the main channel of Narragansett Bay from off

Brenton's Reef light-ship to a point opposite the north end of Prudence Island, which demonstrated that at this season of the year the salinity of the water in this passageway continued nearly uniform at all times of the tide. Between the North Point of Prudence Island and the mouth of Providence River, the examination was made in much greater detail and showed that while at the bottom the densities varied only slightly with the tides, at the surface the changes are more perceptible. Within this area the bottom is mostly covered with a thick layer of mud; no natural oyster beds exist, but a planted bed of about 8 acres in extent is located to the south of Conimicut Point. Starfishes were found to be abundant on a small mussel bed lying to the south of Nayat Point, but only a few were taken in the dredgings elsewhere.

Plottings were made of the larger and more productive beds in Providence River, the same being based upon the surveys of the *Fish Hawk*, with additional information furnished by the oystermen. A comparison of this work with the State oyster map of 1880 shows that a large area of oyster bottom has been abandoned within the past eight years, but its extent was not determined. The set of spat, moreover, was inconsiderable during that period, and the planters have been obliged to obtain their seed chiefly from Connecticut and other waters. The oysters raised about Bullock Point and in its vicinity are considered the finest in the river. The beds nearest the river channel suffer more or less from the depredations of starfishes, which do not reach the inner beds, the latter, however, being subject to the attacks of drills and periwinkles. Off Sabine Point there is also a good oyster bed, which is not troubled by starfishes except to a very slight extent along its outer edge. Great Bed, so called, was once regarded as one of the best pieces of oyster bottom in the river, but since the freshet of 1886, when it was covered with mud, it has greatly deteriorated, and most of the leases have been canceled. A few small patches of oysters occur between Gaspe Point and Pawtuxent Beach, but drills and periwinkles are so abundant upon them and have been so destructive that the present owners propose to relinquish their claims. The *Fish Hawk* found starfishes most plentiful on a bed of 100 acres just to the north of Nayat Point, where, it was estimated, they had already destroyed about one half of its crop of two-year-old oysters. The greatest amount of damage observed, however, had been done by the drills. The beds about Field's Point and in Bullock's Cove, formerly said to have been the most productive in the river, were in a very bad condition, due to their inroads. Large quantities of oyster shells, one, two, and three years old, with scarcely a living specimen among them, were frequently brought up in the dredges. Over a large proportion of these grounds fully 95 per cent of the oysters had been killed in this manner. One owner estimates his loss of seed oysters during 1887 and 1888 at 40,000 bushels, worth 40 cents a bushel, his entire stock having practically been wiped out.

The observations made upon the distribution of starfishes as determined by the salinity of the water are not conclusive, owing to the fact that they were confined to a single month, during which there was a considerable rainfall, although the latter apparently had only a slight effect upon the bottom densities. According to the statements of the oystermen, the upper limit of the starfishes in Providence River is usually in the vicinity of Field's Point, but during seasons of prolonged drought they have been known to ascend as far as the Ohio bed, near the lower bridge at Providence. The mean density of the water at the bottom off Field's Point in September, 1888, was about 1.0187. Off Mobjack Bay, in the southern part of Chesapeake Bay, the average density in April, 1889, was about 1.015. As starfishes are rare, if not entirely absent, in the latter locality, well known for its oyster beds, it is possible that the lowest limit of density in which they can survive for any length of time may be found between the two figures given above.

That these animals might be driven out of Providence River by the freshening of its waters was demonstrated in 1886, but under conditions which proved nearly as destructive to the oysters, although the direct cause of the injury done to them was probably not the same. Starfishes had been very plentiful in 1885. In February, 1886, while the ground was coated with a frozen crust of snow, a heavy rainfall occurred over the drainage tributary to Providence River, producing an unusual freshet and bringing down large quantities of mud, which covered the beds on the west side of the river, and is said to have destroyed nearly the entire crop of oysters there. The starfishes disappeared at the same time throughout the entire river, because, it was supposed, of the great inroad of fresh water, and they did not again become abundant until the summer of 1888, after a lapse of a year and a half. Those observed at the mouth of the river by the *Fish Hawk*, in September, 1888, were of large and nearly uniform size, very few young ones being found among them.

Several means of protection have been suggested for Providence River, but none of them seem feasible. Inclosures in the way of screens about the beds, while they might exclude large objects, would not keep out the young starfishes and drills, and as both of these species remain in the river during the entire year, they would have to be constantly removed by the methods now in use. Furthermore, such barriers would be expensive and could not readily be made durable. Should the pond system of oyster-culture be introduced in this region, however, the trouble with enemies could be largely, if not entirely, overcome. Starfishes are known to have a great fondness for the common mussel (*Mytilus edulis*), and it has been considered that colonies of that species planted around the oyster beds might serve as a partial protection to the latter. Two extensive mussel beds are situated at the mouth of Providence River, one on either side of the narrow channel opposite the Nayat Point light-house, but, while a half bushel of starfishes were

taken from them on nearly every trial made with the large oyster tongs, they seemed to have little, if any, effect in shielding the neighboring oyster beds. Moreover, this method is said to have been tested unsuccessfully off Bridgeport, Conn. Under favorable conditions the mussels also grow very rankly, tending to displace the oysters and accumulating much mud about them as well as other unwholesome matters. Baited traps placed on and about the oyster beds have likewise been tried by the oystermen and by the Fish Commission, but they have not proved generally effective, although a certain measure of success has been reported from their use in some localities.

At New Haven a large map was prepared showing the location and extent of all the planted oyster beds in the harbor, and of the natural beds on the west side of the entrance. Density and temperature observations were also taken as in Providence River, but not so closely together.

Arrangements have been completed to begin upon the investigations in Long Island Sound during the summer of 1889, and they will subsequently be carried southward along the coast. Other inquiries pertaining to the Atlantic coast, conducted during the past year, are described under special headings.

INVESTIGATION OF INTERIOR WATERS.

The object of investigating the different lake and river systems of this country upon a broad and comprehensive basis has been explained in the preliminary remarks, but while the importance of such inquiries has all along been recognized, the subject received comparatively little attention from the Fish Commission until the present year, when it was taken up as an essential feature of the scientific work. The problems involved here, as in other branches of the field work, are of two classes, physical and biological, the latter being again divisible in conformity with popular classification, according to whether they relate to fishes, invertebrates, or plants.

The collection and study of the fishes may proceed with considerable rapidity, owing to their relatively large size and the convenient means devised for their capture both by naturalists and fishermen, but the physical questions, and more especially the aquatic invertebrates, represented by a countless number of varieties and composed in large part of almost microscopic forms, present far greater difficulties in the way of detailed observations, and will require a much greater length of time to secure appreciable results. Owing to the different nature of the field work called for by each of these branches, they must to a great extent be taken up and carried along independently of one another. No other method is generally expedient unless it is desired, by means of a reconnaissance, to obtain immediate information respecting the combined features of any particular region. A party, specially

equipped, need not, however, entirely limit its operations to a single subject, as has been shown by the experience of the past year, during which the fishermen obtained many important data respecting the character and conditions of the streams they visited. Fortunately the United States is well provided with competent ichthyologists, and many students are now in course of training in this popular branch of natural history. Physicists, however, have paid but little attention to the requirements of the fisheries, and few specialists have yet displayed an active interest in the lower organisms which inhabit our fresh waters. The ichthyologists are therefore best prepared to render prompt assistance, and many of them are so situated as to be able to give their services gratuitously during two or three months of each year. Without their liberal support very little could have been accomplished in this division of the inquiry, owing to the slender means available for the purpose.

Having determined upon the advisability of expanding the work in this direction, the Commissioner held a conference at Detroit, Mich., during May, 1888, with the commissioners of several States, who not only gave the project their approval, but urged that it be taken up without delay. Dr. David S. Jordan, president of the University of Indiana, but best known for his extensive studies on American fishes, was also present at the meeting and offered his hearty coöperation; under his able management a school of ichthyology has been founded at Bloomington, Ind., its graduates taking high rank for accurate and painstaking observations. A proposition made by him to organize temporary parties of volunteers from among his former pupils and those now studying under his direction was accepted by the Commissioner, and the work was started early in the fiscal year. Depending upon the services of students and professors occupied with college duties for eight or nine months of every year, the field excursions must be limited chiefly to the summer, but it is expected that some satisfactory arrangement will soon be possible whereby the inland investigations may be organized upon a permanent basis, and, in fact, one of the river explorations now in progress is being executed by regular employés of the Commission.

The plan of work adopted in regard to the volunteer service contemplates, first of all, the somewhat rapid investigation of those regions with which we are the least acquainted, in order to obtain, as soon as possible, a general, though not superficial, knowledge of all our fresh-water fishes, their varieties, distribution, abundance, and habits. Upon the completion of this survey, which may occupy three or four years, the more careful study of each lake and river system can be taken up. Of the inquiries conducted during the past year, as described below, all excepting those which relate to the Hudson River, the Upper Ohio River, and the Alaskan salmon rivers were planned and carried on under the direct supervision of Dr. Jordan, who also participated in the field work during most of the summer of 1888. The cost of these

expeditions amounted only to the actual field expenses of the assistants, while the reconnaissance of the Ohio River by Dr. Henshall and Prof. Gilbert involved no outlay whatsoever on the part of the Fish Commission. The collections made by Dr. Jordan's parties were sent directly to the University of Indiana, where they were studied and where the reports upon them were prepared. The first series of the specimens of fishes has been deposited in the U. S. National Museum at Washington, and the second series in the museum of the University of Indiana. Over 7,000 specimens, representing 141 species and subspecies, of which 14 were new to science, were obtained during the summer investigations in the Alleghany region. From this material 30 duplicate sets of fishes were made up, the same being donated to as many educational institutions, some located in the States where the work had been conducted, the others elsewhere in the United States and in Europe. The crayfishes, of which many specimens were secured in the different regions examined, have been referred to Prof. Walter Faxon, of the Museum of Comparative Zoölogy, Cambridge, Mass.

Dr. Jordan has already begun, with the coöperation of Prof. B. W. Evermann, a complete record of all that has so far been discovered respecting the fresh-water fishes of North America, which, when published, will serve as a basis for future explorations. Its completion will be delayed, however, until the preliminary surveys now in progress have been finished.

The States and Territories into which the investigations were extended during the year 1888–89 numbered eighteen and are as follows: New York, Virginia, West Virginia, North Carolina, South Carolina, Tennessee, Kentucky, Georgia, Alabama, Mississippi, Louisiana, Ohio, Indiana, Michigan, Iowa, Missouri, Arkansas, and Alaska. The work accomplished in each region is summarized below:

The Hudson River, New York.—That the Hudson River is not a natural salmon river is probably due in greater part to the fact that all localities suited to the spawning habits of the fish have been cut off from the main river by insurmountable obstructions. The first systematic attempt to stock the Hudson artificially by the planting of fry from the Penobscot River, of Maine, was begun in 1882 and has been continued down to date. In order to test the utility of these efforts an investigation of this river and of some of its tributary streams was made during the summer of 1888 by Mr. Fred. Mather, of the Cold Spring hatchery, New York, under the direction of the U. S. Fish Commissioner. The specific objects of this inquiry were to ascertain as nearly as possible the number of adult salmon (*Salmo salar*) caught in the Hudson River during the previous season; to determine the possibilities of taking salmon eggs on that river in sufficient numbers to warrant the establishment of a temporary station for that purpose; to examine the small streams with reference to their fitness for developing the young fish during their river life; and to learn the height and

character of the natural and artificial obstructions to the ascent of salmon.

Mr. Mather's report upon the results of his observations was published in the Bulletin of the U. S. Fish Commission, vol. VII, for 1887, pp. 409–424. In a preliminary statement he describes the plantings that were made from 1882 to 1888, inclusive, amounting to over 2,000,000 fry and 150 yearlings. These young fish were all liberated in good trout streams, chiefly in the Adirondack region of Essex and Warren counties, N. Y. Several adult salmon were taken in the Hudson River both in 1886 and 1887, some of which found their way to the markets of New York City. The salmon captured in 1888 could not have belonged to later plantings than those of 1884, up to which time only 864,600 fry had been placed in the river, and any comparison of results should be based upon that number. Mr. Mather experienced considerable difficulty in obtaining information respecting the catch of 1888, as a State law, passed in 1887, prohibits the taking of salmon on the Hudson River except with hook and line. Nearly all of the fish secured were captured incidentally in the nets of the shad fishermen, who were naturally reluctant to testify against themselves or against their neighbors. The inquiry, however, finally resulted in a record of 134 salmon so obtained, but Mr. Mather estimates that fully four times as many were probably taken by this class of fishermen alone. Of the number mentioned, 28 were caught in Gravesend Bay, 20 in New York Bay, 3 in Princess Bay, 5 along the New Jersey shore, and the remainder at points along the Hudson River as far up as Mechanicsville, 26 having been secured below the dam at Troy. The weight of these fish ranged from 5 to 26 pounds each, but very few weighed less than 8 or 9 pounds.

As to gathering salmon spawn in New York waters for use in stocking the Hudson River, the above record indicates that there are at present only two localities where the prospects are at all favorable for obtaining the necessary parent fish, namely, below the dam at Troy and in Gravesend Bay. Considering that these fish are taken rather early in the year, it would, however, be necessary to pen them until the spawning season, and the water of the Hudson River below Troy is apparently too warm for this purpose during the summer. Deep, cool spots exist between Troy and Mechanicsville, and also at the latter place, to which the fish collected in the upper part of the river could be transferred, while the hatching station at Cold Spring Harbor, Long Island, might be used as the depository for those captured in Gravesend and New York bays. The number of eggs to be secured in this way would probably not be sufficient, however, to warrant the expense attendant upon the work until salmon have become more abundant in the river.

