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

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INTRODUCTION.

During the two years covered by this report the field researches assigned to this division have extended over a large part of both the Atlantic and Pacific seacoasts, and have embraced a wide area of fresh-water drainage. Most noteworthy from the novelty and importance of their results have been the investigations by the steamer *Albatross* in Bering Sea and along the coasts of Washington, Oregon, and California.

A very thorough reconnaissance has been made of the eastern or shallow-water part of Bering Sea, including its fishing-grounds for cod, the shore lines as far north as the Kuskokwim River, and the general characteristics of the bottom to the western border of the continental platform, whose position also was determined. The principal fishing-bank in this region, which has been named after the late Prof. Baird, was discovered to have a very large area, exceeding even that of Georges Bank, off the New England coast. The distribution of the fish on this and on other grounds, as well as their abundance and average size in different places, has been ascertained for the summer season, and much further information of value to the fishermen has been placed on record. The importance of a more thorough knowledge of the physics and natural history of Bering Sea, in view of the grave questions connected with its seal and other fisheries, suggests, however, many additional problems, for the study of which the *Albatross* is well adapted, and which require early attention.

The preliminary examination of the continental slope off the States of Washington, Oregon, and California, from the Straits of Fuca to the Mexican boundary line, was completed in the fall of 1890. The location of all the fishing-grounds contained within these limits has now been determined, and sufficient material has been collected to illustrate the different varieties of food-fishes, and their distribution throughout the region, as well as the principal features of the bottom fauna. Very

encouraging results have attended the observations made in San Francisco Bay with respect to the breeding of the Atlantic coast oyster, and an important scientific investigation has been conducted off the western coast of Mexico and Central America, under the direction of Prof. Alexander Agassiz.

The field operations on the Atlantic coast have been directed chiefly to the study of the oyster-grounds of Long Island Sound, of Tangier Sound in Maryland and Virginia, and of the coast of South Carolina. Extensive surveys were made in Long Island Sound with respect, mainly, to the conditions of the bottom, the natural enemies of the oyster, and the varying distribution of the set of spat. The absence of any pollution in the oyster-ground waters was also fully demonstrated by careful physical and chemical observations. The extent and causes of the deterioration of the oyster beds in Chesapeake Bay has been made the subject of a special investigation, which is still in progress, Tangier and Pocomoke sounds having been selected for the first examinations. The inquiries in South Carolina were conducted for the purpose of ascertaining the character and distribution of the natural oyster-cultural resources and of determining the proper measures for their development. The work was completed in the course of a single winter, and has afforded very satisfactory results. Arrangements have also been made for the preparation of a series of reports descriptive of the methods of oyster-culture practiced in European countries, which will, it is hoped, be at least suggestive to American oyster-growers.

The study of the physical characteristics of the coast waters off the Northern Atlantic States, especially in the region traversed by the mackerel during their seasonal migrations, has been taken up for the first time in a thoroughly comprehensive manner, and has now been actively prosecuted during two summers. While the principal part of this work has been limited to the southern New England coast, a series of observations has also been carried southward to Virginia. These inquiries will have an equal bearing upon the habits of all other migratory fishes which resort to this region during a greater or less part of each year, and nearly all of the important economic species which enter into the fisheries there are of this character.

Among the investigations relating to the fresh waters the one of most direct importance has probably been the study of the salmon rivers of Alaska with respect to the natural history of the salmon, the threatened depletion of the schools by the destructive methods of capture now in use, and the measures necessary to preserve this extensive food supply. The observations were made on Kadiak and Afognak islands, and on Wood River at the head of Bristol Bay. The freshwater systems have also been examined in eleven different States and Territories, as follows: The Yellowstone National Park, Colorado, Utah, Missouri, Arkansas, Iowa, Wisconsin, Indiana, Ohio, Kentucky, and

Florida. The majority of these surveys have been very thorough, affording much desired information regarding the natural features of a large number of lakes and rivers, in respect to which fish-cultural operations have been undertaken or proposed.

The Woods Holl laboratory has been open continuously during the entire period, a competent scientific expert having been employed to study the biological questions which are constantly arising in connection with the hatching work conducted at this station. During both summers the facilities of the laboratory have also been extended, as in former years, to a large number of naturalists, some of whom have given their attention exclusively to the Fish Commission work. Many special observations have been made on the life history of the seacoast fishes, and interesting experiments have been conducted relative to their artificial propagation. One result of these inquiries has been to demonstrate conclusively that the attempts recently made to increase the supply of cod on some parts of the New England coast have met with complete success. Not only has the number of fish augmented from year to year, but schools of this species are making their appearance in many places where they had never been seen before. Twelve other species of fishes have also been studied to a greater or less extent, the greatest amount of progress having been made with respect to the sea bass and Spanish mackerel. A thorough investigation into the life history of the lobster is likewise now being made.

PACIFIC COAST.

The steamer *Albatross* was at work on the coasts of Washington and Oregon at the close of the fiscal year ending June 30, 1889, and on July 8 following left Tacoma, Wash., with several members of the U. S. Senate Committee on Indian Affairs to visit the principal Indian settlements in southeastern Alaska. The trip was made by way of the inland passages and extended as far as Sitka and Juneau. It terminated July 28, and the *Albatross* then started for Bering Sea, but when only a few days out the port engine became disabled, and she was obliged to return to Seattle for repairs. When these had been completed the season was too far advanced to warrant making the long passage to Alaska, and the steamer again took up the investigations off Washington, carrying them southward along the coasts of Oregon and California as far as Cape Mendocino. During the following winter repairs were made at the Mare Island navy-yard, and during March and April, 1890, the region between Point Arena and Point Conception was examined, thereby nearly completing the preliminary survey of the California coast.

On May 5, 1890, the *Albatross* left San Francisco and proceeded to Alaska, where several months were spent in defining the fishing-grounds and in determining the physical and natural-history features of the

eastern part of Bering Sea. Subsequently some additional observations were made in regard to the fishing region south of the Alaska Peninsula, which had been surveyed in 1888; a short stop was made on the coast of Washington, and the examination of the continental platform was finished between Cape Mendocino and Point Arena, California. The last of January, 1891, the *Albatross* was dispatched on a special expedition off the west coast of Mexico and Central America, and to the region about the Galapagos Islands, under the scientific direction of Prof. Alexander Agassiz. This occupied about three months, and by the end of June, 1891, the steamer had been refitted for a third cruise to Alaska.

The conduct of these investigations was in charge of Lieut. Commander Z. L. Tanner, U. S. Navy, commanding the *Albatross*, assisted by an efficient staff of naval officers in the management of the ship and in connection with the physical observations. The civilian staff has consisted of Mr. Charles H. Townsend, naturalist; Mr. A. B. Alexander, fishery expert, and Mr. N. B. Miller, assistant naturalist. Prof. Charles H. Gilbert, of Indiana University, was also attached to the steamer as ichthyologist and chief naturalist from January to August, 1889, and during the Bering Sea cruise of 1890.

ALASKA.

During the summer of 1890 the *Albatross* was in Bering Sea, where an examination was made of all the principal cod-fishing banks as well as of the general features of the shallow-water area which composes the entire eastern part of this important region. The *Albatross* entered Bering Sea by way of Unimak Pass, in May, and carried a line of soundings in a northerly and easterly direction a distance of about 80 miles, when stormy weather made it necessary to proceed to Unalaska, the dredgings and soundings being continued, however, in that direction. Leaving the latter place on May 28, the vessel began a reconnaissance of the shore line of Bristol Bay, which was conducted first along the north side of the Alaska Peninsula as far as the Kvichak River, and thence to the Kuskokwim River. During this cruise the contour and topography of the coast were sufficiently well defined to serve as a basis for the subsequent hydrographic observations. From Cape Newenham a line of stations was run in the direction of the Northwest Cape of Unimak, and the latter part of June investigations were commenced on Slime Bank, being carried thence over Baird Bank to the head of Bristol Bay and the Kulukak Ground. Two visits were paid to Port Möller and Herendeen Bay, where a coal mine had recently been opened, and partial surveys were made of each of these inlets, which define their entrance and the channel leading to the coal landing.

During the first part of August a line of soundings was made from off Cape Cheerful, Unalaska, to Bogoslof Island and volcano, from the

latter locality in a westerly and northerly direction and subsequently in a southerly direction, for the purpose of determining the western boundary of the elevated platform characterizing the eastern part of Bering Sea. The remainder of the season was employed in the vicinity of Unalaska, mainly in ascertaining the positions and value of the cod banks lying off the northern side of that island, but on leaving Bering Sea a few stops were made upon the fishing-grounds south of the Alaska Peninsula.

Slime Bank.—This is the first of the large fishing-banks which is reached after entering Bering Sea through Unimak Pass. As defined by the surveys of the *Albatross*, it begins directly off the Northwest Cape of Unimak Island, is elongate in shape and follows approximately the trend of the adjacent coast to within a few miles of Amak Island. It measures about 85 miles in length by about 17 miles in average width, and thus has a total area of about 1,445 square miles. The inner margin of the bank lies only a short distance off the land and the depths range from 20 to 50 fathoms, although some cod were taken in deeper water. The bottom consists chiefly of sand, gravel, and pebbles, changing to mud on the offshore limits.

The bank derives its name from the occurrence of immense numbers of a large jelly-fish, brownish or rusty in color, and provided with long slender tentacles, having great stinging powers. These jelly-fishes, it is said, have never been observed at the surface, but seem to occupy an intermediate zone toward the bottom, where they occasion much annoyance to the fishermen by becoming entangled about their fishing gear, and in this way are often brought on board the vessels. It is also reported that sometimes they even interfere with the hooks reaching bottom, and, by covering the bait and lines with a prickly slime, render the former unattractive to the fish and the latter very uncomfortable to handle. In the early part of the season not much trouble is experienced from this cause, but by July 1 the jelly-fishes become so thick that it is almost useless to remain longer upon the bank, and other localities farther north are then resorted to. Except for this unusual phenomenon, however, the advantages for fishing on Slime Bank are excellent. The largest and most thrifty looking cod were taken by the *Albatross* some 6 or 8 miles from shore, but fish of fair size and good quality were plentiful over nearly the entire bank. Small specimens of halibut were also secured occasionally, and the beam trawl disclosed a rich bottom fauna. Attempts have been made to use cod trawls upon this bank, but without success, owing to the obstacles which the jelly-fishes interpose. The depths of water, however, are everywhere so moderate that hand lines can be employed conveniently, and that is the only method of fishing now followed.

There are, unfortunately, no available harbors for fishing vessels along the coast adjacent to Slime Bank, although Shaw Bay offers some pro-

tection from southeast to southwest winds. Winter fishing would, therefore, be attended with much danger from the heavy storms which prevail during that season, and operations are chiefly limited to the summer months. According to Capt. Tanner, a well-found schooner could anchor anywhere on the bank between May and September, with an even chance of being able to ride out any gale she might encounter.