All tributary streams suited to the spawning habits of salmon enter the upper part of the river, and the ascent of salmon to them is now

prevented by both natural and artificial obstructions. In case these obstructions are overcome by the building of fishways, there is every reason to suppose that the Hudson will in time become a natural salmon-producing river, a result which it is very desirable should be consummated. Preliminary steps in that direction have already been taken, and it is to be hoped that they will soon be followed by more active measures. The first impediment met by the fish in their movement up the river has been the State dam at Troy, but this has already been provided with a suitable fishway. The second obstruction is a dam at Mechanicsville, at the foot of which salmon were seen jumping in 1888. Above this place there are ten or more falls and dams, the uppermost being Rockwell Falls, at Lucerne, and the most formidable Palmer Falls and Dam, at Jessup Landing. Appropriations have been made by New York State for fishways over the Mechanicsville Dam and over the next one, at Fort Miller. Their construction will open up a continuous run to Fort Edward, 45 miles above Troy. Here there is an old dam which will soon have to be rebuilt, and in so doing a fishway will undoubtedly be added by the owners, a law obliging such construction now being under consideration by the State legislature. Next follow Baker and Palmer falls, both of which present many difficulties, but it is probable that they can be surmounted, if sufficient money is made available. It is probable, however, that with the river opened up to Fort Edward or Baker Falls, the salmon will find good spawning-grounds in some of the lower tributaries. Mr. Cheney, of Glens Falls, N. Y., is confident that such will be the case, and his wide acquaintance with the region in question entitles his views to every consideration. The following remarks upon this subject are abstracted from a letter written by him since the completion of Mr. Mather's survey:

The Moseskill comes in on the left bank of the Hudson about 5 miles below Fort Edward. Above and below it are smaller streams. Snookill, a good spawning stream running back 7 or 8 miles, comes in on the right bank below Moseskill. The Battenkill, or "Lovely Ondowa," is a good trout stream that runs up into Vermont; it comes in below Thompson's Mills. Below this is Hoosick River. I believe that when the salmon find that the State of New York has not provided a way for them over the falls, they will go into some or all of the streams above mentioned, and there spawn. I, for one, will feel quite easy about the salmon when the two fishways are built at Mechanicsville and Fort Miller. Without doubt, the salmon have spawned in the river below Mechanicsville, and many more ascended the dam at Troy than has generally been supposed. The adult salmon evidently tried to get up the Mohawk River, and spawned below Cohoes Falls.

From Mr. Mather's investigation it is, therefore, evident that the results of salmon planting in the Hudson River have been very satisfactory, and promise to repay the outlay of time and money which have been applied to it. With proper legislation, the removal of further barriers, and the added efforts of fish-culture, this important stream should eventually provide good salmon fishing upon a commercial scale.

The Alleghany region of Virginia, North and South Carolina, and Tennessee.—The investigation of this region was conducted personally by Dr. Jordan, with the assistance of Prof. O. P. Jenkins, of De Pauw College, Indiana; Prof. B. W. Evermann, of the State Normal School, Terre Haute, Ind.; and Prof. S. E. Meek, of Coe College, Iowa. Work was begun at Luray, Va., July 25, and continued until September 8, when high water in the rivers prevented further seining. The survey had reference to the two general river systems, one flowing into the Atlantic Ocean between Chesapeake Bay and the Santee River, the other into the Ohio River, and in many instances operations were continued down the river courses a considerable distance toward the coast.

The following rivers of the Atlantic drainage were examined, namely: The Shenandoah, a tributary of the Potomac River; the James River and several of its tributaries; the Dismal Swamp, Elizabeth River; the Blackwater, a tributary of the Chowan River; the Staunton, one of the main branches of the Roanoke River, in Montgomery and Roanoke counties, Virginia; the Tar River, a tributary of the Pamlico; the Neuse River and several of its tributaries; the Haw River, a tributary of the Cape Fear; the upper waters of Great Pedee River; the Santee River and many of its upper tributaries. In the Ohio River drainage, the streams examined were several tributaries of the Kanawha River in Virginia, of the Holston River in Virginia and Tennessee, and of the French Broad River in North Carolina. The total number of seining stations was 54.

The collections obtained were transmitted to the University of Indiana, where they were studied by Dr. Jordan, whose report upon the inquiry has been published in the Bulletin of the Fish Commission for 1888.* The limited time that could be given to the investigation, considering the wide area which it covered, prevented the party from paying attention to other subjects than the fishes, with some reference to the physical characteristics of the rivers. Dr. Jordan's paper is one of the most comprehensive and valuable contributions of its kind that has yet been published anywhere, and will prove of great interest both to fish-culturists and to the fishermen of the region which it describes. The subject is treated by river systems, and under each heading is given a brief account of the physical features of the main river and its tributaries as determined at the localities visited, followed by a list of the fishes taken, with notes upon their habits and special habitats. Several new and little-known species and varieties are also discussed at greater length. The new species were described in a preliminary paper which has been printed by the U. S. National Museum.†

*Report of explorations made during 1888 in the Alleghany region of Virginia, North Carolina, and Tennessee, and in Western Indiana, with an account of the fishes found in each of the river basins of those regions. By David Starr Jordan. Bull. U. S. Fish Commission, VIII, 1888, pp. 97–173, plates VIII–XV.

† Descriptions of fourteen new species of fresh-water fishes collected by the U. S. Fish Commission in the summer of 1888. By David Starr Jordan. Proc. U. S. National Museum, XI, 1888, pp. 351–362, plates XLIII–XLV.

The Upper Ohio River and its tributaries.—During August, 1888, Dr. James A. Henshall and Prof. Charles H. Gilbert, of Cincinnati, made an ichthyological reconnaissance of the Ohio River and its tributaries between Marietta and Cincinnati, Ohio, in the joint interests of the U. S. Fish Commission and the Cincinnati Society of Natural History. For the conduct of this exploration the Hon. Nicholas Longworth, of Cincinnati, placed his steam yacht *Mink*, with its crew of six men, at the disposal of Dr. Henshall, an act of liberality which was much appreciated. Rainy weather, causing unusually high water for the summer season, greatly interfered with operations and curtailed the anticipated results. The streams explored were the Ohio River at numerous places, the Muskingum, Little Miami, and Hocking rivers, and Raccoon, Brush, and White Oak creeks, in Ohio; the Kanawha and Guyandotte rivers, in West Virginia; and the Big and Little Sandy rivers and Kinnikinnik and Tygert creeks, in Kentucky. Nearly 100 species of fishes were obtained, a few of which had not previously been recorded from those waters.

The most abundant species observed in the Ohio River were the channel catfish (*Ictalurus punctatus*), red-horse (*Moxostoma*), buffalo (*Ictiobus*), carp sucker (*Carpiodes*), fresh-water drum (*Aplodinotus grunniens*), toothed herring (*Hyodon*), gizzard shad (*Dorosoma cepedianum*), and skipjack (*Clupea chrysochloris*). Pike perches or Ohio salmon (*Stizostedion*), newlights (*Pomoxis annularis*), black bass, chubs, and shiners were also common. The catfishes, suckers, buffaloes, red-horses, and white perch (drum) sell well in the markets, and appear to be esteemed as food in all the towns along the river; the pike perch (Ohio salmon) and the black bass rank highest among the river fishes, but are not caught in sufficient quantities to supply the demand. The fishermen have shanty boats at the mouths of all the smaller streams. They use fyke-nets, drag seines, and trot lines, and have no difficulty in selling all the fish they catch.

The Muskingum is a swift, beautiful stream, flowing through one of the most attractive and fertile valleys of Ohio. Its banks are well wooded with gigantic elms, maples, beeches, and sycamores. The river has a rocky bed with many rapids, but it is navigated for a hundred miles by means of locks. The party proceeded up the river some 60 miles, to within a short distance of McConnelsville, passing through six locks. They explored the main stream at the foot of the dam at each lock, and a few of the small tributaries. The young of the black bass and pike perch were quite abundant, showing that favorable results have attended the stocking of these streams by the Ohio Fish Commission. In the Kanawha River the red-horse, carp sucker, drum, and skipjack were again found to be the most abundant, with the pike perches, gars, and sunfishes less numerous. The waters of the Little Kanawha were so impregnated with petroleum that fish life seemed to

be entirely absent. In the Hocking, Raccoon, Brush, and White-oak creeks, in Ohio, were found the usual river minnows and darters, with the young of the larger river fishes, but the creek species were driven far up the streams by the unusually high water, and no favorable places for seining could be discovered. In the Big and Little Sandy, Kinnikinnik, and Tygert creeks, in Kentucky, newlights, black bass, pike perches, and sunfishes were quite abundant, as these streams have more fall and a swifter current than those on the Ohio side. In Little Miami River the trout perch (*Percopsis guttatus*) was common, as it was also in the Muskingum. Dr. Henshall thinks these are the first instances of its having been taken in southern Ohio, as it was hitherto supposed to be peculiar to the Great Lakes. It is possible that it has found its way to the Ohio basin through the canals.

Indiana.—Early in September, 1888, Prof. B. W. Evermann began the investigation of certain areas in western Indiana whose fishes had not previously been studied, continuing the work until cold weather interfered. He was assisted by Mr. C. H. Bollman and Mr. A. J. Woolman. The following rivers were examined: St. Joseph River, between Mishawaka and South Bend; Yellow River at Plymouth; Upper Wabash River, on several of its tributaries; Lower Wabash River and its tributaries; Lower Ohio River, near Evansville and Mount Vernon; and White River, at Spencer and Cataract. An account of the results of this inquiry has been included in Dr. Jordan's report on the Alleghany region of Virginia, etc., referred to above.

Michigan.—An examination of the lakes and rivers of Michigan was begun in 1885 by the fish commissioners of that State, the object of the same being to ascertain the results of previous efforts in stocking those waters and their suitability for different kinds of food-fishes. A small party, composed of regular employés of the State commission, has been assigned each summer to this field work, and an account of its researches down to 1888 will be found in the Seventh and Eighth Biennial Reports of the Michigan Fish Commission, published in 1887 and 1888. Not having had the services of a professional naturalist, the results have hitherto been incomplete from a biological standpoint, but by arrangement with the U. S. Fish Commission Mr. Charles H. Bollman, assistant in the University of Indiana, was designated as ichthyologist during the season of 1888. He was in the field from July 10 to August 19, when the investigations practically ended. The localities examined, arranged according to river basins, are as follows: *St. Joseph Basin:* Long, Austin, Indian, Gourd Neck, Rawson, and Howard lakes in Kalamazoo County. *Kalamazoo Basin:* The main river at Battle Creek and Marshall, Cognac, St. Mary's, Barnum, and Payne lakes, Upper and Lower Brace lakes, and Lyon Lake in Calhoun County. *Elk Basin:* Torch and Clam lakes, Rapid River and Spencer Creek in Antrim County.

In his report* Mr. Bollman briefly describes the physical characteristics of the several lakes, including their temperature at the surface and bottom, and notes the distribution of the species collected, which number 53. On account of its northern position, Michigan has, he states, comparatively few kinds of fishes, and as all the waters examined in 1888 had essentially the same physical features the list which he presents was, necessarily, a small one. The bottoms of the lakes were found to consist chiefly of fine mud or pulverent vegetable matter. Reference is made to the food of 23 species, which exhibited little diversity in that respect.

Iowa.—In the autumn of 1888, after the close of the Virginia explorations, Prof. S. E. Meek, whose residence is in Cedar Rapids, began the preparation of a report upon the fishes of Iowa, which will necessitate the examination of many localities where no collections have yet been made. This work will be continued from time to time, as his college duties will permit. In 1888 it was limited to Cedar River and its tributaries, chiefly in the neighborhood of Cedar Rapids.

Missouri and Arkansas.—The proposed establishment of a new hatching station at Neosho, in the Ozark region of Missouri, made it desirable to examine with some care the different streams in that vicinity. The services of Prof. C. H. Gilbert, of the University of Cincinnati, and of Prof. S. E. Meek, of Coe College, Iowa, were secured for that purpose, and the work was begun about the middle of July, 1888. The former, however, having been severely prostrated by malarial fever early in the season, the inquiry had to be deferred until the summer of 1889, when it will be taken up by Prof. Meek. The country about Neosho is chiefly drained by tributaries of the White River, but it is intended to extend the examination to the Osage River in Missouri, and the Arkansas and Washita rivers in Arkansas.

Alabama.—The investigations in Alabama were begun in the first part of May, 1889, and were continued a little over one month. The party consisted of Philip H. Kirsch, Everett O. Jones, and William M. Andrews, all students in the University of Indiana. Before reaching Alabama collections were made in Lake Pontchartrain, La., and in Biloxi Bay, Ocean Springs Bay, and Fort Bayou, Miss. In Alabama the explorations covered the greater part of the State, the number of places visited being indicated in the following summary: The Tennessee River and nine of its tributaries; the Alabama River and eleven of its tributaries; the Escambia River and eight of its tributaries. Prof. Charles H. Gilbert, who has reported upon the results of this expedition,†

*A report upon the fishes of Kalamazoo, Calhoun, and Antrim counties, Michigan, obtained in connection with the investigations of the Michigan Fish Commission during the summer of 1888. By Charles H. Bollman. Bull. U. S. Fish Commission, vol. VIII, for 1888, pp. 219–225.