Baird Bank, so named by Capt. Tanner in honor of the late Prof. Spencer F. Baird, is the largest and most important fishing-ground yet discovered in Bering Sea. Having a total area of about 9,200 square miles, it exceeds in size Portlock Bank, the largest bank south of the Alaska Peninsula, by 2,400 miles, and Georges Bank, the second largest fishing-ground in the North Atlantic, by 800 miles. Commencing a few miles east of Amak Island, it extends eastward, just off the northern coast of the Alaska Peninsula, to the vicinity of Cape Chigagof, at the mouth of the Ugaguk River, a distance of about 230 miles, and has an average width of about 40 miles. The depth of water ranges from 15 to 50 fathoms, and the bottom corresponds both in character and in the richness of its fauna with that of Slime Bank. The adjacent mainland affords a weather shore during southeast winds, and Amak Island offers fairly good protection on its southeast and southwest sides. Port Möller and Herendeen Bay, which were partly charted by the *Albatross*, will be ports of call when they are better known, and Port Haiden may also become available for shelter after it has been surveyed.

The examination was begun at the western end of the bank, and was carried thence northeastward, the conditions improving with each line of stations until off Port Möller, where the best fishing was obtained. Cod were taken at nearly every trial, but their abundance and quality varied with the locality, the largest and finest specimens having been secured from 15 to 20 miles from shore, in depths of 25 to 40 fathoms. Beyond the Port Möller region they continued abundant and of good size to near the northern end of the bank. The extreme head of Bristol Bay has no value as a cod-fishing ground, and only a few specimens in poor condition were captured here and there. The water is not only too fresh for this species, but owing to the strong currents produced by the immense discharge from several rivers and by the tides an unusual amount of sand and mud is constantly held in suspension.

Kulukak Ground.—Kulukak Bay occupies a large part of the region included between Cape Constantine and Cape Newenham, and contains Hagemeister Island and the Walrus group. Within this area codfish are found in various isolated spots, scarcely entitled to the name of banks, but for convenience sake the name of Kulukak Ground has been used to designate them. Extensive shoals occur off Hagemeister and the Walrus Islands, a depth of 6 fathoms being found about 18 miles to the southward of the latter. The principal fishing-spots are outside

of these shoals, as well as to the eastward and westward of them, and have depths of 12 to 15 fathoms. The bottom in this region consists generally of sand, with some mud and gravel, and the fauna is essentially the same as on Slime and Baird banks. Cod are plentiful at times, but they are smaller than on the more southern grounds. An exception in this particular, however, has been reported with respect to a small spot called Gravel Bank, situated about 16 miles SSW. from the southern end of Hagemeister Island, in depths of 16 to 20 fathoms, but its extent is inconsiderable. Small fish predominate among the islands of the Walrus group, but larger ones may be taken in some of the indentations and on some of the rocky patches. The Kulukak grounds were formerly resorted to by a few vessels, but they are not visited at present.

Cod were found to be abundant in the vicinity of Cape Peirce, but, owing to the number of diseased fish among them, this ground has been named Hospital Bank by the fishermen. Off Cape Newenham no cod were taken, and it is supposed that their absence may be due to the great volume of fresh water issuing from the Kuskokwim River.

Port Möller and Herendeen Bay.—The recent opening of a coal mine near the head of Herendeen Bay has called particular attention to this locality, and it was visited twice by the steamer *Albatross* during the summer of 1890. Although the first purpose in going there was to obtain a supply of coal, partial surveys were made which now render these inlets accessible to fishing vessels during stormy weather. Port Möller and Herendeen Bay are closely adjacent to one another, and open on the north side of the peninsula, the principal passage into the latter being by way of Port Möller entrance. They are located, as before explained, in the vicinity of the best fishing-grounds on Baird Bank, and their availability for shelter is an important consideration for the fishermen. Should this locality, moreover, become a coaling center, it will increase the number of vessels resorting to the region, and tend greatly to develop its resources.

The entrance to the mine which has just been opened, and from which the *Albatross* received the first output of coal, is about 1¼ miles from the water front, on the east side of the head of Herendeen Bay, the coal being transported to the landing over a tramway operated by a small steam motor. A small bight at this place has been called Mine Harbor. The survey made by the *Albatross* has defined the entrance to Port Möller and the channel thence through Herendeen Bay to its extreme upper part, where there are good places for beaching and repairing small vessels, the rise and fall of the tide amounting to 15 feet, and where fresh water and fuel can readily be procured in any quantity.

The Herendeen Bay coal was used on board the *Albatross* with satisfactory results, but, owing to the lack of proper screening facilities, much fine material and dirt was delivered with it, and it was found

necessary to burn from 20 to 25 per cent more of it to obtain the same results as with a fair quality of Wellington coal. Capt. Tanner states, however, that considering that it was taken from a vein near the surface, the extra amount required to furnish the same quantity of steam will not seem excessive. It was shown that the coal possesses merit, and it will doubtless improve with the development of the deeper veins.

South of the Alaska Peninsula.—While on the way south from Bering Sea in September, 1890, a line of dredgings and soundings was carried along the line of islands lying off the Pacific coast of this peninsula. From off the Trinity Islands the soundings were continued in deep water as far south as the Queen Charlotte Islands. The deep ocean trough described in former reports as lying south of the Aleutian Islands and the peninsula, and trending in the same general direction, was traced as far west as latitude 56° 02′ N., longitude 151° 12′ W., which is to the southeastward of Kadiak Island.

Southeastern Alaska.—Practically nothing has yet been done toward investigating the fishery resources of southeastern Alaska, all of the time suitable and available for work in northern latitudes since the *Albatross* arrived in the North Pacific having been spent off the southern coast of the Alaska Peninsula and in Bering Sea. During July, 1889, however, a trip was made through the inland passages of the southeastern part of the Territory as far as Juneau, with several members of the Senate Committee on Indian Affairs, who were desirous of inspecting the principal Indian settlements. The steamer left Tacoma on July 8, and returned on the 28th of the same month. Stops were made at Fort Tongass, Port Chester, Karta Bay, Port Wrangall, Sitka, Pavloff Harbor, Hoonyah Bay, Portage Bay, Chilkat, and Juneau. Several important fishing stations and canneries were visited, and some investigations were made by means of the beam trawl, and other kinds of fishing apparatus. Good photographic views were also obtained of Patterson, Muir, and Davidson glaciers.

WASHINGTON, OREGON, AND CALIFORNIA.

Puget Sound to Cape Mendocino, California.—The investigations begun in this region in 1888 were continued as far south as Cape Mendocino during the latter part of the summer and the fall of 1889, and again for a short time in the fall of 1890. This completed the preliminary examination regarding the general features of the continental platform within these limits, and the location and principal resources of the fishing-grounds. Very few soundings had been made on this coast previous to the surveys of the steamer *Albatross*, in 1888, and none outside of the 50-fathom curve. The hydrographic work thus far accomplished by the *Albatross* affords the necessary information to define the contour of the bottom into depths of at least 200 fathoms, and as the fisheries for a considerable time to come will not be carried beyond the 100-fathom curve, the characteristics of the bottom observed within those limits

are sufficient for all immediate considerations in connection with fishery matters. The distance of the 100-fathom curve from shore varies in different places from 7 to 40 miles, averaging broadest at the north, and becoming reduced to from 7 to 9 miles off Cape Orford; Trinidad Head, and Cape Mendocino. The superficial area of the submerged platform within this depth is computed at 3,700 square miles for the outer coast of Washington, 4,750 square miles for the coast of Oregon, and 1,160 square miles for the coast of California north of Cape Mendocino, a total of 9,610 square miles.

The soundings off Cape Flattery are irregular and suggest the existence of submarine ridges trending parallel with the coast. A semicircular depression, with depths of 100 to nearly 200 fathoms, was found between Cape Flattery and Flattery Rocks, at a distance of about 10 miles from shore. From the latter place to Yaquina Head the depths increased regularly toward the sea, except upon the rocky bank off Grays Harbor and Willapa Bay, where elevations of a few fathoms occur. A triangular platform having depths under 100 fathoms lies between Yaquina Head and Umpqua River, Heceta Bank being located upon its southwestern extremity. Thence to Cape Mendocino the soundings are regular.

Distinct fishing-grounds in this region are few in number and of small extent, the principal ones being the following: Flattery Bank has an area of about 1,100 square miles, with a least depth of 27 fathoms. Halibut and other fishes have been taken upon it in considerable numbers for some years past. The former species occurs in greatest abundance on a very rough, rocky bottom, having an extent of about 35 square miles near the southeastern end of the main bank. A small bank covering about 110 square miles and with a least depth of 42 fathoms lies 23 miles W. by S. (magnetic) from Toke Point light-house, Willapa Bay. The bottom consists of sand and mud with rocky patches. Another bank having an area of only about 40 square miles, with the same minimum depth as the preceding, and with a bottom of clay, mud, and rock, is located 19 miles SSW. ¼ W. from Yaquina light-house. Heceta Bank, the largest fishing-ground south of Cape Flattery on this part of the coast, is situated 35 miles SW. ½ W. from Heceta Head, Oregon, and has an area of about 600 square miles. The least depth, 41 fathoms, has been found near its southern end, where the bottom is rocky and rough.

Only occasional specimens of halibut were taken off Flattery Rocks and Tillamook Rock and on Heceta Bank. Several species of rock-cod were generally distributed along the coast, as well as on the banks, and flounders were found everywhere, being especially abundant in depths of 50 to 100 fathoms. The flat surface of the plateau is particularly rich in the latter group of fishes, and is destined to become a favorite ground for the beam trawl when that method of fishing is introduced. Cultus-cod occur on all the banks and on Orford Reef, while

the black-cod inhabits the deeper waters, half-grown individuals also being found in moderate depths, together with the ling or Pacific whiting. Large red prawns of excellent quality are likewise very abundant and widely distributed, having been captured frequently in considerable numbers in the beam trawl.

Although gales are of rare occurrence in this region during the summer months, yet the coast winds blow constantly from the northward and maintain a boisterous sea and strong currents. During the fall and winter southeasterly storms are frequent. Owing to the scarcity of good harbors, the fishermen have, therefore, many hardships to contend with, and the lack of sufficient markets to handle a large catch interferes at present with the rapid development of the fishery.

Cape Mendocino to Point Conception, California.—During March and April, 1890, the coast waters between Point Arena and the Santa Barbara Channel, including the important fishing-grounds off San Francisco, were surveyed by the *Albatross*, and in September of the same year the region from Cape Mendocino to Point Arena was examined, thereby completing the preliminary investigations on the California coast. Capt. Tanner reports that he found the slope very abrupt near Cape Mendocino, but it gradually widens toward the south, the 200-fathom curve off Point Arena being distant about 12 miles from shore. There are no fishing-banks properly so called within these limits, but the same fishes which are commonly met with farther north are distributed also through this district, and the beam trawl may be used off Point Arena, although some rocky patches occur in places.

Between Point Arena and Point Conception the width of the continental platform into depths of 200 fathoms varies considerably, the extreme range being from less than 1½ to 26 miles. Within these boundaries the most active fisheries on the California coast are now being conducted. The character of the bottom is generally very uniform, the area between the Golden Gate, Point Pillar, the Farallones, and Point Reyes being sandy and free from rocks, except in the immediate vicinity of the islands or of the shore. South from Pillar Point rocky patches frequently occur near the shore, with fine gray sand farther off, finally merging into green mud at varying distances from the land. Rocky spots also exist in depths of 30 to 70 fathoms on sand and mud bottoms.

One hundred and eleven trawling and fishing stations were made in this region, and a very large variety of fishes was obtained, many being of excellent food quality. Flounders, including several choice edible species, composed the principal features of every haul. The beam trawl and other corresponding forms of drag nets are the only appliances by which these forms can readily be secured. Several species of rockfish were also common.

Oyster investigations, San Francisco Bay.—Investigations having for their object to determine if the waters of San Francisco Bay are suitable for the breeding of the Atlantic coast oyster (*Ostrea virginica*) have been conducted by Mr. Charles H. Townsend, naturalist of the steamer *Albatross*, during such periods as that steamer has been detained at San Francisco or Mare Island. These inquiries have been carried to all parts of the main bay and to San Pablo Bay, and have had reference to the temperature and density of the water, the character of the bottom, and the actual attachment and growth of spat derived from the planted beds. The results are very gratifying, and, while not conclusive on all points, they seem to indicate that the conditions existing in some portions of the bay are not unfavorable to the establishment of self-sustaining colonies of the eastern oyster.

The oyster industry of the Pacific coast, exclusive of the trade in the small indigenous species, has never extended beyond San Francisco Bay, where it is restricted to the growing or fattening of seed or yearling oysters, brought annually in large quantities from the Atlantic coast. This method of transplanting oysters has been practiced ever since the completion of the first overland railroad, and a supply of the eastern species has thereby been constantly maintained in the waters of San Francisco Bay, yet it has generally been understood that no natural increase has taken place in this region. To account for this supposed failure to propagate, it has been assumed that the temperature of the water during the breeding season is lower than it should be, but the subject has never been investigated and practically nothing has been known regarding it.

While the observations of Mr. Townsend were limited to a few months in each year, temperature data covering all seasons have been obtained from other sources, and these lead to the conclusion, based upon a comparison with the eastern coast, that the water temperature in at least the southern part of San Francisco Bay is sufficiently high to fulfill all the necessary requirements of reproduction. Any failure to produce spat would therefore have to be traced to other causes; but, as a matter of fact, Mr. Townsend finds that the *Ostrea virginica* does breed in this region and that the young attaches itself under suitable conditions. To what extent this prevails, however, can only be determined after a more complete study of the bottom. The largest and most important tract of oyster propagation, according to Mr. Townsend, is the region of the natural shell banks of native oysters along the east side of the bay, beginning at Bay Farm Island and extending well southward and offshore into the deeper water. Here wild oysters of the Atlantic coast type may be found during the low tides which expose the outer portions of the shell banks. They are numerous, and when the tide is sufficiently low it is possible to gather them by hand, ranging in size from yearlings to specimens several years old. Considerable quantities are obtained annually in this region, and also on other

smaller tracts farther south, for transplanting to the cultivated beds. Oysters of the same species were likewise found at greater distances from the planted beds, in San Leandro Bay and at Sheep Island and Point San Pedro, attached to rocks and to piles driven in the bottom, leaving no room for doubt that they had originated through the spawning of oysters in the bay.

OFF MEXICO, CENTRAL AMERICA, AND THE GALAPAGOS ISLANDS.

On January 30, 1890, the steamer *Albatross* left San Francisco for Panama to engage in a special scientific inquiry, authorized by the President of the United States. The expedition was under the direction of Prof. Alexander Agassiz, director of the Museum of Comparative Zoölogy at Harvard College, who also paid a large proportion of the expenses incidental to the cruise. The area marked out for investigation lay off the western coast of Mexico and of Central and South America, from Cape San Francisco in the south to Guaymas in the north, and extended seaward to and including the Galapagos Islands. The biological and physical features of this region, as well as the contour and character of the bottom, except in the vicinity of the coast, were then almost entirely unknown, the *Albatross* having made only a few observations there during the voyage from Washington to San Francisco, while H. M. S. *Challenger*, during her famous expedition around the world, sailed directly from the Sandwich Islands to Chile, and thence into the Atlantic Ocean.

The present inquiry had reference mainly to the natural history and temperature of the deeper waters off the coast, at the bottom and surface, and also at intermediate depths. The ordinary outfit of the *Albatross*, frequently described in previous reports, was well adapted to the greater part of the observations, but for collecting organic forms at intermediate depths a new form of net was improvised by Capt. Tanner, and gave entire satisfaction. It is so arranged that after being lowered and dragged for any desired distance through the water it may be tightly closed by the falling of a messenger, thus preventing any objects from entering it while it is being hauled on board. It is, therefore, well suited for determining the character and amount of animal life at any depth below the surface, without the danger of its contents being added to at other levels. An appliance of this sort would have been of material assistance in the researches hitherto made respecting the mackerel-grounds on the Atlantic coast of the United States, and it is proposed to utilize the new invention during the future investigations in that region.

Beginning off Cape Mala, near Panama, a line of stations was carried to Cocos Island, and thence, with some deviation toward the south, to Malpelo Island and back to Panama, where several short lines were run immediately outside of the 100-fathom curve. On the second cruise

the steamer proceeded first to the vicinity of Cape San Francisco, thence to the Galapagos Islands, and from there to Acapulco. Subsequently, dredgings were made from off Cape Corrientes to Guaymas, in the Gulf of California. The greatest depth of water explored was 2,232 fathoms. Short stops were also made at the different islands lying in the course of the expedition, for the purpose of studying the land and shallow-water animals and plants. While it was observed that the marine fauna of this region is not so rich as that occupying the corresponding waters off the east side of the continent, very large collections were secured, and the general results obtained are of great importance. Soon after this material was received in Washington the different groups were carefully sorted out, and the greater number have already been assigned to specialists for study under the direction of Professor Agassiz.

One of the most important outcomes of the expedition has been the determination by Prof. Agassiz, through the instrumentality of the intermediate towing net, of the vertical distribution of the surface pelagic fauna, which he considers to descend only to a depth of about 200 fathoms. Some forms among the bottom animals may work up a distance of several fathoms, but between these levels in the open sea he finds no evidences of life. Regarding this subject there are still some differences of opinion among explorers, and further investigations will be awaited with much interest. As a solution of the problem may have some bearing upon the study of the habits of the Atlantic coast mackerel during its migrations in the deeper water, the practical importance of continuing the experiments can readily be appreciated.

Detailed accounts of this investigation will be found in the report of Capt. Tanner, contained in the appendix to this volume, and in the publications of the Museum of Comparative Zoölogy, Cambridge, Mass.*

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* Three letters from Alexander Agassiz to the Hon. Marshall McDonald, U. S. Commissioner of Fish and Fisheries, on the dredging operations off the west coast of Central America to the Galapagos, to the west coast of Mexico, and in the Gulf of California, in charge of Alexander Agassiz, carried on by the U. S. Fish Commission steamer *Albatross*, Lieut. Commander Z. L. Tanner, U. S. N., commanding. Bull. Mus. Comp. Zoöl., XXI, No. 4, pp. 185–200, 1891.

General sketch of the expedition of the *Albatross*, from February to May, 1891. By Alexander Agassiz. Bull. Mus. Comp. Zoöl., XXIII, No. 1, pp. 1–89, plates 1–22, including a detailed chart of the explorations, 1892.

Calamocrinus diomedæ, a new stalked crinoid. By Alexander Agassiz. Mem. Mus. Comp. Zoöl., XVII, No. 2, 96 pp., 32 plates, 1892.

ATLANTIC COAST.

OYSTER INVESTIGATIONS.

LONG ISLAND SOUND.

The steamer *Fish Hawk*, Lieut. Robert Platt, U. S. N., commanding, was at work upon the oyster-grounds of Long Island Sound during a part of both 1889 and 1890. In the former year the investigations were begun on August 18 and terminated on October 8; in the latter year they continued from June 11 until October 16.

During the season of 1889, Dr. C. F. Hodge, of Clark University, served as naturalist, and the operations were restricted chiefly to dredging on and about the oyster beds, and to experimenting with traps and other devices intended for the capture of starfishes. Certain statements having gained currency, to the effect that the waters of Long Island Sound do not interchange freely with the waters of the open ocean, and are thereby rendered more or less stagnant and impure from the accumulation of town sewage and the effects of the dumping-grounds, to the serious detriment of the oyster beds, the greater part of the season of 1890 was occupied in making physical and chemical investigations to determine the actual sanitary condition of the region, but after their completion the dredging and natural-history work was again taken up. Mr. E. E. Haskell was detailed by the Superintendent of the U. S. Coast and Geodetic Survey to conduct the physical inquiries, while Mr. Fred Neher, of Princeton College, was employed to make the chemical observations. The natural-history work was attended to by Mr. James E. Benedict, of the U. S. National Museum, and Mr. W. C. Kendall, of the Fish Commission.

The natural oyster beds of Connecticut are restricted to the bays and inlets and to the shallow waters near the shore, extending sometimes, however, into depths of 3 to 5 fathoms. The artificial or planted beds are for the most part outside of the natural ones, and they have been carried in some instances as far as the middle of the sound, and into depths occasionally of 13 to 14 fathoms. Both the natural and planted beds are mostly limited to the western half of the sound, comparatively few areas occurring to the eastward of New Haven Harbor. The Fish Commission obtained for its use, through the courtesy of the State Fish Commission, a complete set of the engineer's charts showing the exact position of all the grounds sold for planting purposes. The same data has since been published by the Connecticut Bureau of Labor Statistics on a smaller scale, and in a very convenient form for reference. An examination of these charts shows that the area of bottom which has been sold for oyster purposes is relatively very large, covering up to 1889 a total extent of over 78,000 acres. It must be borne in mind, however, that not all of this bottom has been planted with oysters; in some

parts of the region the proportion under cultivation is relatively small, and a part of the designated area is unsuited to oyster-planting in its present condition. Just what extent of bottom is now in actual use it has been impossible to ascertain.

The waters of Long Island Sound within the territory of Connecticut (the State line being midway of the sound) are divided into a number of districts by straight lines extending due north and south, each district being named after the adjacent township. In nearly all of the western districts a certain area has been set aside as a dumping-ground for the materials dredged up in the course of the improvements in the neighboring harbors and river mouths. While these dumping-grounds have well-defined boundaries, and it is intended that no refuse shall be deposited elsewhere, they have come to have a rather unenviable reputation among the oystermen, who consider them the source of many of their troubles.

While the attention of the Fish Commission was first requested toward the depredations of starfishes upon the oyster beds, so many other questions have since been raised respecting the conditions of the latter that it has become necessary to greatly increase the scope of the inquiry and to give it rather the character of a general investigation.

In 1889 the work was begun in the Norwalk district and was carried thence eastward through the Westport, Fairfield, Bridgeport, Stratford, and Milford districts, into Orange district. Dredgings were made at frequent intervals, and sometimes under guidance of the owners of oyster territory, who were able to indicate particular localities where starfishes were then abundant. The oyster traps were also set under many different conditions, but always with practically negative results, as explained below. In 1890 the physical and chemical examinations occupied nearly all the time from the beginning of the season until the middle of September. Self-registering tide gauges were first established at New London and New Haven, Conn., and at Willets Point, N. Y., after which observations upon the direction and velocity of the currents were made at regular intervals between the mouth of the Connecticut River and East River, by means of the Ritchie-Haskell electrical meter. The chemical analyses of the water were conducted in the same connection, and covered samples taken from every variety of location, from the harbors and river mouths to the outer and deeper portions of the sound. The subsequent dredging operations were chiefly restricted to Bridgeport and Stratford districts, and were carried on with greater detail and precision than in 1889, stations being made at regular intervals of half a mile in both directions. In this manner it was expected to obtain a continuous record showing the character and condition of the bottom.