†Report of explorations made in Alabama during May and June, 1889, with notes upon the fishes obtained in the bend of the Tennessee, the Alabama, and the Escambia rivers, and descriptions of three new species. By Charles H. Gilbert. Bull. U. S. Fish. Com., IX, for 1889, pp. 143–166.

states that with the exception of the larger river fishes, which were not obtained, the list of species presented is probably approximately complete for the bend of the Tennessee River, in the northern part of the State, but additional collections are still needed from the Alabama River. The examinations made in the bend of the Tennessee were chiefly noteworthy as showing the presence in the clear, cold, spring-fed tributaries of that portion of the river, of an unexpectedly large number of species characteristic of the headwaters of the French Broad and Holston rivers, which were studied by Dr. Jordan during the summer of 1888. Prof. Gilbert also includes in his paper the results of explorations made by himself and Prof. Joseph Swain, in 1884, and by Jordan, Evermann, and Bollman, in 1886. The number of species recorded from each river basin is as follows: The Tennessee River, 74 species; the Alabama River, 49 species; the Escambia River, 38 species.

Georgia.—In the latter part of June, 1889, Mr. Charles H. Bollman and Mr. Bert Fesler, both of the University of Indiana, began an investigation of the lowland region of Georgia. It was intended to continue the inquiry until about the middle of August and to extend it into the State of Florida. Mr. Bollman, however, was taken sick with dysentery fever at Waycross, Georgia, on July 4, and died on the 13th of the same month. The work was therefore abruptly terminated. Mr. Bollman was a recent graduate of the University of Indiana, where he was held in high esteem. Under the careful training of Dr. Jordan, he had acquired great proficiency as an ichthyologist and in other branches of zoölogy, having published several important papers on fishes and on the more obscure group of Myriapods. He gave promise of a bright and useful future and in a few years would, undoubtedly, have taken high rank among American naturalists. His loss is severely felt by the Fish Commission and by his many friends. During the short time this party was in the field, collections were made in Brier Creek, at Waynesboro; in a small creek in the southern suburbs of Savannah; in the Ogeechee River and one of its tributaries and in Buckhead Creek at Millen, and in the Satilla River at Waycross. Thirty-one species of fishes were obtained, including one new form, *Opsopœodus bollmani* Gilbert. The results accomplished have been described by Prof. C. H. Gilbert.*

Alaskan salmon rivers.—The great decrease in the production of the salmon fisheries of the Pacific coast between San Francisco and Puget Sound, during the past few years, has caused the salmon-packers of that region to turn their attention toward Alaska, where several species of the *Salmonidæ* occur in extraordinary abundance. Large and fully equipped salmon canneries have already been established at many

*Notes on fishes from the lowlands of Georgia, with a description of a new species (*Opsopœodus bollmani*). By Charles H. Gilbert. Bull. U. S. Fish Com., VIII, for 1888, pp. 225–229.

places in that territory, and an important and profitable industry has thereby gained a strong foothold in what is otherwise almost a primitive wilderness. In 1889 there were 36 of these canneries, 4 of which were located in Bristol Bay, 8 on Kadiak Island, 2 on Afognak Island, 5 on the east side of the Alaska Peninsula, 2 in Cook Inlet, and the remainder farther south along the coast. The total amount of capital invested was about $4,000,000, while the output for the year was valued at about $3,000,000. The resources of the Alaskan rivers in respect to this product have been considered by many persons, the fishermen and canners especially, to be practically inexhaustible, and such might be the case were the fishery conducted in a judicious manner and the habits of the salmon not materially interfered with. Many of the rivers, however, to which the salmon resort in great numbers, and which are conveniently located for the business, have short courses and comparatively shallow water near their outlets at times of low tide. In streams of this character the fish can readily be brought more directly under the control of man than in the longer and larger rivers in which the fishery has hitherto chiefly been carried on. The fishermen have been quick to recognize this advantage in devising means of capture, the most formidable and destructive of which have been traps and other forms of barricades reaching partly or entirely across the river. Meeting such a barricade the salmon congregate below it, and, still impelled by the breeding impulse to continue the ascent, remain entirely at the mercy of their captors, who can remove them with little trouble and at slight expense. To what extent this practice is now indulged in is not precisely known, and, we are, therefore, justified in supposing that only a small proportion of the fisheries are thus maintained, but a number of instances of gross misuse of the natural privileges have been reported, and as the canneries in any one locality increase in number the abuses are said to multiply.

The salmon interests of Alaska are actually of greater value than the sealing, and by proper management they can be made more permanent, but with unrestricted license they will as rapidly be destroyed. A knowledge of the habits of the salmon, joined with past experience in regard to the fisheries which they have provided, establishes the fact that this very important food product is also one of the easiest to exterminate, and should be well cared for.

During the winter of 1888–89 the attention of Congress was called to the salmon question in Alaska by residents of the Pacific Coast, who made an earnest appeal for immediate legislation to protect this source of industry before the rivers had become depleted. In compliance with their request the following act was passed and became a law on March 2, 1889:

AN ACT TO PROVIDE FOR THE PROTECTION OF THE SALMON FISHERIES OF ALASKA.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the erection of dams, barricades, or other obstructions in

any of the rivers of Alaska, with the purpose or result of preventing or impeding the ascent of salmon or other anadromous species to their spawning-grounds, is hereby declared to be unlawful, and the Secretary of the Treasury is hereby authorized and directed to establish such regulations and surveillance as may be necessary to insure that this prohibition is strictly enforced and to otherwise protect the salmon fisheries of Alaska; and every person who shall be found guilty of a violation of the provisions of this section shall be fined not less than two hundred and fifty dollars for each day of the continuance of such obstruction.

SEC. 2. That the Commissioner of Fish and Fisheries is hereby empowered and directed to institute an investigation into the habits, abundance, and distribution of the salmon of Alaska, as well as the present conditions and methods of the fisheries, with a view of recommending to Congress such additional legislation as may be necessary to prevent the impairment or exhaustion of these valuable fisheries, and placing them under regular and permanent conditions of production.

In accordance with the provisions of section 2 of this act, the U. S. Fish Commissioner made arrangements to undertake the investigation therein directed during the summer of 1889. No specific appropriation having been made for that purpose, the expenses of the expedition were provided from the general appropriation. A party of four persons was organized to conduct the field work, the charge of the same being confided to Dr. Tarleton H. Bean, the ichthyologist of the Fish Commission, a well-known authority on Alaskan fishes and personally acquainted with the region to be studied. His associates were Mr. Livingston Stone, fish-culturist, Mr. Franklin Booth, topographical engineer, and Mr. Robert E. Lewis, rodman and general assistant. With the exception of Mr. Booth, these persons were all regular employés of the Commission. Dr. Bean left Washington in June, 1889, but the party was detained in San Francisco until July, through inability to obtain the necessary transportation, there being no regular line of steamers to that part of the Alaskan coast where they were to go. This exploration belongs, therefore, to the next fiscal year, but the plans and objects of the trip may be briefly stated here.

Kadiak and Afognak islands were selected as requiring first attention, as the greatest danger from overfishing had been reported from those places. In case the time permitted, the work was to have been extended subsequently to Cook Inlet, but the season proved too short to include that region in the scheme of operations. The observations of the party were to relate to the natural history of the salmon and their associated species, and the physical characteristics of their environment; the methods, statistics, and conditions of the salmon fishery; and the necessities and advantages of Alaskan waters for the artificial propagation of salmon. From the results obtained, it was expected to determine the extent and causes of any injury that had been done, and the proper remedies to apply, whether through legislation or through the aid of fish-culture.

PHYSICAL INQUIRIES.

Physical inquiries of one kind or another form a part of nearly all the field work that is carried on, and reference to them has been made under several other headings. Temperature and density observations are taken frequently by all the vessels in connection with their dredging and sounding operations at sea, principally at the surface and bottom, but to some extent also at intermediate depths. The arrangements made a number of years ago with the Light-House Board and Signal Service for continuous temperature records at certain of their stations still continue with satisfactory results, but the number of stations used for that purpose is much smaller now than formerly. Through the courtesy of the Southern Pacific Railroad Company similar observations are also taken at the railroad crossings of several of the large western rivers. The number of permanent stations in operation has proved totally inadequate, however, to accomplish what is most desired, namely, to determine the precise relations of temperature to the movements of migratory fishes, the isotherms corresponding with the advance schools. This subject has been partly worked up with respect to the shad, mackerel, and menhaden, but further data are required before definite conclusions can be reached. In case the laws which govern their movements can be fully demonstrated, it is rational to suppose that the arrival of any pelagic or anadromous fishes upon the sea-coast or along a river course may to some extent be anticipated and the fishermen be given warning of their near approach. The difficulties in the way of such a fortunate solution of this problem may be insurmountable, but as yet the matter has not been fairly tested, and it is only recently that the proper course to be pursued has been thoroughly comprehended.

The temperature stations of the Light-House Board, the Signal Service, and the Southern Pacific Company furnish continuous series of observations, which are taken twice daily at the light stations, and once a day at the others, the reports being submitted monthly. The light stations are chiefly in more or less exposed positions; those of the Signal Service in harbors, and those of the Southern Pacific Company at river crossings, as before explained. The names and locations of the stations which furnished information during the year are as follows:

TEMPERATURE STATIONS ON THE ATLANTIC COAST.

Stations of the Light-House Service:

Coast of Maine: Petit Manan Island, Mount Desert Rock, Natinicus Rock, Seguin Island, Boon Island.

Coast of Massachusetts: Race Point, Pollock Rip light-ship, Nantucket New South Shoal light-ship, Cross Rip light-ship, Vineyard Sound light-ship.

Coast of Rhode Island: Brenton Reef light-ship, Block Island southeast light.

Long Island Sound: Bartlett Reef light-ship, Stratford Shoals light-ship.

Coast of New York: Sandy Hook light-ship.

Coast of New Jersey: Absecon Inlet, Five Fathom Bank light-ship.

Stations of the Light-House Service—Continued.
Delaware Bay: Fourteen Foot Bank light-ship.
Coast of Virginia: Winter Quarter Shoal light-ship.
Chesapeake Bay: Point Lookout, Windmill Point, Stingray Point, Wolf Trap Bar, York Spit.
Coast of North Carolina: Bodys Island, Cape Lookout, Frying Pan Shoal light-ship.
Coast of South Carolina: Rattlesnake Shoal light-ship, Martin's Industry Shoal light-ship.
Coast of Florida: Fowey Rocks, Carysfort Reef, Dry Tortugas.
Stations of the Signal Service:
Eastport and Portland, Me.
Boston and Nantucket, Mass.
New York City, N. Y.
Charleston, S. C.
Key West, Cedar Keys, and Pensacola, Fla.
Stations of the Fish Commission:
Wood's Holl, Mass.
Fort Washington, Potomac River, Md.
Washington, District of Columbia.

TEMPERATURE STATIONS ON THE PACIFIC COAST AND SLOPE.

Stations of the Signal Service:
Portland, Oregon.
Stations of the Southern Pacific Company:
Colorado River at Yuma, Ariz.
Sacramento River, at Tehama and Yolo Bridges, Cal.
San Joaquin River, at the Upper and Lower Railroad Crossings, Cal.
King River, at Kingsbury, Cal.

Among the rivers the Potomac is best provided with observing stations, there being one at Fort Washington and another at the city of Washington, both operated by the Fish Commission, in addition to those above enumerated from Chesapeake Bay. It would add greatly to the value of the results if other important rivers could be as well supplied. Unfortunately, there are no stations at exposed positions on the Pacific coast, where arrangements have yet to be made for the study of temperature variations.

In Section III of the Fisheries and Fishery Industries of the United States, published in 1887, the writer presented a first report upon the results of observations made at the light stations on the Atlantic coast during the years 1881 to 1885, inclusive, the curves of temperature at each locality being plotted separately for each year on graphic charts. A more complete report, for which all the records down to date are being combined, is now in course of preparation.

The observations above discussed have reference chiefly to the shore waters and the rivers, although a few of the light-house stations are located somewhat off the shore, in exposed positions. The data derived from those sources can not, therefore, have much bearing upon the movements of pelagic fishes until they actually approach the coast. It is impracticable to establish permanent temperature stations in the open sea at a distance from the land, owing to the depth of water and

the expense of maintaining a sufficient number to afford appreciable results. Recourse must be had to other means for obtaining that information. The Fish Commission vessels are all provided with thermometers and density apparatus of the most approved patterns, but hitherto these have been regarded rather as accessories to the dredging and fishing outfit, and the temperature and specific-gravity observations have been supplemental to the collecting work. Consequently these observations have not been carried on systematically, either at fixed stations or along definite lines, and the records are of little value for determining the temperature and density variations in any special region. Until this subject has been studied in a thoroughly comprehensive way, we can not expect to make any advancement toward the explanation of those mysterious laws which govern the arrival and departure of pelagic fishes. Observations taken at the surface and bottom only are inadequate for the purpose. They must be carried through successive depths of water, being most numerous at those levels where the variations are most pronounced and the changes most frequent.

The investigations made by the steamer *Albatross*, between 1883 and 1887, have furnished the clearest insight into the physical characteristics of the waters off the Atlantic coast of the United States, especially south of New England and Long Island, where the greatest amount of work was done, and yet her observations are altogether incomplete for the purposes set forth above. The superficial relations of the Arctic current, flowing southward along the coast, and the Gulf Stream, flowing northward on the outer side, are generally understood. The serial temperatures taken by the *Albatross* show, however, that the transition from warm to cold water is not uniform at all depths and at all times, the Arctic current tending to indent the Gulf Stream on its inner face, producing in the same section very unequal bands of temperature, and indicating superimposed currents flowing in opposite directions. Another feature demonstrated by the *Albatross* was, that the border of the continental platform where the slope begins is partly bathed by the warmer waters pertaining to the Gulf Stream belt. Thus a somewhat tropical fauna is carried far northward, occupying a rather narrow zone between the cold water covering the inner surface of the platform and that which characterizes the deeper portions of the adjacent ocean. Here also was the habitat of the tilefish (*Lopholatilus chamæleonticeps*), whose sudden extermination in the spring of 1882 gave additional proof that the conditions which prevail in this region are unstable and fluctuating. The facts are insufficient to explain those conditions, but they indicate an interesting and perplexing problem in the solution of which important practical results may be anticipated. The principal pelagic fishes make their appearance from the direction of the Gulf Stream, moving inshore and northward as the season advances. With what hydro-isotherm is the approach of each species coincident, and do the movements of those isotherms correspond

with changes in the surface and atmospheric conditions which may be kept constantly under observation?