Both the physical and chemical investigations were conclusive in demonstrating that, so far as regards the general conditions of the

waters in Long Island Sound, the oyster-growers have nothing to fear for the safety of their beds, no great amount of pollution having been found at any place examined, and the interchange of waters with the open sea being sufficient also to insure their purity far above the standard required for oyster-raising. Much has been learned with respect to the present condition of the oyster beds and of the adjacent bottom, and as to the natural-history features of the region, including the habits of starfishes; but no new methods have been discovered for the destruction of this enemy, although suggestions have been offered which may prove of some value.

During the course of the investigation it was not observed that any of the oyster beds were being harmed to any appreciable extent by the growth of sponges or worm tubes, the latter, however, having occasioned some loss in 1882 in the vicinity of New Haven. The large winkles (*Fulgur* and *Sycotypus*) are said to do a greater or less amount of damage, but no instance of their destructiveness came directly to the attention of the party, and, owing to their size, they may readily be detected and removed. The oyster-growers claim, moreover, that when they have once been cleaned from the beds they give them no further trouble during the same year, and they also state that they are rapidly decreasing in abundance, due no doubt to the numbers which are destroyed annually, together with their conspicuous egg capsules. The drills and starfishes dispute the title of being the most destructive of the oyster pests, the former operating chiefly in the more brackish and shallow waters, and the latter invading all other territory, although not entirely absent from the former. The drill, however, feeds generally on smaller oysters than the starfish, and the extent of its damage is less appreciated by the oystermen. The starfish, therefore, is usually most dreaded, and very justly so, in the more open waters of the Sound, where the great majority of the beds are situated.

It is unnecessary in this connection to enumerate the mass of facts that has been obtained to show the amount of damage caused annually by these two enemies of the oyster. In fact, it is very difficult to estimate the money value of the losses, which may include only the outlay in the planting and tending of the beds, or extend to the prospective profit on the crop after it has matured. An invasion by starfishes may be detected early enough to insure their being dredged up before they have accomplished much injury. Otherwise they may succeed in destroying a portion of a bed, or even an entire bed of large area, and they generally appear suddenly, without any warning.

Opinions differ as to the months during which starfishes are most destructive. The evidence collected, however, tends to prove that they are feeding on or about the beds during the entire year, and when the food in one locality is exhausted they move elsewhere, the places where they congregate and do the most damage changing more or less from year to year. The breeding season appears to extend over nearly, if

not quite, three months—from June to August. It is the popular belief that during a part of this period the starfish bunch up in large clusters, the supposition being that this habit may have some relation to the spawning functions. Both this occurrence and the reasons assigned for it may be true, and it seems very probable that the starfish do sometimes collect together in large masses, but this can also be explained, in a measure, as an incident of their feeding. It has been noticed, in connection with the large invasions, that these animals clean the beds up very thoroughly as they go. It can well be imagined that, on reaching a new ground, the first arrivals begin to feed at once, while those in the rear, pressing forward, pile up over them, forming for the time a sort of windrow, but these conditions would probably not continue long.

The rate of movement attained by a body of starfishes when invading an oyster-ground has been variously estimated, but the observations in respect to this matter must, for the most part, be very unreliable. One planter, however, has informed us on good authority that a dense line of starfishes advanced about 2,000 feet over one of his beds in the course of four days, while his steamers were engaged in dredging them. In connection with some experiments made by Dr. Hodge, specimens of medium size were seen to move at the rate of 6¾ to 11½ inches per minute, and if this rate were to be maintained without intermission they might cover, on an average, a mile in a little over five days.

Unfortunately records are seldom kept of the quantity of starfishes removed from any of the beds, but a large planter in the Bridgeport and Stratford districts has furnished a detailed statement which shows that from 1884 to 1889, inclusive, about 36,000 bushels were dredged up by his steamers, the average catch per month, computed for the six years, being as follows: January, 460; February, 250; March, 180; April, 90; May, 400; June, 490; July, 620; August, 560; September, 560; October, 480; November, 350; December, 440. It should be borne in mind, however, that these figures relate to only a comparatively limited area, and might not apply to other districts. It is also possible that his steamers were less watchful at some times than at others, and that the averages for the catch of starfishes would not indicate with exactness their relative abundance during the several months. The principal utility of this statement consists in its showing that starfishes are always present on the oyster-grounds, and may be regarded as plentiful in every month of the year, but whether they are always feeding or not still remains to be determined. They are said to begin to feed on oysters when very young, selecting individuals, of course, which are in proportion to their own size, and several have frequently been found attached to the same oyster. They also live on other bivalves, such as mussels and clams, and even on small gastropods, barnacles, etc.

As to the distribution of the attacks of starfishes, it seems probable that, the conditions being equal, all the beds are subject to their in-

roads in about the same proportion. If kept cleared from any given area, those owning beds around the margin have the most to do in fighting them, and in so doing they shield their neighbors. Mutual and persistent efforts in this direction furnish the only means by which all the beds can at present be protected, and by coöperation not only may the destructiveness of starfishes be greatly lessened, and the security of the beds be more or less insured, but the cost of removing starfish or of guarding against their attacks will fall less heavily on the planters who are now most active in their watchfulness. It is these men whose grounds are kept in the best condition and who are securing the most benefits, while those who are careless or indifferent in their attentions are subject at any time to heavy or entire losses.

It is generally considered that the beds or parts of beds in close proximity to a reef or other obstruction on the bottom are among the most liable to be invaded at frequent intervals, as the starfishes can not be completely eradicated from such places. The natural beds may also be cited as a fruitful source of danger, in that the stars may breed and grow upon them practically undisturbed, and may at any time pass to the neighboring cultivated areas. Steam dredging is not allowed upon these public grounds; no one is responsible for their condition, and no one has the power, even if he had means and interest, to keep them free from pests. As matters stand at present they are a constant menace to valuable private interests—a condition of affairs never tolerated in respect to agricultural pursuits.

Despite the amount of damage caused by natural enemies, the oyster industry of Connecticut is exceedingly prosperous, yet no one doubts that this prosperity might be increased by a removal of this source of injury. While this can, probably, not be done effectually, a great measure of protection might be afforded through the intervention of the State, as well as by a reduction in the relative extent of the planted area to such a limit that all the grounds could be under constant supervision. The greater losses have resulted from a lack of vigilance, and unfortunately the diligent cultivator is too often made to suffer from his neighbor's carelessness. In the Norwalk district they do not, as a rule, attempt to cultivate more ground than they can properly attend to, and a reduction in the abundance of starfishes has been noted there, but the same was not found to be the case in some of the other districts examined.

During 1888 and 1889 only a small set of spat was secured throughout the sound, and a great amount of damage by starfishes was recorded. In 1890, however, a heavy set was obtained, although it was not evenly distributed. It was fairly good from the Thimble Islands to the Milford district, being very abundant in the latter region, and especially so on the natural bed off Stratford and on some of the planted grounds in the same vicinity. The region farther west was less favored in this respect, except in some places of limited extent.

In ridding their beds of starfishes the oystermen generally make use of the common oyster-dredge, which also brings up everything from the bottom, and the living oysters may then be transplanted to other grounds if desirable. This method is necessarily laborious and expensive, as well as destructive, as many oysters are often damaged by the dredge, especially if they are young and thin-shelled. A special dredge, invented by Mr. Landcraft, of New Haven, and designed to remove only the starfishes, has been employed with some success, but its use does not seem to have become very general. Other devices having the same object in view have recently been patented, but nothing has been learned regarding their effectiveness. The tangles, suggested some years ago for this purpose by the Fish Commission, have been tried occasionally, but they are said not to work the ground clean, and it is difficult to extricate the starfishes after the apparatus has been landed on the deck. The first of these troubles also manifested itself in the trials made by the *Fish Hawk* with the beam trawl, but it was partly overcome by attaching a drag chain between the runners slightly in advance of the net. This appliance would not, however, present any advantage over the oyster dredge, and, as a whole, might be regarded as very inferior to it, its expense and the difficulty of working it from a small steamer also operating to its disfavor.

Baited traps were experimented with in 1889 under the direction of Dr. Hodge, but only with negative results. They were made of iron rings, 2 feet in diameter, filled in with a shallow bag of netting, and when in use were suitably weighted, and their positions marked with a small wooden buoy. Many different kinds of bait were employed, and they were as thoroughly tested as was possible at the time in the Norwalk district, but no starfishes were secured on any trial. This experiment is not, however, to be regarded as conclusive, because traps have been and are still being used for this purpose with some success in Providence River. They are there made box-shaped, of laths, something after the pattern of the rectangular lobster pots. It is not expected that any devices of this sort will prove effectual where starfishes are very abundant, but under some circumstances they might serve a good purpose, and further tests should be made whenever the opportunity occurs.

Physical inquiry.—The following preliminary report by Mr. E. E. Haskell, upon the results of his current observations in Long Island Sound, has been transmitted by the Superintendent of the U. S. Coast and Geodetic Survey.

PRELIMINARY REPORT UPON THE CURRENT OBSERVATIONS IN LONG ISLAND SOUND.

By E. E. Haskell.

The observations for this discussion were made during the summer of 1890, from the U. S. Steamer *Fish Hawk*, during a joint investigation by the U. S. Commission of Fish and Fisheries and the U. S. Coast and Geodetic Survey, for the purpose of studying the condition of and the circulation of the sea through Long Island Sound.

For a knowledge of the tides that traverse the Sound we placed at New London, New Haven, and Willets Point—practically at each end and the middle—a self-registering tide gauge. With the tide gauges in operation, we made from the steamer *Fish Hawk* a series of current observations, occupying therefor current stations which in location give a cross section near each end of the Sound; a current station about every 10 miles in the longitudinal axis of the Sound; and a current station on each of the dumping-grounds of the towns of New Haven, Milford, Bridgeport, Norwalk, and Stamford.

In illustration of the tides of the Sound, the mean establishment of Block Island and that of Sandy Hook are about the same, namely $7^h\ 31^m$ and $7^h\ 35^m$, respectively. There being but about ten minutes difference in time, due to difference in longitude, it is practically high water at both places at the same time. From these places the tide wave that causes high water travels by two different channels, the Block Island branch through Long Island Sound from its eastern entrance, and the Sandy Hook branch passing through New York Harbor and East River into the Sound from its western entrance, and give to this inland channel a compound tide.

From our observations, which confine us to the reach from New London to Willets Point, we find it is high water at New London (the mouth of the Thames) $9^h\ 47^m$, at New Haven (Light-House Point) $11^h\ 17^m$, and at Willets Point $11^h\ 24^m$ after the moon's transit. The opposite phase of the tide takes place at New London $3^h\ 31^m$, at New Haven $5^h\ 03^m$, and at Willets Point $5^h\ 45^m$ after the moon's transit. These figures give for the duration of rise $6^h\ 16^m$, $6^h\ 14^m$, and $5^h\ 39^m$ for New London, New Haven, and Willets Point, respectively; and, for the corresponding duration of fall, $6^h\ 08^m$, $6^h\ 10^m$, and $6^h\ 45^m$.

The distance from New London to New Haven, measured on a central line through the Sound, is 36 nautical miles, and the distance from New Haven to Willets Point, measured on the same course, is 48 nautical miles. From the mean establishment of these points, given above, and the corresponding distances between them, it appears that the tide wave travels from New London to New Haven in $1^h\ 33^m$, or at the rate of 23 nautical miles per hour, while it travels from New Haven to Willets Point in 10^m, or at the rate of 288 nautical miles per hour. This remarkable difference in speed of the wave in these two reaches is undoubtedly caused by the interference of the two waves that have arrived on the scene by the two different routes. It is the meeting-ground; or, to be more explicit, the reach from Hell Gate to Stratford Shoal is where the energy of these waves, traveling in opposite directions, is spent.

An interesting feature in the tide of the Sound is the vertical motion of the water that takes place. Mean sea level at all points throughout this water course is at the same elevation, and might be represented by a straight line so far as the present discussion is concerned. At New London the average rise of the tide is 2.6 feet, or it has a semi-amplitude in its oscillations above and below the straight line representing mean sea level of 1.3 feet. At New Haven the average rise of the tide is 6 feet, or its semi-amplitude is 3 feet. At Willets Point the average rise of the tide is 7.3 feet, or its semi-amplitude in reference to the line is 3.65 feet. These figures show that with every tide the water surface of the western portion of the Sound is alternately made a hill and a hollow when compared to the water surface in

the eastern portion, or perhaps a better reference would be to the open sea either at Block Island or Sandy Hook, where the amplitude of the tide is 1.5 feet and 2.3 feet, respectively.

Having indicated briefly the tides of the Sound, we will now consider the other and far more important component in the circulation, viz, the horizontal movement of the water, or the tidal current.

Beginning at the eastern cross section at the mouth of the Connecticut River, the station located near the axial line of the Sound gave for the mean velocity of the maximum flood vertical curve of velocities 3.2 feet per second, and for the mean velocity of the maximum ebb vertical curve of velocities 2.8 feet per second.

The current station located similarly on the western cross-section at Matinicock Point, Long Island, gave for the mean velocity of the maximum flood vertical curve of velocities 0.86 of a foot per second, and for the mean velocity of the maximum ebb vertical curve of velocities 0.77 of a foot per second.

The striking contrast in the difference in the strength of the flood or ebb currents of the eastern and western ends of the Sound indicated by the figures given above shows clearly what was to be expected from the tidal data, namely, that as we approached the meeting-point of the two waves from opposite directions the horizontal motion of the water should decrease. The series of current stations, located at intervals of about 10 miles on the axial line of the Sound, when considered in connection with the two mentioned above, illustrate very well this decrease and furnish a knowledge of the horizontal movement throughout the Sound. Taking any station in the series, its flood and ebb velocities will be greater or less than those given above for the stations on the eastern or western cross-sections in almost direct proportion to its distance from those cross-sections.

By comparing the maximum flood and ebb velocities for the central stations on each of the cross-sections, we find that the flood velocity is to the ebb velocity as 1.15 is to 1.0 for the eastern cross-section; and that for the western cross-section the flood velocity is to the ebb velocity as 1.12 to 1.0. These indicate clearly a resultant movement to the westward, for in the diagram of current velocities, which can not well be reproduced here, the duration of flood and ebb stream are seen to be about equal. The maximum in the former takes place at the VIII lunar hour and the maximum in the latter at the II lunar hour, and at these times the stream is a continuous maximum stream throughout the Sound.

This excess of westerly over the easterly flow was to have been expected, for in Prof. Mitchell's report, "The circulation of the sea through New York Harbor," Appendix No. 13 of the Report of the Coast and Geodetic Survey for 1886, are given the results of a series of gaugings of East River at Nineteenth street, and in round numbers there is as a mean value 448,000,000 cubic feet more water transferred to the southward on every ebb tide of New York Harbor than is brought northward by the flood tide.* This surplus of water must come through the eastern entrance of the Sound, hence from the open sea, where it must be pure; and although small in quantity in comparison with the volume in the Sound, it is a constant force to crowd out at the western end stagnant or polluted water.

Another interesting phenomenon brought out by our observations, and one which plays a prominent part in the circulation of the Sound, is the "underrun." Beginning at the eastern entrance, the change from ebb to flood current takes place by the denser sea water of the outside forcing its way in along the bed of the Sound while the surface is still running ebb. The beginning of this "underrun" was found to be about one and a half hours previous to the surface reversal of the stream. The neutral plane between the two currents running in opposite directions would gradually rise (the "underrun" or flood current increasing while the ebb current was decreasing), reaching the surface finally when the ebb current disappeared altogether. The

* It must be here noticed that the flood tide of Long Island Sound corresponds in direction to the ebb tide of New York Harbor and *vice versa*.

effect of this movement is a raising to the surface and a crowding gradually seaward of the water that had in previous tides performed the part of a purifying agent.

The strong winds of the winter season are also a factor in the circulation, as they take part in the annual cleansing of the Sound by either drawing in an extra supply of water over that brought by the tide, or forcing out water in excess of that taken out by the ebb flow.

The question of fresh water brought down by the rivers and creeks has been ignored, because, in my judgment, it plays no essential part in the circulation of the Sound. Fresh water on reaching the sea simply slides off on the surface of the much denser sea water, to be carried ebb or flood with the current prevailing at the time.

In regard to the current stations located on the dumping-grounds, the current shown, with the possible exception of those in the towns of New Haven and Milford, is not strong enough to transport the dredgings dumped on them, so that little fear of the distribution of this material in the Sound need arise.

In conclusion, the circulation of the sea in Long Island Sound seems to me to be sufficient to allay all fears of its waters becoming polluted. It is time, however, to raise in general a warning voice against what is now a common practice, and that is converting our rivers, harbors, lakes, and sounds into receptacles for the sewage and refuse of the cities and factories that line their banks. In the long run it can only work an injury, which as population becomes more dense will of necessity have to be considered and a remedy applied.

Chemical inquiry.—Mr. Neher joined the *Fish Hawk* on June 9, 1890, and the remainder of that month was mostly occupied in perfecting the arrangements for the chemical analyses, in preparing the reagents, and in making the preliminary tests. For the convenience of this work a small, temporary laboratory was constructed on the hatching deck of the steamer, where observations were conducted in comparative security.

The object of the investigation being simply to ascertain the relative purity of the water in the Sound, the tests applied were chiefly those used to detect sewage contamination by volumetric, colorometric, and gasometric methods. The Wanklyn test was resorted to for determining the amount of free and albuminoid ammonia contained in the water, for which purpose it is unsurpassed by any other. Ammonia being one of the products of decomposition of organic substances, the determination of its quantity in any given sample of water offers a means of measuring relatively the organic pollution of the same. A few tests were made by the aluminium method for ascertaining the amount of nitrogen as nitrates and nitrites, and the ratio of the dissolved oxygen was also determined in some instances. The samples of water analyzed were taken both from the surface and from the bottom in all depths down to 28 fathoms, and under many different conditions, as in the open sound over clean bottom, on and about the dumping-grounds, and in some of the harbors.

Owing to the fact that no standard of purity of sea water with reference to oysters or to the general health of adjacent land has been established, Mr. Neher found it difficult to interpret his results in that respect. The standards followed with regard to potable water may be used for comparison, but it is not to be expected that such low organisms as oysters would be as readily affected by these impurities as the

human system, and a very liberal margin may be allowed in favor of the former. In fact, it is probable that a very large percentage of what might ordinarily be regarded as impurity in potable water is more beneficial than harmful to oysters. When the amount of free ammonia in potable water exceeds 0.01 it is generally considered to be due to recent sewage contamination; and the amount of albuminoid ammonia in a safe drinking-water should not much exceed 0.015 parts per 100,000 parts of the water. The figures furnished by Mr. Neher's tests may be summarized as follows: At the mouth of the Connecticut River, .005 of free ammonia and .013 of albuminoid ammonia; on a line across the Sound opposite the mouth of this river, .002 and .015, respectively; a second line somewhat further west, .005 and .01; a line opposite Matinicock Point, .01 and .016; at Throgs Neck, .023 and .018. The last two undoubtedly show the influence of the East River. On and near the dumping-grounds off New Haven, Bridgeport, Norwalk, and Stamford the amount of free ammonia ranged from .006 to .013 and the albuminoid ammonia from .014 to .019. These dumping-places have always been regarded as the most serious menaces to the oyster-grounds in Long Island Sound, but the chemical observations fail to support that claim. In New Haven Harbor the free ammonia amounted to .013 and the albuminoid to .018, while in Bridgeport Harbor they were .02 and .018, respectively.

The results of analyses made in three other bodies of water may be noted here for the sake of comparison, the first figures given in each case being those for the free and the last for the albuminoid ammonia, as above. Lake Ontario, 0.002 to 0.004 and 0.013 to 0.020; Oneida Lake, 0.004 to 0.008 and 0.015 to 0.024; Thames River, England, 0.004 to 0.176 and 0.028 to 0.035.

It may, therefore, safely be concluded that so far as regards organic impurities, the oyster beds in Long Island Sound are in no immediate danger from that cause. The results of the dredging work also support this conclusion, the animals taken of all kinds being generally in a good and healthy condition.

Life history of the starfish.—In connection with the investigation of starfish depredations, a special study of the embryology and life history of this species was begun at Woods Holl Station during the summer of 1889 by Prof. W. K. Brooks, of Johns Hopkins University, and was again taken up during the season of 1890, by one of his assistants, Mr. George W. Field. Both of these biologists have published brief notices of their preliminary results in the Johns Hopkins University circulars, vol. x, No. 88, 1891.* This inquiry will be continued in subsequent years, and it is expected that some conclusions may be reached which will be of considerable practical importance.

* On the early stages of Echinoderms; by W. K. Brooks. Contributions to the embryology of *Asterias vulgaris* (*Forbesii*); by George W. Field.

SOUTH CAROLINA.

During the winter of 1890–91, the steamer *Fish Hawk*, Lieut. Robert Platt, U. S. Navy, commanding, was detailed to investigate the coast waters of South Carolina in the interest of the development of their oyster resources. This inquiry necessitated the determination of the position, extent, and characteristics of the natural oyster beds, and of the bottom areas not now producing oysters but suitable for their cultivation, as well as the study of the natural history of the oyster, as displayed in this region. Surveys of a similar character, previously made by the U. S. Coast and Geodetic Survey on the coasts of North Carolina and Georgia had greatly stimulated the oyster industry in those States, and had demonstrated the practical utility of such an investigation. In arranging for the work in South Carolina, however, it was deemed expedient to increase the scope of the observations, so as to provide for a careful study of the biological features of the region, with special reference to the feeding of the oyster, chemical analyses of the water, and a more detailed inquiry than had been customary respecting the physical characteristics of the latter.