Plans were proposed sometime ago for running lines of observing stations across the mackerel region off the New England coast, with the object of obtaining several vertical sections to show the distribution of the bands of temperature, but owing to the press of other work they had to be indefinitely postponed. The subject was again brought up in the autumn of 1888 by Commissioner McDonald, who, after determining upon the character of results desired, referred the matter to Prof. William Libbey, jr., of Princeton College, to elaborate the details, the latter also having expressed his willingness to direct the investigations during the summer of 1889. The schooner *Grampus* was selected for making the experiments, and was thoroughly equipped for that purpose. It is intended that the work shall be carried on during the months of July and August.

During April and May, 1889, a series of density observations was carried through Chesapeake Bay from Baltimore southward, by Dr. C. F. Hodge, of Johns Hopkins University, with the view of obtaining data for comparison with the observations previously made on the oyster-grounds of Providence River and Long Island Sound. This work was incidental to a natural-history cruise conducted by students of the university.

Demands are frequently made upon the Commission for copies of the unpublished records of ocean temperature by persons interested in the study of climatology and of the health of seacoast towns, indicating that the value of those observations is not confined to fishery matters. All such requests have been complied with.

Acknowledgments are due to the Chief Signal Officer, U. S. Army, for the testing, gratuitously, of the delicate thermometers used in connection with the marine investigations.

THE WOOD'S HOLL STATION.

This station is one of the largest and most important of the Fish Commission, and is adapted to the needs both of scientific investigations and of fish-culture. Its location is excellent for both of those branches, being in the center of extensive marine fishing-grounds, whose threatened depletion first attracted the attention of Prof. Baird, and lying adjacent to the pathway of such well-known pelagic species as the mackerel, bluefish, and menhaden. The causes which led to the establishment of the station have been recorded in previous reports, as have also the incidents connected with its construction and equipment. During its first summer, that of 1871, the Fish Commission made its headquarters in this quiet little village, while its members found occupation in studying the surrounding fisheries whose unfavorable condition had occasioned much alarm. The results of that fishery investigation,

the first founded upon a scientific basis, were more than local in their effect, demonstrating, moreover, that precise methods of observation and deduction might be made as beneficial for this industry as for the kindred ones of agriculture and mining. The second year fish-culture was taken up as an adjunct in the replenishment of impoverished fishing-grounds in fresh water, but the work of exploration along the seacoast was continued and its scope enlarged. In the summer of 1872 the headquarters were at Eastport, Me., the center of the herring and of other important fisheries; in 1873 they were transferred to Portland, Me., and in succeeding years to Noank, Conn., Wood's Holl for a second time, Salem, Halifax, Gloucester, Provincetown, and Newport, ending with the latter place in 1880.

Down to the last-mentioned year, while the apparatus employed was the most perfect then available, the means for using it were more or less crude and were improvised for the occasion. The vessels were mostly small and not suitable for long trips, especially away from land, making it advisable to change the base of operations from time to time until the building of the steamer *Fish Hawk* in 1880. The importance of extending the inquiries to the offshore banks was made evident in that year by the researches in the tilefish region, and the project of building a larger sea-going steamer for that class of work brought with it the question of a permanent station where the vessels could find a rendezvous and the working party proper accommodations for their studies. Experiments in the propagation of cod had also been sufficiently advanced to indicate the utility of extensive operations in that respect. To join forces and build a station which should answer for all these purposes seemed most expedient, and this was the course pursued. Some of the reasons for selecting Wood's Holl as the site were the freedom of its waters from contamination and their high salinity (the strong tidal currents insuring a perfect circulation), and the somewhat temperate winters—the season when the cod work must be undertaken. At this point, moreover, several important species whose distribution is to the south of Cape Cod could be obtained, and a much greater scope could be given to hatching operations.

The essential features of the Wood's Holl Station are the large building serving as a hatchery and laboratory, the pump house or water tower, and the adjacent basins for the storage of living fishes. Besides these there is a dormitory for the assistants (the town itself affording insufficient accommodations for them), an ample coal shed, a storehouse, and well-constructed wharves for the mooring of the vessels. The first building was completed in 1884, the last in 1886.

During the lifetime of Prof. Baird, the steamers *Albatross* and *Fish Hawk* and the schooner *Grampus* made this place their headquarters during the warmer months, while engaged upon the survey of the northern fishing-grounds, returning after each cruise to deposit their load of specimens, to report their observations, and to replenish their

supplies. Many assistants skilled chiefly in the line of systematic zoölogy were required to care for the material brought in and to determine its character and bearing, but specialists in other branches were also present.

In the autumn of 1887 the *Albatross* started on its voyage to the Pacific coast, and subsequently the *Fish Hawk* was assigned to the investigation of the oyster-grounds. The withdrawal of these vessels from their customary summer grounds necessitated for a time the abandonment at the Wood's Holl Station of that class of inquiries for which their researches had so liberally provided. During the summer of 1888 the scientific laboratory was, therefore, chiefly utilized for the study of problems relating to the local fauna, the most practical being those which bore upon the embryology and life histories of useful fishes. The importance of such inquiries at the present time is especially great, in view of the efforts now being made to increase the fish supply along that portion of the coast. Of the daily habits of marine fishes very little is yet known, and the details of their embryology and later development have still to be explained with the majority of useful species. As our knowledge of the life history of each species becomes more perfect, its artificial culture becomes easier, and larger results are secured with less trouble and expense. Knowing the requirements of an egg for successful incubation, the appliances for hatching can be accommodated thereto and the mortality greatly lessened, while the young may be released in a more healthful and vigorous condition. Knowing the natural habits of the embryos, they may be planted more judiciously where the food and physical conditions are most suitable, and arrangements may be made in many cases for their feeding and rearing in confinement until they reach a size where their instincts and activity enable them much better to search for food and to escape their enemies. Similar studies are equally important for the lawmakers, affording them the information necessary as a basis for legislation regulating the fishing season and the methods of fishing to be permitted.

Researches of this character have always been encouraged at the Wood's Holl Station, but they have never been carried on there so extensively as during the summer of 1888. The small amount of money available for these inquiries permitted of the employment of only a few temporary assistants, and it was therefore, necessary to resort to the same measures which had prevailed in former years. The services of a number of volunteers were readily obtained in consideration of the facilities for work afforded by the laboratory, and properly qualified applicants for the remaining tables were allowed to be in attendance. While it is neither possible nor expedient in all cases to limit the investigations of such volunteers to subjects of immediate practical utility, their studies are nevertheless essential to the work and afford results which contribute in very great measure to its success. It is often impracticable to obtain the eggs of economic species at the time when the student is able

to conduct his observations, and, moreover, the eggs of some are so opaque or so minute as to make their study difficult. The eggs of kindred and non-commercial forms may then be utilized to good advantage, and their history may explain the facts desired. The teachings of morphology and histology, as well as of physiology, are equally essential to the interpretation of many questions which constantly tax the ingenuity of the breeders of aquatic animals, and it is only upon the broadest basis of biological deductions that their operations can be conducted intelligently and successfully.

In spite of these facts, the Government contributes nothing toward the compensation of those specialists whose time is not expected to yield a more or less direct gain. They are accorded such facilities as remain after the Fish Commission representatives have been provided for, and their good work is chiefly carried on under the stimulus which actuates the genuine seeker after truth. They are mostly professors and students in scientific institutions, who devote their vacation time, in such manner as they are best fitted, to the general advancement of knowledge. To the unselfish labors of men of this stamp and to their discoveries of great fundamental principles are largely due not only the development of fish-cultural methods, but of many important modern industries. The expediency of extending opportunities for research to this class of students is undeniable, and were it possible to offer still more substantial aid, the results would fully justify the means, as has been recognized in other branches of the Government service. By the payment of small salaries during about three months of each year a very able staff of workers could be organized, and under competent supervision their inquiries could be directed in the most appropriate channels.

The facilities of the Wood's Holl Station for observations and experiments respecting marine animals are unsurpassed elsewhere in this country, and probably also in Europe, except by the famous Naples laboratory. In the large laboratory building, the lower story has been specially fitted up for hatchery purposes, and contains the most approved appliances adapted to the propagation of marine fishes. These are at the service of the biological student who desires to trace the development of any set of eggs, permitting him to keep them constantly in view under the most favorable conditions afforded by a perfect system of water circulation. In the same room there is a larger series of aquaria and tanks, designed for the storage of embryo fishes while awaiting distribution, but available also for observations upon the growth and habits of any marine forms. The second story has been furnished chiefly in the interest of biological inquiry, being divided into several rooms, one of large size, the others suited to the requirements of one or two workers each. Salt water is distributed around the entire story by means of hard-rubber pipes having outlets at each window, where aquarial and study tables are provided. Larger aquaria

occupy the center of the main room, which is also supplied with other necessary conveniences for this branch of work. In the upper story there is a physical and chemical laboratory and a photographic studio. In front of the station are three basins of water, two of which are entirely inclosed, the third having an opening on one side for the passage of boats. The former are adapted to the penning of live fishes, and afford facilities for the study of their habits under conditions which are more or less natural. Several live-cars are anchored near the shore, and the station is well provided with small boats, including a sailboat and steam launch. The steamer *Fish Hawk* was at work in the neighborhood of Wood's Holl from August 5 to September 7, 1888, and the schooner *Grampus* made its headquarters at the same place during the latter part of the season, while investigating the mackerel region between Nantucket and Virginia. Opportunities for collecting were afforded by both of these vessels.

During the summer of 1888 the laboratory was in charge of Prof. John A. Ryder, of the University of Pennsylvania, formerly an assistant on the Commission, and widely known for his extensive and careful researches on the embryology of fishes and other aquatic animals. For the details of the work accomplished under his direction reference should be made to his report printed in Appendix 5 to this volume, pp. 513–522. The season lasted from July 1 until October, and during that period seven important educational institutions were represented at the station by the following investigators: The University of Pennsylvania by Prof. Ryder and Mr. W. S. Marshall; the Museum of Comparative Zoölogy of Harvard College by Mr. H. H. Field, Mr. W. McM. Woodworth, and Dr. and Mrs. C. H. Eigenmann; Johns Hopkins University by Prof. W. K. Brooks, Dr. E. A. Andrews, Mr. S. Watase, Mr. C. F. Hodge, and Mr. T. H. Morgan; Princeton College by Professor Miller, Mr. C. F. McClure, and Mr. J. Warne Phillips; Swarthmore College by Prof. Spencer F. Trotter; Wooster University, Ohio, by Prof. H. N. Mateer; and the Lake Laboratory at Milwaukee, Wis., by Dr. William Patten, who arrived at Wood's Holl early in June and remained until the latter part of July. Dr. Benjamin Sharp, of Philadelphia, was at the station in March, 1888, making a study of the development of the winter flounder or flatfish, *Pseudopleuronectes americanus*, which spawns at that time. Prof. S. F. Clarke, of Williams College, Prof. J. S. Kingsley, of the University of Indiana, and Mr. G. H. Parker, instructor in biology in the Museum of Comparative Zoölogy, were also present for a few days during the summer, chiefly for the purpose of obtaining material to be used in class demonstrations. The Commissioner established his office at the station during the latter part of the season, and Dr. T. H. Bean, the ichthyologist of the Commission, was there during the last few weeks, making some observations respecting the local fishes.

Professor Ryder's studies related to the embryology of the sea bass (*Serranus atrarius*) and the development and anatomy of the Atlantic

coast sturgeon (*Acipenser sturio*), but in addition he obtained a large collection of specimens representing the larval and post-larval stages of other fishes, on which his observations will be continued at Philadelphia. The work on the sturgeon was begun in Delaware Bay the previous spring, and was taken up with the object of preparing a comprehensive monograph on this important food species, whose rapid decrease in abundance is creating much apprehension among the fishermen. The results obtained, discussed elsewhere under the heading of the species, furnish the necessary information on which to base a successful system of artificial propagation. Regarding the material collected during the summer, Prof. Ryder states that it will help materially to fill in many existing gaps between the embryo and adult forms of fishes, thereby tending to throw much light upon the life history and habits of certain marine species respecting which more complete records are desired. Recognizing the importance of recording permanently the shape and coloration of the young as well as the adult stages of food-fishes, for the benefit of fish-culturists and of others interested in the subject from either a practical or a scientific standpoint, the services of Mr. S. F. Denton, an excellent artist and experienced naturalist, were secured for that purpose. His colored sketches made during the season represent twenty-three species, and were prepared from living specimens confined in the aquaria. This series, when completed, will, according to Prof. Ryder, "constitute a monograph of the most enduring, economic, and scientific value, as a contribution to fish-cultural literature."