The hydrographic work, including the delineation of the natural oyster beds, the determination of suitable bottoms for oyster-planting, and the specific-gravity observations, was placed in charge of Mr. John D. Battle, formerly associated with Lieut. Francis Winslow, U. S. Navy, in the oyster survey of North Carolina, and with Ensign J. C. Drake, U. S. Navy, in that of Georgia. The services of Dr. Bashford Dean, of Columbia College, New York, were secured for the more special biological researches respecting the oyster and its food and the chemical and physical considerations, subjects to which he had previously given much attention in connection with the investigations of the oyster-grounds of New York State. The general natural history of the waters was studied by Mr. James E. Benedict, of the U. S. National Museum, and Mr. W. C. Kendall. The officers of the *Fish Hawk* participated in all the branches of the work, and their hearty coöperation, especially in regard to the hydrographic part of the survey, was essential to its success.

Operations were begun December 23, 1890, in the neighborhood of Winyah Bay, in the northeastern part of the State. The creeks in that vicinity had already been examined by Mr. Battle, in the interest of an oyster company, and the privilege of using his results being obtained, but little time was spent there. The steamer then proceeded to the Savannah River and worked thence northward to the northern part of Bull Bay, near Cape Romain, completing the survey March 30, 1891.

The coast region of South Carolina consists chiefly of very low land, marshy to a great extent, which in many places extends inland a considerable distance. It is indented or cut through by a number of sounds, bays, and river mouths, which are connected by an intricate

system of winding creeks and rivers, separating the sea islands from one another and from the mainland. Oysters are found in most of the creeks and rivers which are suited to their growth, but they occur mainly as fringing ledges along the borders between the levels of high and low tide. In only a few localities do they grow naturally in the stream bed, and their cultivation or improvement by transplanting has not hitherto been attempted, except upon a very limited scale.

The water that circulates through these oyster-bearing channels is derived from several sources, the sea on one side, the rivers from the interior, neighboring springs, and land seepage on the other. That coming from the sea has the high salinity or density of the ocean, while the rest is fresh. As is naturally to be expected from the positions and relations of these numerous bodies, their contents, resulting from the mixture of different waters, present a great diversity as regards saltness, and the density in each is subject to great and frequent variations through the tides and seasonal changes. Moreover, the larger rivers bring down an immense quantity of sediment, which, becoming widely disseminated, fills many of the channels with highly discolored water, especially during times of freshets. From this source, and probably from others also, the channels have derived, over a large part of their extent, a very soft, muddy bottom, not capable of supporting heavy objects of any character.

The reason for the peculiar distribution of the oysters, above referred to, which obtains also in Georgia, in some parts of North Carolina, and on the outer coast of Virginia, has not positively been determined, but it may possibly be due to the high specific gravity of the water. The heavy sediment and soft character of the bottom may also have some influence in that respect. The solution of this question is of great practical importance, as the result will have much weight in determining the methods of oyster-culture best suited to the State, and it is proposed to give further attention to the matter at the first convenient opportunity. The problem involved is as to whether the spat derived from mature oysters planted on the bottom will attach themselves in similar situations; in fact, as to whether such beds would be self-sustaining, as they are, to a greater or less extent, in all the principal oyster regions farther north. The present indications are that in the South Carolina waters whose salinity is above a certain standard the spat or embryos, which are free-swimming during the earlier part of their existence, float only at the surface, and therefore have the means of attaching themselves only between the levels of high and low tide. In any case, however, a very simple and effective means of cultivation is presented in the transplanting of the raccoon oysters from the tide ledges to suitable bottoms in deeper water, where they rapidly attain a better shape and quality. The raccoon ledges are a source of seed, which, if properly protected, can be made the basis of an extensive industry, and one probably of great profit.

The total water area surveyed amounts to about 81,280 acres, or 127 square miles, of which it is estimated that about one-fourth, in its present condition, is suitable for oyster-planting. The extent of the natural oyster beds in the same area is placed at about 775 acres. Other territory, which was not examined, from the lack of time, would greatly increase these figures, and much of the bottom not now regarded as favorable might be rendered so by proper treatment. Furthermore, it is believed that the marshes and flats along the coast channels are well adapted for the establishment of tidal ponds, which could readily be constructed by excavating the soft material to a slight depth or, in some places, by building dikes. In this manner the oyster-producing territory could be greatly extended, and the plan suggested would give the oysterman complete control over his stock.

Two reports respecting this investigation have been published. One, by Mr. John D. Battle,* contains a detailed account of the hydrographic survey, including the density observations at all the localities visited. It is accompanied by seven charts, showing the topography of the coast region, the location and extent of all the natural oyster-beds discovered, and the specific gravity of the water in each stream. The base charts used for this purpose were furnished by the U. S. Coast and Geodetic Survey. A second report, by Dr. Bashford Dean,† treats especially of the character and conditions of the natural oyster-beds and their environment; the food of the oyster, its character, distribution, and abundance in the region examined, and the chemical composition and physical characteristics of the water upon the oyster-grounds. The account of the general natural history of the region has not yet been completed.

MARYLAND AND VIRGINIA.

The oyster inquiries were extended to the waters of Chesapeake Bay, adjacent to the States of Maryland and Virginia, during the spring of 1891. Tangier and Pocomoke sounds, located on the east side of Chesapeake Bay, were first selected for examination, both because they have been for many years the seat of very extensive and important fishing operations, and because their oyster-beds had previously been subjected to careful investigations, which furnished a suitable basis for comparison. The *Fish Hawk* began its work in this region on May 15, 1891. The middle of June, however, this vessel was temporarily withdrawn to engage in the hatching of Spanish mackerel, and her place was taken by the launch *Petrel*. The survey was still in progress at the close of the fiscal year, and was continued until late in the fall.

*An investigation of the coast waters of South Carolina with reference to oyster-culture. By John D. Battle. Bull. U. S. Fish Com., vol. x, 1890, pp. 303-330, 7 charts.

†The physical and biological characteristics of the natural oyster-grounds of South Carolina. By Bashford Dean. Bull. U. S. Fish Com., vol. x, 1890, pp. 335-361, pls. LXII-LXVII.

During the years 1878 and 1879, Lieut. Francis Winslow, U. S. Navy, then attached to the U. S. Coast and Geodetic Survey, made a very detailed study of the oyster bottom in Tangier and Pocomoke sounds, in the course of which he determined accurately the positions and outlines of all the oyster beds and calculated the number of living oysters upon them to the square yard. The small proportion of live oysters to the quantity of dead shells and other débris, which he discovered to exist, occasioned much surprise, and also furnished tangible proof of the gradual depletion of the beds through overfishing. A few years later Prof. W. K. Brooks, of Johns Hopkins University, made a second but less exhaustive examination of the same ground.

The plans for the present survey and the methods to be pursued in executing them were based upon those of Lieut. Winslow, but with some changes and additions. Besides the customary hydrographic and physical observations, the outlines of all the natural oyster-beds or "rocks" and of the areas of scattered oysters are to be accurately determined, and also the characteristics of the entire bottom not occupied by oysters. The following are among the principal facts to be ascertained regarding the condition of the beds and of the oyster crop: The number of oysters of different sizes and the relative quantity of débris to the square yard, and also the composition of the latter; the abundance and distribution of the set of spat with reference to the physical conditions of the water; the size at which oysters begin to spawn, the limits of the spawning season, and the proportion of ripe spawners on the beds at any time; the character and abundance of natural enemies, and the general natural history of the grounds. The inquiry differs entirely in character from that previously made in South Carolina, in that it has to deal with grounds which have long been drawn upon, instead of with crude and undeveloped resources. The region is a natural and typical producing district, and the information which it is expected to obtain from the work now in progress will be suggestive in regard to future surveys on any part of the coast. The States directly interested in the investigation, Maryland and Virginia, are chiefly concerned to know the conditions of their grounds and the manner in which they may be extended and enriched, and also to obtain the necessary data on which to base a standard of production for defining the natural or public beds in case the present movement to permit the lease of oyster bottom to private parties shall be carried out.

Mr. John D. Battle has acted as chief assistant in connection with the hydrographic work, and has also been in charge of the observations upon the material obtained by dredging, while special biological subjects have been attended to by Mr. J. Percy Moore, of the University of Pennsylvania. Much delay was occasioned in the beginning from the fact that nearly all of the original triangulation points established in this region by the Coast Survey had disappeared, and the shore lines had also been greatly modified by the action of the currents since the

last survey was made. It was, therefore, necessary to place new signal stations before commencing upon the regular observations, but by July 1 the hydrography in Tangier Sound had been nearly completed, and the dredging was soon to be taken up. The former consisted chiefly of cross lines of soundings with appropriate instruments, which were run at close intervals and with sufficient care and accuracy to permit of the construction of a chart showing the precise outlines of all the oyster-beds, of the bottom occupied by scattered oysters, and of the barren ground.

Tangier Sound is about 36 miles long, from Watts Island to the head of Fishing Bay. Along both sides of the channel the oyster-ground is practically continuous, except in the vicinity of Jane Island light-house. Covering more or less of this bottom are large natural oyster-beds, generally elongate in shape, many of them bordering close upon the channel. It was found that the persistent dredging which has been kept up in this region for so many years has tended to extend the area of oysters and oyster shells, and to consolidate the beds by filling up the intermediate areas. Without having complete returns from the investigation, however, it is only possible to say that the total area covered by oysters seems to be considerably greater now than it was in 1878, but the comparative richness of the bottom can not be determined until the information obtained by dredging has been compiled. Comparatively little variation was found in the density of the water, which, during May and June, averaged 1.011 in the northern part of the sound, 1.012 in the central part, and 1.0124 in the southern part.

PROPOSED STUDY OF EUROPEAN OYSTER-CULTURE.

In some parts of Europe, where the market supply of oysters is largely maintained by resorting to artificial methods of propagation, oyster-culture has been carried to a high state of perfection, quite in advance of any system that has been practiced in this country. Where the natural beds of oysters along our own coasts are still sufficiently productive, or where the seed for forming new beds can be obtained abundantly under natural conditions, no further efforts are demanded for the conduct of the oyster industry than to follow the simple methods now in use. Unfortunately, in many of the older and more extensive oyster districts, it is complained that the natural supply of seed is not equal to the requirements, and much concern is felt lest the beds become impoverished on that account. Genuine oyster-culture is unknown in the United States, and none of the experiments hitherto tried in that line have served to develop a thoroughly practical American system. The Fish Commission report for 1880 contains translations of the principal French and German publications on this subject which had appeared previous to that date, but many changes have taken place since then, and in France especially the industry has made great

advancement. It has, therefore, seemed advisable to undertake a careful study of the modern European methods for the information of the oystermen of this country, and to guide them in any efforts they may desire to make for the improvement of this fishery. In providing for this investigation it has been deemed important to secure the services of some one who is thoroughly conversant with the American oyster and oyster-grounds, in order that his observations shall be conducted with due regard to the requirements of our own coast.

Dr. Bashford Dean, of Columbia College, New York, who was intending to visit Europe for the purpose of scientific study, offered to coöperate in this matter, and his services have been accepted. Dr. Dean was an assistant of Mr. E. G. Blackford in the oyster surveys of New York State during several years, and was also naturalist and physicist on the steamer *Fish Hawk* during the oyster investigations on the coast of South Carolina in 1890. He is, therefore, well qualified to undertake the proposed inquiry, and has been given explicit instructions regarding the matters deemed of most importance. Dr. Dean left New York in June, 1891, and will be absent over a year. He will visit the oyster-fishery centers of France, Spain, Portugal, Italy, Germany, Holland, and Great Britain.