The investigations of the scientific experts at the laboratory covered a wide range of subjects respecting the embryology, anatomy, histology, and physiology of fishes and marine invertebrates, such as the general and specific development of fishes, their osteology, the growth, structure, and functions of the different alimentary organs, the vascular system, the kidney, the brain, and other nerve tissues; the development, anatomy, and physiology of the king crab, the bait squid, annelids, ascidians, planarians, etc. Mr. C. F. Hodge, who had been engaged as naturalist to the steamer *Fish Hawk* for the oyster-starfish investigations in Providence River and Long Island Sound, began at Wood's Holl certain observations regarding the natural history of the starfish, with special reference to ascertaining what, if any, animals, preyed upon that species, and their relations to it. Dr. Brooks continued his elaborate studies on the life histories of the medusæ and hydromedusæ, begun some ten or twelve years before, and conducted previously on the southern Atlantic coast of the United States and at the Bahama Islands. The monograph which he now has in preparation will be one of the most complete and important ever published on these interesting groups, the wonderful transformations undergone by the different species being fully illustrated by the author's drawings. In the course of his summer's experiments Dr. Brooks found that delicate marine organisms will retain their form and structure and remain

flexible if killed in a solution of Perenyi's fluid and glycerine of the density of sea water and afterwards transferred to a mixture of alcohol and glycerine having the same density. As these qualities are exceedingly desirable in the case of all soft objects when preserved, Dr. Brooks's observations will prove of great utility.

Summarizing the results accomplished during the season, Prof. Ryder affirms that at least eight important monographic reports may be expected as the outcome, wholly or in part, of the investigations carried on at the Fish Commission laboratory.

The aquaria as a means of displaying living objects for the information of the public and for the study of their growth and habits, were made the subject of considerable experiment by the Commissioner, who has devised several improvements in respect to their aëration and illumination, and their adaptation for the drawing or photographing of marine specimens. As a direct result of his efforts, the aquarial display at Wood's Holl has been rendered more effective and its educational benefits have been increased. The importance of any improvements of a popular character at this place is very great, for, notwithstanding the comparative isolation of the village, the station is visited during each summer by a large number of persons, representing nearly every section of the country, and coming from the neighboring resorts or stopping over from the trains and boats which center there. The Commissioner also made a thorough study of the present and future needs of the station with respect to the supply and methods of distribution of both salt and fresh water, the former occasioning much trouble from its corrosive action on all kinds of metal piping.

Assistance was rendered to the investigators and students connected with the Marine Biological Laboratory recently established in Wood's Holl, by giving them the opportunity to make collections in company with the naturalists of the Fish Commission, on the expeditions with the steamer *Fish Hawk* and the steam launch. A similar courtesy was also extended to Prof. William B. Dwight and his pupils in natural history, of the summer school at Cottage City, Martha's Vineyard.

Although the Wood's Holl station has been regularly occupied for scientific puposes only during the summer months, or from June to October, there is one direction in which the work has been continued uninterruptedly and with great profit since the summer of 1871. In that year Mr. V. N. Edwards, a resident of the village and a self-trained collector and observer in natural history, was employed by Prof. Baird as a member of his party. After the close of the first season his services were retained for the collecting of fishes during the balance of the year, and his employment in that capacity has since been made permanent. Having become acquainted with the names of most species, his duties have been to record from day to day their presence and abundance as well as all other important facts regarding them, and to save and forward to Washington all the rarer forms taken and such exam-

ples of the commoner ones as seem desirable. So complete a record and collection have never been made elsewhere in this country or in Europe, and it is to be regretted that similar arrangements were not perfected at an early day with respect to other important places along the coast. The facts to be deduced from such a series of observations are the precise times when each species first approaches and leaves a particular region; the period of its increasing and maximum abundance; its spawning season; the character of the localities which it frequents for spawning and feeding purposes; its rate of growth and the habits and habitats of the young at different ages, and much other information respecting both the migratory and stationary fishes. The value of these data and their bearing on the broadest fishery questions in the directions both of fish-culture and of legislation, are too evident to require an explanation. Mr. Edwards's notes, which are very voluminous, are now being collated and prepared for publication. They will form a unique and valuable contribution to the literature of the fisheries. His material has been obtained by the use of different kinds of nets, by daily visits to the fixed appliances of the fishermen, and by keeping a constant watch upon the local markets. Moreover, since the completion of the new station a fish trap has been maintained alongside the stone pier during a part of each year, for the double purpose of obtaining food for the specimens kept in confinement and of adding to the natural-history record. During the summers, Mr. Edwards assists in the collection of specimens for the laboratory in addition to his regular duties, and he has also taken part in the experimental work of fish-hatching, as explained elsewhere. A complete collection of the fishes belonging to the Vineyard Sound region, including many rare and curious forms, has been brought together in the Wood's Holl laboratory by Mr. Edwards, as a type series for the use of specialists.

In order that the scientific observations respecting the embryology of food-fishes, many of which breed during the autumn, winter, and spring, may be continued during the entire year, Dr. H. V. Wilson, a graduate of Johns Hopkins University, has been appointed permanent naturalist at the Wood's Holl station, but his services were not secured until the middle of May, 1889. Dr. Wilson will also have immediate direction of the laboratory during the summer months, and opportunities for carrying on investigations will be offered to naturalists at all seasons.

No material changes have been made in the laboratory since it was first completed and equipped, beyond the addition of a few pieces of apparatus rendered necessary by the exigencies of the work. Only one of the small rooms has been plastered and made comfortable for occupation during cold weather, but in view of the proposed opening of the laboratory during the winter, it will be advisable to have other rooms finished in the same manner. The large laboratory, moreover, in order to adapt it to the greatest possible number of investigators, was fur-

nished with closely adjoining windows, leaving scarcely any wall space for shelving to accommodate the necessary books and reagents. It is proposed to partly remedy this defect by dividing a portion of the room into small compartments by low partitions, more for the convenience of storage than for isolating the different workers.

During the summer of 1888 a marine biological laboratory, designed to afford educational facilities as well as the means for special research, was established at Wood's Holl, within a block of the Fish Commission station. A two-story frame building suited to those purposes, measuring 63 feet by 28 feet, has been constructed and equipped, and was occupied during most of last season. The founding of an institution of this character so close at hand has been heartily welcomed as promising a friendly and sympathetic neighbor, whose opportunities for promoting the study of certain oceanic problems kindred to those which interest the Fish Commission will have a widespread appreciation. Not limited in its scope by questions of practical utility, its activity may include the widest range of subjects within the province of marine biology, and the vicinity of Wood's Holl furnishes abundant means to satisfy a majority of its needs. It is sincerely to be hoped that the beginning now made will eventually result in a large and permanent establishment, occupying a place in this country corresponding to the well-known Naples station of the Italian coast.

The requirements of the seaside student have hitherto been very poorly met in America, and there has been little encouragement for those engaged in this branch of education. Nearly all of the so-called summer schools have been chiefly occupied with instruction of a more or less elementary character, and none have been long-lived. The first of this class in the United States was established by Prof. Louis Agassiz on Penikese Island, but its duration was determined by its distinguished founder's death. Several others have followed on a smaller scale, one of the most prosperous and deserving being the seaside laboratory at Annisquam, maintained from 1880 to 1886 by the Woman's Education Association of Boston, in coöperation with the Boston Society of Natural History. The present marine laboratory is an outgrowth of the latter, and its organization is due to the efforts of several representative scientific men and women, of whom the larger proportion are residents of Boston and its vicinity. The necessary funds for the purchase of the land at Wood's Holl, and for the building and its equipment, were secured by contributions. A small fee is charged for instruction, and during last summer the investigators also were required to pay something for the privileges obtained, but in the future it is proposed to grant them all facilities without expense. The laboratory is still dependent upon the generosity of its friends, whose interest, however, is probably sufficient to insure its stability.

The director of the laboratory is Dr. C. O. Whitman, formerly of the Lake Laboratory, Milwaukee, Wis., but now professor of biology in Clark

University, Worcester, Mass. Seven persons were present last summer in the department of investigation and eight in the department of instruction. The facilities incidentally afforded at this place through the location there of the Fish Commission station probably had much to do with its selection as the site for the Marine Laboratory. On the other hand, the Commission has much to gain from its new neighbor, through the results of studies which its specialists are certain to make on the biology of fishes and through the opportunities to interest its workers in the practical objects of the fishery investigation, in regard to which substantial assistance may ultimately be derived.

SPECIAL INVESTIGATIONS.

The Sturgeon (*Acipenser sturio=oxyrhynchus*).

The condition of the sturgeon fisheries, both in Europe and in America, has occasioned much concern among the fishermen, owing to the steady decrease in the abundance of the common species, which form the object of this important industry. The Atlantic coast fishery in the United States, on its present distinct and extensive basis, is of comparatively recent origin, and has resulted in part from the increased favor with which sturgeon meat is now received, but even more from the growing demand for caviare both for local consumption and for the export trade. The statistics for 1888 place the catch of sturgeon on the Atlantic and Gulf coasts at 7,300,000 pounds, valued at $103,000, and the production of caviare at 486,000 pounds, valued at $68,000. New Jersey and Delaware lead all the other States in this industry.

In order to obtain more positive information respecting the advisability of attempting the propagation of the American species, and to determine what arrangements could be made for taking up that work, Mr. S. G. Worth was detailed in the spring of 1887 to make an examination of the extensive fisheries on the Delaware River and Bay. After diligent inquiry and personal observations extending through several weeks Mr. Worth was able to indicate the duration of the spawning period and to estimate the number of ripe fish obtainable during each season, besides collecting valuable statistics and visiting several places suggested as convenient sites for the location of a hatchery. Following out the same line of investigation, Prof. John A. Ryder, of the University of Pennsylvania, was induced the following spring to undertake for the Fish Commission a careful study of the embryology and life history of the sturgeon, on which to base a practical system of propagation. It was at first proposed that Prof. Ryder should operate in conjunction with the steamer *Fish Hawk*, then engaged in shad-hatching near the city of Philadelphia, but as the spawning fish could not conveniently be obtained in that locality, he proceeded to Delaware City, where his observations and experiments were conducted. While the field work relating to this subject was carried on during the fiscal year 1888, the material obtained was not fully elaborated until near the close of the present year.

Before discussing Prof. Ryder's investigations, it will be interesting to note the progress previously made in the actual hatching of sturgeon eggs. The principal activity in that direction has been displayed in Germany, where the work has been successfully prosecuted since 1877. The Germans, however, give credit for the first practical results to the New York State fish commission in connection with experiments on the Hudson River in 1875, and the Seth Green box then employed was used in Europe in its original form as late as 1885. On the German rivers the eggs are generally collected as they flow from the ovarian duct of the ripe females, their emission being sometimes aided by slight pressure. The last of the eggs are also occasionally obtained by making an incision into the abdominal cavity. The male organs are usually removed from the body and the milt is then extracted from them. After fertilization has been effected in pans, the eggs are transferred to floating-boxes. Difficulty has been experienced in obtaining a large quantity of well-advanced eggs, and especially in securing both the mature eggs and milt at the same time. The contents of the hatching-boxes were sometimes injured or scattered by storms and mold occasionally made its appearance on the eggs, but, considering the means available, the results have been exceedingly gratifying, although not as extensive as had been expected.

Prof. Ryder's observations,* beginning about the middle of May and extending through nearly all of June, 1888, were not confined to the embryology of the common form and the practical methods of handling its eggs, but extended also to its later growth, anatomy, and habits, to the present aspects of the fishery, and to the distinctive characters and relations of the two species which inhabit our eastern-coast waters. According to Prof. Ryder there are two sharply defined species on the Atlantic coast, the *Acipenser sturio* Linné, or common sturgeon, and the *Acipenser brevirostris* Le Sueur, the short-nosed or blunt-nosed sturgeon. The former is the only species of commercial value on the Delaware River and probably elsewhere along the coast. The latter is a much smaller form, and is also very rare, only five specimens having been obtained by Prof. Ryder during the entire season. Its characters had not hitherto been well defined, but Le Sueur, who first described it about 1817, while noting its scarcity, speaks of it as being much sought after as an article of food, commanding a higher price at Philadelphia than the larger species. At present, however, it is not marketed on the Delaware River, although it may be more common and attain a a larger size in other localities.

With respect to the embryology and development of the common species, Prof. Ryder explains that the ova when first extruded measure 2.6 millimeters in diameter. On the exterior of the eggs there is a

*The Sturgeon and Sturgeon Industries of the Eastern Coast of the United States, with an account of experiments bearing upon Sturgeon-Culture. By John A. Ryder. Bull. U. S. F. C., VIII, for 1888, pp. 231–281, pls. XXXVII–LIX.

considerable layer of glairy, viscid substance, "which becomes soft and stringy upon contact with the water, but hardens later into a firm substance, which finally cements the ova firmly to whatever they may be brought into contact with." The period of incubation lasted six days. The embryo when first hatched measures barely half an inch in length, and is provided with a large yolk sac. After a few days the latter is absorbed, and the young fish, then measuring nearly three-fourths of an inch long, must begin to forage for itself. Owing to its small mouth at this time, the food taken must be microscopic in character, and probably consists of rhizopods, unicellular algæ, infusoria, the minute larvæ of insects and worms, the very smallest crustaceans, etc. Specimens 1 to 1½ inches long were provided with minute teeth on the pharyngeal floor and had been feeding upon certain groups of the entomostraca, while amphipod and isopod crustaceans formed the principal food of those having a length of 5 inches to 2 feet. The adult fish, as may be inferred from the conformation of the head and mouth, are essentially scavengers and bottom feeders, and their diet probably includes a wide range of the more stationary forms of aquatic invertebrates. In the majority of the roe fishes brought to the butchering floats the spawn is nearly mature, being, however, still hard and firm and in the condition most highly prized by the packers of caviare. The variety best suited to the purposes of the fish-culturist is that which is just mature and ready to be artificially fertilized. According to Prof. Ryder,

> Most of the eggs of the ripe roe have ruptured their follicles, and as soon as the abdomen is cut open the ova escape in great quantities, to the amount of several gallons in the case of a large fish. The quantity of eggs yielded by a single fish may, in fact, vary between 5 and 15 gallons. * * * It may be assumed that the average is about 10 gallons. * * * The eggs measure 2.6 millimeters in diameter, or a little less than one-ninth of an inch. At this rate we should find about about 168,000 eggs to the gallon, and a total of from 800,000 to 2,400,000, according to the amount of roe in a single fish, estimated in gallons.
>
> The eggs, when in exactly the right condition, are globular, nearly a ninth of an inch through, and vary in color from a very light brown to a very dark brown. At one side a darker round disk may be observed, the diameter of which is about one-fourth of the circumference of the egg. This disk is also quite as visible in ova which have not yet escaped from the follicles in which they were developed as in the "hard roe," for example. The darker discoidal area is the germinal area of the egg of the sturgeon, and is the point where development first manifests itself to the unaided eye, through certain changes in its shape. The eggs of the kind above described should retain their globular form, like so many shot, and should show no sign of adhering to each other. If the round area at one side of the eggs should appear distorted or broken it is also a sign that the eggs are probably worthless for fertilization. Eggs with a round disk, if they flow freely from a slight cut through the walls of the abdomen of the recently caught living fish, may be fertilized without difficulty, provided a ripe male is at hand. Eggs which do not answer the requirements given in this paragraph it is not worth while to waste time over.

The reproductive organs of the males are not nearly as large as the ovaries of the females, and probably never much exceed 10 to 15 pounds in weight. If removed from the living male when mature, and cut open,

the milt may be extracted by pressure, and while Prof. Ryder was not successful with the milt obtained in this manner on two occasions, he thinks the eggs themselves may have been at fault and advises further experiments in this direction. In Germany this method has given good results.

The course to be pursued in the handling of the eggs is described by Prof. Ryder as follows:

Not more than twenty minutes should be allowed to elapse after the time the milt and eggs are mixed together till they are spread upon cheese-cloth trays, one egg deep, or in a single layer. If this is not done immediately the eggs will stick together in large masses, causing those at the center of these masses to be asphyxiated for want of oxygen, which under such circumstances can not find access to them. * * * It is, therefore, very important that a large number of trays properly constructed be at hand upon which to spread the eggs if any extensive hatching operations are to be conducted. The eggs will adhere very firmly to the surface of the cheese cloth in a few hours, after which further watchfulness is necessary in order to keep down any fungus which may appear upon the dead eggs, of which there will always be some. It may be possible that panes of glass would serve the same purpose as the cheese-cloth trays if a current of water were allowed to flow very slowly between a superimposed series of glass plates properly disposed in a trough. * * * Upon admixture with water the adhesive material with which the eggs are covered seems to be dissolved somewhat and becomes diffused through the water, so that the whole becomes ropy. * * * This glairy or ropy character of the partly dissolved coating of the egg persists for some time, usually for thirty minutes or so, after which time the glairy substance hardens or coagulates in the presence of the water and the gases held in solution by it. In process of hardening the glairy, sticky coating of the eggs firmly fastens them to whatever they are brought into contact with, and after that has occurred it is scarcely possible to detach them without injury to their delicate, thin envelopes and their soft, viscid contents.

* * * * * * *

The trays used at Delaware City, on board the steamer *Fish Hawk*, were made by tacking cheese cloth to light wooden frames a foot wide and 18 inches long, then loading the edges of the frames with strips of sheet lead to keep them immersed. These trays, placed on ledges in a superimposed series, in a trough through which the water is allowed to flow gently, is a very efficient hatching device. Floating hatching-boxes with brass-wire gauze bottoms and small openings at the sides covered with the same kind of gauze have been successfully used by the Germans, one having been brought from Germany by Mr. S. Feddersen, of Port Penn, Del., from Hamburg. The floating box in which the writer succeeded in hatching out a batch of the eggs of the sturgeon was exceedingly simple in construction, and consisted of a soap box with top and bottom removed, the bottom for which was then replaced by tacking cheese cloth to the lower edge of the rim, and by nailing wooden strips to serve as floats to the sides of the box a very efficient hatching device was extemporized. These boxes so modified were placed at the edge of the large fresh-water pool near the extreme eastern end of the Chesapeake and Delaware Canal, at a point where there was a constant flow of fresh water under them. The only lot of fertilized eggs which the writer succeeded in obtaining were spread on the bottoms of these boxes and left to hatch. In six days from the time of fertilization the young fish made their appearance. The rapid appearance of a parasitic fresh-water fungus, however, caused such extensive mortality amongst the eggs that very few embryos survived to escape from the egg membranes. This fungus, which appeared to be a *Saprolegnia*, is developed from spores which seem to be almost everywhere present in fresh water.

Prof. Ryder regards the development of this fungus as one of the most serious obstacles to sturgeon-culture, and, owing to the firm manner in which the eggs are fastened together, the separation at any time of the infested from the good eggs is practically impossible. As a prevention he suggests the filtering of the water supplied to the hatching boxes or its sterilization by means of heat.

The best source of supply for eggs was found to be the live fish which are brought to the Delaware City butchering floats, directly from the gill nets. If handled with a slight amount of care, they can be carried alive with the spawn in good condition. "Judging from the number of live spawning fish brought into Delaware City, Port Penn, and other places on the Delaware, there is but little doubt that several millions of ova for hatching purposes might be obtained each season by vigorous and faithful exploitation of all the sources of supply."

Prof. Ryder states his general conclusions with respect to the possibilities of sturgeon-culture and the methods to be followed in the following words:

> The results which were obtained were to some extent unsatisfactory, owing to the difficulty of obtaining an abundance of living ova and the difficulties attending their fertilization by artificial means, as well as rearing the embryos. Notwithstanding this untoward condition, a number of novel facts were collected and experiments were carried out which must be of great significance in any further attempts at the artificial propagation of these immense fishes. Amongst the most important of my results, the observations which I regard as of the greatest practical value is the determination by experiment that it is possible to quickly obtain both living ova and spermatozoa from recently captured fishes by Cæsarean section. The only ova which I succeeded in fertilizing were obtained from females of the common sturgeon by cutting open the abdomen of the still living fish. Forcing out the ova by pressure, as practiced with the shad and salmon, is not feasible in the case of the sturgeon, and the removal of the ripe ova from the abdominal cavity of the parent fish may be far more expeditiously effected by slitting open the body cavity, in the manner usually practiced in dressing the carcass for market. * * * The success which followed the usual methods of fertilization proves conclusively that vast numbers of embryos could be hatched annually from eggs thus obtained and treated. The number of millions which could be reared in this way would depend entirely upon the number of trained spawn-takers promptly on duty when spawning fish are taken by the fishermen, and the extent of the facilities for hatching them and protecting them against the attacks of *Achlya* and *Saprolegnia*, forms of fungi which are found to be most seriously destructive to the life of the ova of the sturgeon in moderately quiet waters.

The Cod (*Gadus morrhua*).

The experiments in cod hatching have now been carried on at Wood's Holl a sufficient length of time to test their efficiency, but it is still too early to expect the presence there of large fish resulting from these efforts. Fortunately abundant evidence is at hand to prove the survival and healthy growth of a large percentage of the embryos produced at that place. In his annual report for 1883, Prof. Baird, referring to the first attempts at the artificial propagation of this species conducted at Gloucester, Mass., in the winter of 1878–79, explains that, "The fish

used for the purpose were the gray variety, believed to come from the offshore banks to the coast of the mainland for the purpose of spawning, the winter season being the period of this migration. During the following summer, small cod of the gray or offshore variety were met with around the wharves in the harbor, and at once attracted attention, such an occurrence being quite unheard of before. Again, the next year, these fish were found outside of the harbor, and of considerably larger size, fairly representing the second year of growth. The third year they were taken of a still larger size, and farther north along the coast, the fish of this school being universally known as the Fish Commission school."

The work was first started at Wood's Holl during the winter of 1879–80, when a few fry were planted in the neighboring waters. In 1885–86 it was again renewed, and has been continued down to date, the number of embryos liberated locally during the former and each succeeding year being, respectively, 3,000,000, 17,445,000, 8,840,000, and 9,175,000, a total of 38,460,000. The adult fish from which the eggs have been obtained belonged partly to the gray or offshore schools and partly to the red or rock variety. During his daily collecting trips in Vineyard Sound, Buzzard Bay, and the adjacent region, Mr. V. N. Edwards has secured much information which proves conclusively that this important experiment is already bearing fruit, and that as soon as the early broods have had sufficient time to grow an abundance of adult cod may be expected along this section of the coast. In considering the value of his observations it must be borne in mind that young cod, except occasional individuals, have not been known to frequent the waters about Wood's Holl within the memory of the oldest fishermen, and there is no reason to doubt that the evidence here presented bears solely upon the work recently conducted at the Fish Commission station. Mr. Edwards has kept himself informed, summer and winter, of the presence and movements of all the varieties of fishes in this region, both young and old, and the accuracy of his statements is unquestioned.

The fry produced in the winter of 1879–80 were planted in the little harbor of Wood's Holl, where the laboratory was then located. The following spring young cod were plentiful in both the little and great harbors, although only a few were seen elsewhere. In the fall of 1880 individuals from the same lot, measuring from 10 to 12 inches long, were found abundant at Menimsha Bight, inside of Gay Head, near the southern entrance to Vineyard Sound. The most pronounced results have been observed, however, since the winter of 1885–86, when the work was first established on a permanent basis, each succeeding year adding its large quota to the embryo colony. The fish hatched during each winter attain a length of 1 to 1½ inches by April 1; by the middle of June their size has increased to from 2½ to 3½ inches. Year-old fish measure from 12 to 13½ inches, and supposed two-year olds from 18 to 22 inches.

The young cod are first taken in the spring, about April 1, and con-

tinue present until about the 12th or 15th of June, when, the water becoming too warm for their comfort, they strike offshore. They are most abundant in May, being found near the shore on gravelly or stony bottoms, sometimes in small schools and occasionally associated with young pollock. During the springs of 1887, 1888, and 1889 they were plentiful about the wharves at Wood's Holl, remaining there until about the middle of May, when the cunners arrive. They leave the harbors earlier than they do the open shores of Vineyard Sound. May 8, 1888, Mr. Edwards estimates that there were at least 25 barrels of young cod, from 2 to 3 inches long, in one of the fish pounds which he examined in the neighborhood of Wood's Holl, and a bucket full was secured in a single scoop with an ordinary dip net. They had been equally abundant for a week previous, and their number did not apparently diminish during the succeeding ten days, when Mr. Edwards visited the same pound every morning. In other traps near at hand they were also very plentiful. This great display of young cod has, moreover, manifested itself during every spring since the winter of 1885–86, both in Vineyard Sound and in Buzzard Bay, the fish remaining near where they were planted until the rise in temperature drives them into deeper and cooler water.

During the spring of 1889 from 10 to 12 cod, measuring about 15 inches long, were taken nearly every morning in each of the fish pounds distributed through the sound between Vineyard Haven and Gay Head. It was the first season that fish of that size had ever been captured in the traps. It is the opinion of Mr. Edwards that the year-old cod will not approach the shore in the immediate vicinity of Wood's Holl, but will continue to frequent the more open waters of the sound and bay, and especially the region about Gay Head and Cuttyhunk, where the fishermen report them abundant during each spring and fall. Information received since July 1, 1889, indicates, however, that the fish of the earlier plantings are returning to the shallow waters in much greater numbers than seemed possible from the previous observations.

MISCELLANEOUS FISHES, ETC.

The excellent facilities afforded by the Wood's Holl Station for observations and experiments relative to the propagation of all kinds of marine fishes, in addition to the cod and lobster, have been put to use during the past few years, with most valuable and interesting results. The most important species for immediate consideration have been the scup and sea bass, both of which are the objects of an extensive local fishery, and were formerly much more abundant than they are at present. The mackerel also spawns in the vicinity of Wood's Holl, where its eggs may be obtained with little trouble. These and several other species breed in the spring and early summer, and the majority have floating eggs whose transformations are completed within a very brief period, the cod apparatus being well adapted to their hatching.

The work thus far accomplished in respect to these forms has chiefly been experimental, accompanied in part by observations on the development of the embryos, but it can, at any time, be placed upon a practical basis with the best assurances of success. Mr. V. N. Edwards has been especially active in regard to these matters, having collected most of the eggs and attended directly to their installation in the hatching apparatus. The following species have received attention during the past year:

The Scup (*Stenotomus chrysops*).

This species has floating eggs, of which 50,000, taken May 22, produced 30,000 fry May 27. In 1888, 50,000 ripe eggs, obtained June 4 and 5, were hatched with a loss of only 3,500.

The Sea Bass (*Serranus atrarius*).

The experiments with this species were also started in 1888 and continued in 1889. The eggs float, and hatch in five days. From 2,660,000 eggs taken in four lots between May 23 and June 10, 1889, 2,480,000 embryos were obtained, an unusually large percentage. The temperature of the water during this period was about 56° to 57° F. The ratio of success in 1888 had been nearly as great, but the number of eggs handled was considerably less.

The Mackerel (*Scomber scombrus*).

Capt. H. C. Chester and Prof. John A. Ryder began the experiments with this species in the spring of 1886, obtaining the spawn from three fish on May 19. As the eggs were of less density than sea water they were treated in the tidal cod jar, and began hatching at the end of ninety-four hours. The embryos were kept alive in the aquaria ten days, giving Prof. Ryder the opportunity to observe and figure their development up to that stage. In 1888 about 1,000,000 eggs were obtained between June 4 and 9, the same hatching between June 8 and 13 with a loss of less than 10 per cent. In 1889 only about 215,000 eggs were handled, having been collected May 21 and 24 and hatching May 25 and 28, with a loss of 30,000.