PHYSICAL INQUIRIES.

Off the Southern New England coast.—The physical investigation of the waters in the mackerel region off the southern coast of New England, the preparations for which were described in the last annual report, was taken up by the schooner *Grampus* in the latter part of July, 1889, and was continued actively until early in September, when stormy weather put a stop to further operations for the season. Prof. William Libbey, jr., of Princeton College, was in charge of the inquiry, assisted by Prof. Wm. F. Magie and Prof. C. G. Rockwood, jr., of Princeton College, and Prof. M. McNeill, of Lake Forest University. The *Grampus*, commanded by Capt. A. C. Adams, was furnished with a small boiler, engine, and reeling apparatus for working the wire cable used in taking the serial water temperatures, and with a complete outfit of physical appliances suitable for the examinations which it was proposed to make. The principal instruments supplied for the water observations were a large series of Negretti and Zambra reversible thermometers for the intermediate and bottom temperatures, Wilder protected thermometers for the surface temperatures, Hilgard salinometers and water bottles for obtaining samples from any depth; and for the observations regarding the conditions of the atmosphere, standard air, dew point, minimum and maximum, and solar radiation thermometers, marine barometers, air meters, rain gauge and ozonometer.

The area selected for examination lay south of Massachusetts and Rhode Island, extending coastwise from the eastern end of Nantucket to Block Island, and seaward a distance of about 130 miles. Through

this region the *Grampus* proceeded to make continuous series of observations along lines of longitude 10′ apart, with stations on each of these lines 10 miles apart. Nine lines were run and four of these were duplicated. Twelve to thirteen stations were made on each line, and at each station the entire series of observations was repeated, thereby resulting in the most thorough and comprehensive inquiry respecting such a body of water that had ever been undertaken up to that time. The serial water temperatures were taken at the surface and at depths of 5, 10, 15, 20, 25, 30, 40, 50, 75, 100, 150, 200, 250, 300, 400, and 500 fathoms, where the water was sufficiently deep, the lower thermometers being successively omitted as the water shoaled toward the coast, but the distance between those that were used remaining always the same. The density of the water was also ascertained at the surface and bottom, and at one intermediate position in deep water. It will be observed that, by this means, the physical conditions of the waters of this region were determined along parallel sections running off from the coast into the warm water bordering the inner edge of the Gulf Stream, and the results can, therefore, be graphically represented by means of profiles, on which the distribution of the belts of equal temperature may readily be shown.

During the summer of 1890 the Fish Commission had the coöperation of the U. S. Coast Survey in continuing this inquiry, the superintendent, Dr. T. C. Mendenhall, detailing for this purpose the steamer *Blake*, commanded by Lieut. Charles E. Vreeland, U. S. Navy, which remained in actual service from July 9 to August 4. The schooner *Grampus* was at work upon the same ground from July 3 until August 25, and a party of observers was also stationed on board the Nantucket New South Shoal light-ship during the entire period of the investigation. Prof. Libbey was again in charge of the observations, and was assisted by Prof. C. G. Rockwood, jr., Prof. M. McNeill, Mr. S. T. Dodd, Mr. L. S. Mudge, Dr. R. P. Bigelow, Mr. J. Zimmerman, Mr. W. H. Dodd, and Mr. A. Harris. It was arranged to have three observers each on the *Grampus* and the light-ship at all times, while only two were necessary on the *Blake*, as Lieut. Vreeland and his officers relieved the civilians of many duties which would otherwise have devolved upon them. The Fish Commission is under many obligations both to the Light-House Board and to the Superintendent of the Coast Survey for their liberal action in respect to this undertaking, and the assistance rendered by them has permitted a much more thorough and extensive study of the problem than was possible in 1889. In acknowledging the coöperation of these Bureaus it is also well to note that these physical studies will probably be as significant in regard to questions of navigation as to those which bear upon the fisheries, and the Fish Commission is, therefore, not alone concerned in the practical results to be derived from their successful prosecution.

The steamer *Blake*, not being dependent upon favorable winds for carrying on the share of work allotted to it, was able to make much more rapid progress than the *Grampus* and to occupy a larger number of stations. The area covered was the same as in 1889, except that the lines run by the *Blake* were carried out to sea a distance of 150 miles, those of the *Grampus* being restricted to 130 miles as before. The vessels were kept as far apart in an east and west direction as was feasible in conformity with the plans, in order that, so far as possible, parallel lines of observations might be made more or less conjointly in different parts of the field. The *Blake* was on the western side of the ground during the early part of July, and the *Grampus* on the eastern side, these relative positions being subsequently changed. Ten north and south lines, 10′ of longitude apart, were marked out as the courses to be followed by the vessels, but each of these was gone over two or more times, and the actual number of lines run was 27, with 382 stops or stations for observation. The total number of observations was, for serial temperatures, 4,000; for specific gravity, 850, and for meteorology, 14,000. The temperature of the water was not taken this year at greater depths than 200 fathoms, but a complete meteorological record was made every hour while the vessels were at sea.

On the light-ship meteorological observations were taken continuously, amounting to 18,000 separate entries for the season, the temperature of the water was noted regularly at the surface and at depths of 5, 10, and 15 fathoms, and the changes in the surface specific gravity were recorded hourly. The direction and velocity of the tidal currents were also determined by means of a Ritchie-Haskell meter.

An account of the investigations made in 1889 has been published in the Fish Commission Bulletin for the same year,* but Prof. Libbey has not yet completed his report for 1890, and any discussion of his conclusions must be left for a future time. In connection with the data obtained by the two expeditions, Prof. Libbey has also utilized the meteorological records for Boston and New York City, which have been kindly furnished by the Signal Office. Information of this character has, therefore, been supplied from three stationary positions, two upon the land and one upon the sea, the latter being distant some 20 miles from shore. It affords an excellent opportunity for comparing the relations of atmospheric variations with those observed in connection with the waters, and by continuing the study of the same for a term of years it will be possible to determine whether there is any coordination of conditions between the two elements, and if a change in one produces any effect upon the other. Some such relationship has been shown to exist, but its full extent can not yet be established.

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*Report upon a physical investigation of the waters off the southern coast of New England, made during the summer of 1889 by the U. S. Fish Commission schooner *Grampus*. By William Libbey, Jr. Bull. U. S. Fish Comm., vol. IX, 1889, pp. 391–459, pls. CXXIV–CLVIII.

In Prof. Libbey's report for 1889 the vertical water temperature curves are represented by nine profiles, and twenty-seven sectional diagrams have been prepared for the report of 1890, as well as several plates showing the surface isotherms from time to time. The hourly changes of air and surface water temperatures for each day while the survey was in progress are also illustrated in the same graphic manner, being based upon the records made at the three stations and on board the vessels. Prof. Libbey has likewise summarized the results of observations upon the direction and force of the winds, as given on the Hydrographic Office pilot charts of the North Atlantic Ocean, in order to afford an insight, if possible, into the relations between the winds and the positions taken by the northern boundary of the warm waters coming from the Gulf Stream.

By means of the observations so far made it has been possible to indicate very clearly, for the region and periods covered by the examination, the distribution of the bands of equal water temperature both vertically and superficially, and the relations of the cold and warm water bodies to one another. The charts of surface isotherms are especially interesting as furnishing a possible key, in connection with meteorological conditions, to the physical changes at greater or less depths, which relate to the movements of fishes.

Aside from the more general subdivision into Gulf Stream and Labrador current, Prof. Libbey states that two different sets of currents have to be dealt with in the study of this region. First are the deep currents which flow in two, and generally opposite, directions alongside of one another, their courses being controlled more by the mechanical influence of the impact of one current upon the other, their relative velocities, etc., than by changes in temperature and density. Second come the surface currents, which flow in the same general directions as the deep ones and are, of course, subject to the same mechanical laws, but their courses are additionally affected to a considerable degree by the frictional influence of the winds. Moreover, they present a peculiarity not detected in connection with the deep currents, in that certain branches are apparently reversed. The outlying bands of warmer and denser water, which pass off from the shore side of the Gulf Stream, seem to be drifted toward the shore or away from it to an extent dependent upon the direction, velocity, and duration of the winds. When they are forced toward the shore, thus bridging over the colder currents, as they proceed farther and farther from the original source of their velocity, they become overpowered. Although retaining much of their temperature and density, even to a considerable depth, their direction is then sometimes at right angles and finally opposite to their first course.

In connection with this investigation, the surface-towing nets were constantly employed, and a large and valuable collection of pelagic

organisms was thus obtained. Those collected in 1889 have been reported upon by Prof. W. K. Brooks, in the paper of Prof. Libbey above cited, and the material subsequently taken has been referred to Prof. Brooks and others for examination. During the first summer Prof. Magie took advantage of the opportunity afforded to secure a set of observations on the electric conditions of the atmosphere, which have also been published in Prof. Libbey's report.

Southern mackerel-grounds.—From May 5 to June 8, 1891, the schooner *Grampus* was engaged in making a series of observations over the mackerel-grounds, from Delaware northward to Massachusetts. This was in continuation of similar inquiries made in previous years to determine so far as possible the temperature and other physical phenomena connected directly with the northerly movement of the advance schools of mackerel along the coast. As is well known, these fish first make their appearance inside of the warm waters of the Gulf Stream at a variable distance north of Cape Hatteras, and work thence northward or approach the shores at successively more northern latitudes. The first schools have generally been seen the very last of March or early in April, and previous to the enactment of the law prohibiting the use of purse seines before June 1, the fishing vessels were accustomed to anticipate their coming with much eagerness, making diligent search for them, and subsequently following the fish during their migrations. In her former cruises over these grounds the *Grampus* was greatly aided by the presence of these vessels, which, scattered over a rather wide area, made it difficult for any schools of fish to pass unnoticed. During the last season, however, her work was necessarily carried on without this very material assistance.

The principal object of the cruise was to locate the early schools of mackerel, to follow their movements northward or in whatever direction they might take, and to learn everything possible regarding the conditions of the air and water in connection with their habits. As it was somewhat late in the season before the trip began it was expected that the schools were already upon the grounds, and that it would not be necessary to proceed very far south before meeting them. Such was found to be the case, but the observations were carried southward from Woods Holl until the fish were encountered, and thence over a part of the area through which they had passed, in order to obtain the necessary data for comparing the conditions in advance of the first schools with those existing in their rear. Subsequently the *Grampus* followed the schools as far as Marthas Vineyard, taking ripe males the last of May and ripe females the first of June, in that vicinity. The physical observations have not yet been reduced and compared.

Permanent temperature stations.—The permanent stations at which temperature observations of the air and water have been taken daily for a greater or less period during the past two years, through the courtesy mainly of the Light-House Board, the Signal Service, and the Southern Pacific Company, are as follows:

Temperature stations on the Atlantic Coast.

Stations of the Light-House Service:
- Coast of Maine: Petit Manan Island, Mount Desert Rock, Matinicus 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.
- 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, 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:
- Gloucester and Woods Holl, Mass.
- Fort Washington, Potomac River, Maryland.
- Washington, D. C.