The Tautog (*Tautoga onitis*).

The egg of this very common species belongs to the same class as the preceding, as regards its specific gravity, and hatches in five days. From 100,000 eggs taken June 27, 1888, 88,000 fry were obtained, and 220,000 eggs taken May 21, 1889, produced 185,000 fry. The first experiments with this form began the latter part of May, 1886, and were carried on by Capt. Chester and Prof. Ryder, the latter paying particular attention to the development of the embryos, as in the case of the mackerel.

The Bonito (*Sarda sarda*).

This species also has floating eggs, of which the first lot, numbering 15,000, were obtained and placed in the apparatus June 7, 1889, hatching June 11, with a loss of only 2,500.

The Lobster (*Homarus americanus*).

Development and propagation.—In "The Fisheries and Fishery Industries of the United States," Sections I and V, the condition of the lobster fishery was discussed upon the basis of the information obtained as late as 1882. It was there shown that a considerable decrease had taken place in the abundance of the American species, the supply in some places having so greatly diminished as to practically destroy the local industry. Since that period the evidence at hand indicates that this decrease is still continuing, in spite of the somewhat rigid laws which have been passed by the New England States and New York. The same trouble has been experienced in Europe, and in both countries the problem of how to protect the grounds and restore their prosperity has been fruitful of discussion and experiment. Among crustaceans the eggs, as they are emitted, become attached to external appendages of the body, where they remain until the hatching takes place. In the artificial propagation of the lobster it has, therefore, generally been considered necessary to confine the parent with its eggs until the appearance of its progeny. The difficulties in the way of such an undertaking may readily be conjectured. The imprisonment, care, and feeding of a sufficient number to afford appreciable results would involve an expense wholly out of proportion to any good that might be accomplished. Several private parks for experimental work in that direction have been established from time to time, but they were soon abandoned.

Early in the summer of 1885, the Norwegian fish-culturist, G. M. Dannevig, announced the successful hatching of lobster eggs that had previously been removed from the parent. The new laboratory at Wood's Holl, with its perfect system of running water, had just been completed, and it was determined to undertake at once similar experiments with respect to the American species, notwithstanding the hatching season had already terminated. The trials were begun by the writer and were continued by him and by Capt. H. C. Chester until about December. The results have been fully discussed in the Bulletin of the U. S. Fish Commission for 1886, pp. 17–32. Only a very small number of embryos, about 50, were produced during this period, indicating that it is not expedient to conduct the work outside of the natural breeding season, but much valuable experience was acquired respecting the manner of obtaining and caring for the eggs. Lobsters with eggs attached to the swimmerets are found during the entire year, but the hatching season is confined to about two months, beginning, in the Vineyard Sound region, early in May and continuing into July. At whatever season the eggs may be extruded they develop slowly until that period, and, with our present knowledge of the subject it is not advisable to collect them at other times. As they pass from the body of the female they are coated with a viscid substance that soon hardens into short, tough, and flexible threads, by means of which they are attached in clusters of variable sizes to the swimmerets or leaf-like

appendages on the lower side of the abdomen or "tail." The eggs are hardy, comparatively large, about one-twelfth of an inch in diameter, and each lobster carries at a time from 6,000 to 36,000, dependent partly upon its size. The circulation of water among them is maintained by the natural movements of the swimmerets, which indicate, in a measure, the amount of motion to be given them in the hatching apparatus. As the attaching threads do not constitute an organic connection between the eggs and the body of the lobster, they may be cut without causing injury to the former or suffering to the latter, and the eggs may be removed rapidly by means of scissors or a sharp knife. They are heavy and the McDonald automatic hatching jar is well adapted to their incubation, although the cod apparatus has also been successfully used for the same purpose.

In the spring of 1886 the experiments were renewed by Capt. H. C. Chester and Prof. John A. Ryder, and were carried to a successful issue, being vigorously prosecuted during the entire hatching season. Prof. Ryder also made a careful preliminary study of the development of the young,* and attempted the rearing of the embryos in confinement. When first hatched the embryo lobster is totally unlike the parent, both in shape and in the character of its appendages, leading also a pelagic or free-swimming existence. Each stage of growth is marked by the casting off of the outer skin or shell and the formation of a new one. The early transformations are quite rapidly accomplished. The history of the embryo at this time was carefully recorded by Prof. Ryder, who found that six molts occurred during the period of their free existence, which occupied from six to seven weeks in the aquaria. The molts take place at intervals of four to fifteen or more days, if the larvæ are well fed. During the first, second, third, and fourth stages, occupying about three weeks, the embryos have the essential characteristics of a low group of shrimps, called schizopods, their appendages being chiefly adapted to swimming. With each molt the embryo becomes slightly larger and new appendages are added. From a length of 8 millimeters at hatching, they attain a length of 13 millimeters in the fourth stage. With the fourth molt, which gives rise to the fifth stage, having a length of 14 millimeters, the embryo loses its schizopodal characters, being abruptly transformed into a type very closely resembling the adults. Formerly transparent, its color now is a bluish green, with more or less brown in some cases. During the fifth week, or toward the close of this stage, the young lobster becomes less partial to its earlier pelagic life, and remains on the bottom a great part of the time. In the sixth stage it has attained a length of 19 millimeters, and in the seventh a length of 22 millimeters, the latter being reached at an age of about seven weeks. During these three last stages the body and its appendages have been rapidly assuming the form and pro-

*The Metamorphosis of the American lobster, *Homarus americanus* H. Milne-Edwards. By John A. Ryder. American Naturalist, XX, No 8, pp. 739–742, August, 1886.

portions of the adult, which are still more marked in the eighth stage, the final one that was observed, and during the same period its disposition to remain upon the bottom has also increased.

Not being supplied with a yolk sac, the embryo lobsters begin to feed immediately after hatching. They are carnivorous and cannibalistic, devouring their own kindred by preference and with evident relish. They are ravenous eaters, very savage and persistent in their attacks upon one another, interposing thereby a serious obstacle to any attempts at their confinement in the aquaria. Otherwise it would be advisable to hold them until they had passed through their early larval stages and were ready to begin their permanent life upon the bottom. At that age they are better able to escape their enemies and to search for food, but under existing conditions it has been necessary to plant them when only a few days old. Prof. Ryder found that the greatest mortality occurred during the first four stages. The fifth and following stages are more hardy, and would give comparatively little trouble in practical operations. Their harder shell, their approach to the adult habits, and the greater ease with which they can be fed all conduce to this. These later stages were fed upon crab roe, copepods, and other minute crustacean life, and sometimes with chopped meat, but it was found essential that the food should be given in a fresh condition and should not be allowed to become stale or to putrefy in the tanks. The experiments with regard to feeding and rearing in the aquaria will be continued during subsequent seasons in the hope of reaching more satisfactory conclusions in that respect.

It is still too early to measure the success of lobster-culture, and until the same can positively be determined it has not been considered prudent to conduct the work upon a large scale or to extend it beyond the Wood's Holl region. In the summer of 1888, 325,000 embryos were planted there, and in 1889, 1,575,000 embryos. The growth of the lobster is supposed to be comparatively slow, the age of individuals measuring 10 inches long having been estimated all the way from 6 to 10 years, although we have no definite information on which to base such calculations. Any increase in the supply would not, therefore, have manifested itself up to the present time, and several years must still elapse before passing finally upon the utility of the experiments. The urgency of the case is such, however, as to warrant most strenuous efforts to attain success. The destruction of lobster eggs in nature through the attacks of eels, cunners, and other small fishes, is known to be very great, while most of the egg lobsters taken by the fishermen find their way to market, despite the laws. Artificial propagation is at least beneficial in insuring the utilization of the latter and the preservation and hatching of a larger percentage of the former, precisely what is accomplished in all branches of fish-culture. It is evident, however, that more stringent and judicious legislation will be required to fully protect the lobster-grounds, even to the entire suspension of

the fishery for a time in certain districts, but that is a matter which falls entirely within the jurisdiction of the States.

Transplanting.—The two commoner species of lobster (*Homarus*) are limited in their distribution to the North Atlantic Ocean, one occurring on the European the other on the American side. The American species ranges as far south as Delaware, but is most abundant on the coasts of New England and the British Provinces. Its north and south distribution is undoubtedly determined chiefly by temperature, and it would, therefore, seem impracticable to attempt its extension artificially in those directions. On the Pacific coast, however, similar conditions are again repeated, although warmer waters are there carried farther north by currents, as on the coast of Europe, producing a somewhat milder and more equable climate in corresponding latitudes. That such a coincidence does exist on both sides of the continent is substantiated by the fact that both the cod and halibut inhabit the North Pacific, ranging south beyond Cape Flattery, and that other fishes and many marine invertebrates seem to be identical in the two oceans. From some cause, however, the lobster has been excluded from the fauna of the Pacific coast, and its place has not been taken by any other species, but it does not seem possible that its absence is due to climate. The only locality in that region for which we have a continuous series of temperature observations of the sea water is San Francisco, where during the six years ending with 1886 the range of temperature was only 10° F., or from 51° to 61° F. At the mouth of Vineyard Sound, off Wood's Holl, Mass., the range of ocean temperature during seven years was 37° F., or from 32° to 69° F. The temperature is, therefore, much more equable at San Francisco than on the southern coast of Massachusetts, corresponding for the entire year, with the conditions prevailing at the latter place between May 20 and the last of June and between the first of October and the middle of November. Both of these periods are favorable to the existence of lobsters on the inshore grounds, and the former is also the spawning season. So far as temperature is concerned, the Pacific coast appears to offer no obstacles to the introduction of lobsters even as far south as San Francisco, and probably Monterey, the next adjoining bay. The coast from here northward presents a succession of sandy and rocky shores, sufficiently rich in life to afford an abundance of nutritious food, and, if once successfully started, there is every reason to expect that they would thrive and multiply.

The question of the introduction of lobsters in this region is not, however, to be decided solely by the fact that the conditions are favorable to them. It is equally important to know if they are wanted by the inhabitants and if they would add a desirable feature to the food supply. This question was practically settled as early as 1873, when California took the initiative in attempting the first transplanting of lobsters across the continent, having, however, in that matter, the coöperation

of the U. S. Fish Commission. The fact that a large crustacean called the spiny lobster or salt-water crayfish (*Panulirus*) occurs to the south of Point Conception is not an argument against the introduction of the genuine lobster. A closely related "crayfish" inhabits the south Atlantic and Gulf coasts, and another species the southern part of Europe, both of these being highly esteemed as food, but not interfering to any extent with the fishery for the true lobster (*Homarus*). On the first shipment the train was totally wrecked soon after crossing the Mississippi River. A second trial was made in 1874, and a third in 1879, only four lobsters reaching San Francisco alive on the former and twenty-one on the latter. Realizing that the planting of such small lots could have no appreciable effect in the stocking of a new region, experiments were made at Wood's Holl in the spring of 1886, by the late Capt. H. C. Chester, with the view of determining some more economical and reliable method of transportation. His efforts were directed chiefly toward the preservation of lobsters by packing them in moist sea weed and reducing the temperature of their surroundings. They were entirely satisfactory, specimens being kept in good condition for several weeks, with the use of only a very small amount of sea water, and, while not strictly imitated in the subsequent shipments, they suggested the methods that were pursued.

As this division of the Fish Commission was called upon to assist in the preparation of these shipments, a brief reference to them may be made in this connection. They have, however, been fully described in the Bulletin for 1888, pp. 453–472. The lobsters were collected in the Vineyard Sound region, and after being loosely packed in rock weed in small wooden crates, were stored in the large compartments of one of the Fish Commission cars, in which the temperature was reduced by means of ice and salt. At least twice each day the specimens were freshened by sprinkling them with salt water, of which a stock was carried for that purpose. The first trip was made between June 16 and 23, 1888, beginning with 610 lobsters, of which 250 were males and 360 females. The second trip took place between January 14 and 22, 1889, starting with 710 lobsters, 279 being males and 431 females. Some of the females in both lots were also provided with eggs. A comparison of the difficulties encountered on these two trips is interesting. The first was made during a period of very warm weather, and the mortality from that cause was very great, despite the free use of ice. The second was, therefore, arranged to obviate that trouble, but unfortunately the temperature during the journey fell at times considerably below zero, and it became necessary to resort to artificial heat to prevent the absolute freezing of the lobsters, but nevertheless the mortality was even greater than before. As a result of the first trip, 302 lobsters were planted in Monterey Bay and vicinity, and 30 off Trinidad light-house in northern California, besides about 100,000 embryos deposited off Monterey. On the second trip 88 individuals were planted off Cape

Disappointment, 22 in Shoalwater Bay, and 123 in different places at the mouth of Puget Sound, all within the limits of the State of Washington. A number of years must elapse before the utility of these plantings can be ascertained, and it is probable that several more shipments will be necessary to place these little colonies on a self-sustaining basis, but the undertaking is sufficiently important to warrant every reasonable effort in its behalf.

The Long Clam (*Mya arenaria*).

A discovery made in regard to the young clam at Wood's Holl, by Prof. Ryder, while at first sight apparently of biological interest only, can be turned to good account in case the transplanting or artificial culture of that species is attempted. In fact, its distribution to different parts of the Pacific coast, where it is not a native, but where it has already obtained an accidental foothold, has been seriously considered, and an unsuccessful trial in that respect was made by the steamer *Albatross* in 1888. Hitherto, in the transplanting of mollusks, the adults generally have been used, and the oyster, most fortunately, is able to withstand the hardships of a long journey. The clams, however, are more delicate and their transportation for stocking purposes has generally ended very disastrously. Respecting his observations, Prof. Ryder wrote in December, 1888, that he had discovered a byssus and byssal sac in the tip of the foot of the common clam, in young specimens collected at Wood's Holl during the previous summer, which fact upsets all previous ideas regarding the life history of that species. Instead of the young clam burying itself at once in the sand like its parent, it probably suspends itself for a time to weeds or sticks or other objects above the bottom until it is large enough to shift for itself in its final home. The presence of a byssus in the young of this animal seems to be a protective measure, and it will be interesting to learn if the giant clam, *Glycimeris generosa*, of the Pacific coast, is similarly provided in its embryo state. The specimens from Wood's Holl were found on floating timbers among ascidians, and ranged in size from less than a millimeter to nearly three-fourths of an inch long. Its transplanting while so attached could readily be effected.

THE CHEMICAL COMPOSITION AND NUTRITIVE VALUE OF AMERICAN FOOD-FISHES, MOLLUSKS, AND CRUSTACEANS.

The first and only extensive investigation of this important subject that has been made in this country was begun for the Fish Commission about ten years ago by Prof. W. O. Atwater, of Wesleyan University, Middletown, Conn., who has continued his observations from time to time as funds could be spared for that purpose. Having, moreover, a deep personal interest in the successful accomplishment of his task, Prof. Atwater has given largely of his time and means without remuneration, and some financial assistance has also been received from Mr. E. G. Blackford, of New York, and Mr. A. R. Crittenden, of Middletown, Conn.

Considering the large number of species of aquatic animals, estimated at about a thousand in this country, which are used for food or for other economic purposes, and the amount of time required to make a careful analysis of a single species, some idea may be formed of the magnitude of any inquiry that would include the entire list. Whether or not it will eventually be considered advisable to analyze all or even the larger proportion of these edible forms is a matter not requiring immediate decision, but in his experiments thus far Prof. Atwater has selected a wide variety of species, including the more important ones, sufficient to furnish most instructive and interesting results. Preliminary reports upon the investigation were published in the Fish Commission Reports for 1880 and 1883, and contributions on the same subject by Prof. Atwater have also appeared in the Report of the Shellfish Commission of New York for 1887, the National Medical Dictionary, and the Century Magazine during 1887 and 1888.

In view of the progress that has been made and the opportunity afforded for deductions, it has been deemed expedient to present in this volume a full account of the researches now completed, and Prof. Atwater's paper (Appendix 10, pp. 679–868) is deserving of careful consideration. The author explains that in its present status the investigation includes: (1) Chemical analyses of the flesh of American food-fishes and invertebrates; (2) experiments upon the digestibility of the flesh of fish; and (3) studies of the chemical constitution of the albuminoids of the flesh of fish. The experiments in regard to the last-named subject are not, however, sufficiently advanced to warrant their discussion at the present time. The report is divided into two parts, the first treating of chemical compositions, the second of nutritive values. Part I is chiefly occupied with the technical details of analyses, while Part II is more popular in character and explains the deductions at which the author has arrived, together with their bearing upon different fishery problems.

The total number of species of fishes analyzed was 55; of mollusks, crustaceans, etc., 11; but the number of specimens, and consequently of separate analyses, was very much greater. The invertebrates made use of consisted principally of oysters from different localities, together with scallops, clams, mussels, lobsters, crayfishes, crabs, and shrimps. Many other kinds of food materials have also been subjected by Prof. Atwater to the same tests for the benefit of the National Museum, and the results obtained thereby are here utilized for comparison.

The comprehensive manner in which the subject has been presented may be inferred from the following references to the principal contents of the report. In Part I are given the classification and origin of the specimens examined; methods of analysis; descriptions and details of the analyses; the results of the analyses presented in tabular statements; protein in the flesh of fishes; classification of the specimens in accordance with their chemical composition; summary of the analyses

of European fishes made by different observers, and the comparison of the same with those of American fishes; and changes in the composition of oysters by removal from salt to brackish or fresh waters. Part II treats of the constituents of foods, their principal nutrients, and the way in which those nutrients are utilized by the human body in the formation of tissues and for sustaining the vital functions; the digestibility of fishery products; the relative value of the different species of fishes, mollusks, and crustaceans, according to the percentages of their component nutrients, the same being illustrated by tabular statements and colored diagrams; the objects and results of the floating of oysters, and oysters considered as an article of food.

Without extending these remarks beyond their proper limits it would be impossible to give an adequate idea of even the more important features of Prof. Atwater's investigations, but his final conclusions may very appropriately be quoted, as they are at least suggestive to all promoters of fishery matters. They are as follows:

The chief uses of fish as food are (1) as an economical source of nutriment and (2) to supply the demand for variety in diet, which increases with the advance of civilization and culture. As a nutriment, the place of fish is that of a supplement to vegetable foods, the most of which, as wheat, rye, maize, rice, potatoes, etc., are deficient in protein, the chief nutriment of fish. The so-called nitrogenous extractives (meat extract) contained in small quantities in fish, as in other animal foods, are doubtless useful in nutrition.

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Late inquiry in agricultural and biological chemistry has brought out some facts which emphasize the importance of fish-culture and the greater use of fish as food from the standpoints of hygiene and domestic, agricultural, and even national economy. Our national dietary is one-sided. Our food contains relatively too much of fat, sugar, and starch, and too little of protein. This is a natural result of our agricultural conditions, which have led to the production of large quantities of maize (which is relatively deficient in protein) and of excessively fat beef and pork. Our agricultural production is in this sense one-sided. Our soils are becoming depleted by culture. The evil results of this are already evident in the older and are becoming so even in some of the newer States of the Union. Of the ingredients of plant food which are needed for the restoration of fertility, the costliest and scarcest is nitrogen, which is the characteristic element of the protein compounds of our food.

A very large amount of the waste products which are left from the consumption of food, instead of being returned to the soil for restoring its fertility and increasing its production, is carried off in drainage waters and through the sewers of the large cities into the rivers and sea. The nitrogenous products are thus especially exposed to loss. The nitrogen, however, is not lost necessarily in this way. It goes for the support of marine vegetation which forms the food of fish. It may thus again be utilized as food for man. Fish has relatively less of fats and more of protein than meats and vegetable foods. By fish-culture, then, we are enabled to supply the very materials which are lacking in our dietaries and from the waste products may be saved the valuable fertilizing elements, including phosphorus and especially nitrogen.

As population becomes denser, the capacity of the soil to supply food for man gradually nears its limit. Fish gather materials that would otherwise be inaccessible and lost, and store them in the very forms that are most deficient in the produce of the soil. Thus, by proper culture and use of fish, the rivers and sea are made to fulfill their office with the land in supplying nutriment for man.

THE WASHINGTON LABORATORY, PREPARATION OF REPORTS, ETC.

During the lifetime of Prof. Baird all the accommodations required for conducting the scientific work of the Fish Commission in Washington were provided by the U. S. National Museum. The same arrangements were also continued until June, 1889, when, upon the refitting of Central Station, the scientific quarters were removed to that building. Formerly the collections of natural-history specimens as soon as they were received in Washington were transferred to the custody of the National Museum, which also provided for their maintenance and, to a great extent, for their elaboration. In the future the Fish Commission will retain possession of such materials until they have been studied, then depositing them in the National Museum, with which it is expected that the friendly coöperation so long maintained will be continued. Dr. Tarleton H. Bean has also been retained by the Museum as curator of the Department of Fishes and Mr. Richard Rathbun as curator of the Department of Marine Invertebrates.

The scientific work to be provided for in Washington, besides the routine of administration and the direction of investigations, is the preparation of reports, maps, and plans, and the study of natural-history collections, and of physical and chemical problems. The accommodations assigned to this division at Central Station comprise an office and laboratory with several storerooms. The laboratory is especially fitted up for biological inquiries, but may also be used for physical and chemical researches upon a limited scale. The facilities for the storage of collections are sufficient for immediate purposes, but they will undoubtedly soon be outgrown. Not having the means for keeping up the very complete physical laboratory established in the Smithsonian Institution under the direction of Dr. J. H. Kidder, the privileges so graciously afforded there were relinquished toward the close of the fiscal year, the apparatus belonging to the Fish Commission being transferred to Central Station. Arrangements were at once made with the Chief Signal Officer and with the Superintendent of the Coast Survey for the testing of all the more delicate instruments, the coarser ones being readily attended to in our own laboratory. The physical observations are made chiefly in the field, and the subsequent preparation of reports upon those subjects seldom requires the use of apparatus. It would, however, be advisable to enlarge the facilities for that branch of investigation in Washington, and it is hoped that this may soon be accomplished.

The scientific collections received in Washington during the past year have been very large and valuable, representing inquiries extending over a wide extent of territory. The most important were those obtained by the steamer *Albatross* on the voyage from Washington to San Francisco in 1887–88, and during the subsequent surveys on the

coasts of Alaska, Washington, and Oregon; by the steamer *Fish Hawk* while on the west coast of Florida and in Providence River and Long Island Sound; by the schooner *Grampus*, on the red-snapper banks of the Gulf of Mexico, and by the inland parties investigating the lakes and rivers. The principal material transferred to the National Museum consisted of the type series of fishes from the inland explorations, the reports of which had been completed, and of the mammals, birds, reptiles, plants, geological and ethnological specimens obtained incidentally during the recent cruises of the *Albatross*. Duplicate sets of the fishes collected by the inland parties were also distributed to several institutions, as described elsewhere, and many groups of animals were sent to specialists for study and report. The distribution of duplicate natural-history specimens, however, is chiefly made through the U. S. National Museum, which is better equipped for that purpose.

The large and fine collection of fishes and marine invertebrates obtained by the steamer *Albatross* during the voyage from Washington to San Francisco in 1887–88, described in the last annual report, was received at Washington in July, 1888. The assorting of the material was undertaken by Prof. Leslie A. Lee, of Bowdoin College, who had been in charge of the scientific work of the expedition, and early in the winter the different groups had been carefully separated and prepared for study. For the working up of these collections, which contain many unique and interesting forms, and the preparation of reports upon them, it was necessary to obtain the coöperation of many specialists who could afford to give their time gratuitously. Much assistance of that character was fortunately secured, and by the close of the year the following assignments had been made: The deep-sea fishes and those collected along the shores of southern South America, to Dr. Tarleton H. Bean; the shore fishes of Santa Lucia, West Indies, Bahia, Brazil, the Galapagos Islands, and Panama, to Dr. David S. Jordan; the fishes from between Acapulco, Mexico, and San Francisco, to Prof. Charles H. Gilbert; the brachyuran, isopod, and phyllopod crustaceans, to Prof. Leslie A. Lee; the stomatopod crustaceans to Prof. W. K. Brooks; the alpheid crustaceans, to Prof. F. H. Herrick; the pycnogonids, to Prof. E. B. Wilson; the annelids, to James E. Benedict; the nematod and trematod worms, to Prof. Edwin Linton; the salpæ, to Prof. W. K. Brooks; the gastropod, scaphopod, and lamellibranch mollusks and the brachiopods, to William H. Dall; the pteropod and heteropod mollusks, to James I. Peck; the crinoids and echini, to Prof. Alexander Agassiz; the corals, to Richard Rathbun; the actinians, to Prof. J. P. McMurrich; the medusæ, to Prof. W. K. Brooks; the hydroids, to J. Walter Fewkes; the foraminifera, to Prof. L. A. Lee; the algæ, to Prof. W. G. Farlow.

Many fishing implements collected on the voyage were added to the fishery exhibition in the National Museum, and all animals and other objects not aquatic were transferred at once to the custody of that

Museum, where they have been placed in the hands of the following persons for study: The mammals, to F. W. True; birds, to Robert Ridgeway and L. Stejneger; bird's eggs, to Capt. Bendire; reptiles and batrachians, to Prof. E. D. Cope; skeletons, to F. A. Lucas; insects, to L. O. Howard; plants, to Dr. George Vasey; archæological specimens, to Thomas Wilson.

The voyage of the *Albatross*, on which this material was obtained, offered exceptional advantages for scientific observations, which were fully utilized, and the reports upon the different subjects will form one of the most important series of contributions yet resulting from any of the Government expeditions. The opportunity afforded was incidental to the transfer of the steamer *Albatross* to the Pacific coast, and was planned by Prof. Baird shortly before his death. The reports will be published mainly in the Proceedings of the National Museum.

Attention is directed to the exceptional advantages for the study of salt and fresh water animals now afforded by the large series of aquaria recently established at the Central Station in Washington under the immediate direction of the Commissioner. These facilities will be appreciated especially by the student of marine zoölogy, and as a means of popular education in respect to the habits of living fishes they will also serve an important purpose.

At the Cincinnati Centennial Exposition, held during the summer of 1888, the opportunity was taken to illustrate the methods of work pertaining to this division and some of the results of its investigations. The steamers *Albatross* and *Fish Hawk* and the schooner *Grampus* were represented by means of models and photographs, and the appliances for marine research chiefly by the instruments themselves. The following material was also exhibited: A relief model of the great offshore fishing banks of Eastern North America; series of dried and alcoholic specimens to show the fauna of the marine fishing-grounds, the character of the ocean bottom, the food of pelagic fishes, and the principal economic fishes and marine invertebrates; living specimens of the food-fishes of the Ohio Valley kept in aquaria; series of microscopic preparations illustrating the development of several of the food-fishes now being propagated by the Fish Commission, and the biology of many other fishes and invertebrates; and the publications relating to the scientific inquiries of the Fish Commission.