Temperature stations on the Pacific coast and slope.

Station of the Signal Service:
- Portland, Oregon.

Stations of the Southern Pacific Company:
- Sacramento River, at Tehama and Yolo Bridges and King's Landing, California.
- Feather River, at railroad crossing, California.
- American River, at railroad crossing, California.
- Mokelumne River, at Lodi, Cal.
- Tuolumne River, at Modesto, Cal.
- San Joaquin River, at the upper and lower railroad crossings, California.
- King River, at Kingsbury, Cal.
- Colorado River, at Yuma, Ariz.

No serious breaks have occurred in the records of any of the light-house stations above enumerated, and the Southern Pacific Company has added several new stations to those reported upon in 1889, but,

unfortunately, through the lack of sufficient means the Signal Service was obliged, in the latter part of 1890, to discontinue its coöperation in regard to this important subject.

During October, 1889, Prof. Libbey, with the steamer *Fish Hawk*, visited nearly all of the temperature light-stations located between Cape Cod and Chesapeake Bay, and inspected the thermometers used in making the observations, also instructing the attendants as to the proper way of reading and caring for them. All instruments were compared with a standard, and those showing any appreciable variation were replaced by new ones. Prof. Libbey suggests several changes in respect to this branch of work, which it is intended shall be introduced at an early date. The stations visited were as follows: Pollock Rip, Nantucket New South Shoal, Vineyard Sound, Brenton Reef, Block Island, Sandy Hook, Five Fathom Bank, and Winter Quarter Shoal.

Changes in density observations.—The hydrometers which have been used by the Fish Commission, as well as by the U. S. Coast and Geodetic Survey, for determining the density of sea water are the so-called Hilgard salinometers, consisting of an elongate glass float and stem, the scale being marked upon the latter. They are described and figured in Appendix 16 of the Coast Survey Report for 1874. Up to the present time the graduation of the scale has been referred to pure water at 60° F., and the observations have been reduced by means of the Hubbard table to a uniform temperature of 60° F. for the purposes of comparison. For certain reasons, however, it now seems advisable to change the former standard by making it conform to the temperature at which pure water attains its maximum density, and 4° C., the nearest integer to that temperature, has, for convenience sake, been adopted as the future standard. Upon this basis the observations will conform more closely with modern European methods. This change was agreed upon by the Superintendent of the Coast Survey and the Commissioner of Fisheries during the winter of 1889–90, but some delay must ensue in the preparation and the introduction of the new instruments, which will be constructed upon the same patterns as the old ones, the only difference being in their graduation.

In the future, moreover, the observations will be reduced to 15° C., instead of 60° F., both of these temperatures, however, being approximately identical, and a convenient table for this purpose, prepared by Mr. O. H. Tittmann has been published in Bulletin No. 18 of the Coast Survey for 1890. This table also gives a constant by which the reductions of observations obtained with the old instruments may be made to conform to the new standards.

Other physical inquiries are discussed in connection with the operations of the steamer *Albatross* in the north Pacific Ocean and of the steamer *Fish Hawk* on the oyster-grounds of the Atlantic coast.

INVESTIGATION OF INTERIOR WATERS.

ALASKA.

In the last report reference was made to the organization of an exploring party in charge of Dr. Tarleton H. Bean, for the investigation of certain Alaskan salmon rivers, in pursuance of an act of Congress approved March 2, 1889. This act was based upon the representations of persons interested in the preservation of the important industries which have been developed on the Pacific coast, and made provisions both for the protection of the salmon and for the study of the natural-history and industrial features relating to the fisheries. The party consisted of Dr. Bean, ichthyologist of the Commission; Mr. Livingston Stone, superintendent of the Fish Commission salmon station in California; Mr. Franklin Booth, topographical engineer, of the University of California, and Mr. Robert E. Lewis, rodman and general assistant. The instructions called for observations respecting the habits, distribution, abundance, etc., of the salmon and associated species; the physical characteristics of their environment; the methods, statistics, and conditions of the fishery, and the necessities and advantages of Alaskan waters for the artificial propagation of the salmon.

The first steamer by which the party could reach Kadiak did not leave Port Townsend until July 19, arriving at the former place on the 28th of the same month. The season suitable for fieldwork was thereby greatly shortened, and it became necessary to restrict their operations to the islands of Kadiak and Afognak, where, however, the principal salmon fishery in Alaska was then being conducted, the catch on Karluk River comprising about one-half the entire yield of the territory. No examination has been made of Cook Inlet, but in 1890 the steamer *Albatross* visited the fishery at the head of Bristol Bay and obtained some important information respecting the methods there employed, as explained below. Kadiak Island, however, afforded the means for making a very satisfactory study of the problem, and the results obtained, combined with previous observations, especially on the habits of the salmon, have enabled Dr. Bean to report in full upon the questions proposed by Congress.*

Examinations were made of Karluk River and Lake, including the open bay into which the former empties; of Uyak Bay adjacent to Karluk, on the northern side of the island; of Alitak and Olga bays at the southeastern end of the island, and of Afognak Bay on the island of the same name, including in the case of each bay the small salmon rivers which empty into them.

* Report on the salmon and salmon rivers of Alaska, with notes on the conditions, methods, and needs of the salmon fisheries. By Tarleton H. Bean. Bull. U. S. Fish Comm., IX, 1889, pp. 165–208, pls. XLV–LXXIX.

The red salmon, according to Dr. Bean, is now the most important species for canning and salting in Alaska, and its flesh is so red as to win for it a reputation not warranted by its edible qualities. The largest and finest species is the king or quinnat salmon, which, while it enters some of the smaller streams like the Karluk, occurs more abundantly in the larger rivers, such as the Yukon and the Nushagak. The humpback is the smallest, most abundant, and most widely distributed of the Alaskan salmon. It is not taken for canning purposes, but being one of the most palatable species in the fresh-run condition it is destined to become of great importance in that connection. The silver salmon is used to some extent for canning, but far less than the red salmon, while the dog salmon is regarded by the whites as one of the least important of the group. The steelhead or hardhead is used only to a limited extent, while the dolly varden trout or malma is not canned.

It was impossible to determine if a decrease had occurred among any of these species in the region examined, owing to the lack of positive information regarding their previous abundance. In fact, it is to be doubted if more than one species—the red salmon—is in imminent danger in that regard, as it is the only species which is fished for to excess. However, any injudicious methods which might be established to increase the catch of this species would have its effect upon all the others entering the streams at the same time, or while the practices in question were continued. An illustration is furnished by Dr. Bean with respect to the dolly varden trout, of which, he says, great numbers are taken in connection with the red salmon and left to die on the beaches.

Dr. Bean states:

> The catch of red salmon has been increasing, owing to the increase in the number of persons engaged in the fishery and in the effectiveness of the implements used in its capture. The size of seines has been greatly enlarged, and the number of boats, seines, and men largely augmented. That there will be a falling off in the supply very soon there can be no doubt. The number of spawning fish in Karluk Lake and its tributaries last year was unexpectedly small. There was, early in the season of 1889 and in previous seasons, injudicious obstruction of the ascent of spawning fish in the Karluk River. At one time an impassable weir, similar to the *Zapor* of the Russians, was placed in this river. At the time of our visit we saw the remains of pound nets, made of wire netting, which interfered so seriously with the ascent of the fish that they were dismantled by unknown parties and were not reëstablished.

The report of Dr. Bean was submitted to Congress by the Commissioner on June 6, 1890, with recommendations as to additional steps necessary to insure the protection of the Alaskan salmon-fisheries.

While engaged in the surveys of Bering Sea, during the summer of 1890, the steamer *Albatross* was dispatched, at the request of the Secretary of the Treasury, to investigate the methods of salmon-fishing practiced in connection with the canneries on the Nushagak River at the head of Bristol Bay, as it had been reported that a barrier was in course of construction across the Wood River, a tributary of

the Nushagak. Lieut. Commander Tanner, U. S. Navy, who made the inspection, found that a double trap was being built upon the Wood River, about 20 miles above its mouth and 40 miles from the Nushagak cannery. The Wood River at this point is a swift-running stream of clear, cold water, between 700 and 800 feet wide and 10 to 14 feet deep. Operations had not progressed sufficiently to indicate the character and extent of the work, but the plans contemplated an opening in mid-stream 100 feet wide, flanked on each side by a trap 40 feet square, with wings extending from the latter to the shores. The report of Lieut. Commander Tanner was submitted to the Secretary of the Treasury, who decided that the proposed traps were obstructions to the ascent of salmon within the meaning of the law, and that their erection was therefore illegal.

Although the salmon-canning industry of Alaska is of very recent origin, the amount of capital invested in it is nearly $4,000,000, while the output in 1889 was valued at about $3,000,000, which is greatly in excess of the value of the yield of seal skins on the Pribilof Islands before the reduction was made in the number of seals that are allowed to be killed annually. That the salmon industry in that region is capable of very much greater development is unquestionable, as the resources have been tapped at only a comparatively few places, but, unless the fishery is carefully guarded, sooner or later there will be repeated in Alaska the same unfortunate condition of affairs which has obtained in every country where salmon have been abundant. The salmon spend most of their time at sea. The spawning instinct leads them into fresh waters, which furnish the necessary conditions for the hatching of the eggs and the development of the young during a portion of their existence. The different species vary more or less in the date and duration of the spawning season and in their spawning habits. Some enter by preference the smaller streams, and others the larger rivers. Some never return to the sea, dying soon after having accomplished their reproductive functions, while others may survive to return again in a subsequent season. This habit of running up the rivers makes them fall an easy prey to the fishermen, especially if the river be small or shallow, or be restricted near its mouth. It is evident that if a river channel be closed against their ascent no spawning can be accomplished in it, and from what is known of their habits it is also probable that the fish will not seek another river the same season. They remain below the obstruction, unable to make progress, but still guided by the common impulse to arrive at the spawning-grounds. Smaller barriers and large nets, of one character or another, accomplish the same result, although on a lesser scale, as they are generally arranged to retard whatever fish are not captured.

The fishing season is, to be sure, restricted in its duration, and in this fact the fishermen find an excuse for resorting to their wholesale

methods of capture; but, whatever may be the circumstances, there is no warrant for destroying any product which is the common property of a country. It would, therefore, seem advisable to institute a system of inspection, by scientific experts, which could determine periodically such facts as might be considered necessary as a basis for regulations, the expenses to be met, if need be, by a slight tax upon the fishery. By paying proper attention to the habits of a species, by prescribing the methods of capture or by limiting the amount of catch, the source of the industry can readily be maintained and its permanency insured. The justice of such provisions are undeniable, and those who are directly interested in the fishery and must profit by its permanence should be the first to recognize its necessity. An inflexible system of police supervision is not adequate to accomplish this purpose. There is a natural fluctuation in the fish supply, and the conditions which surround it vary more or less from time to time.

Considering the present abundant stock of salmon in Alaska, and the possibility of preserving it from destruction, it seems unnecessary to bring up the subject of artificial propagation as a means of maintaining or increasing the supply. Should a resort to such measures become necessary at any time, however, it would not be difficult to find proper sites for hatching-stations, or to obtain the eggs in sufficient quantities from the fish captured for canning or salting purposes; but at present a system of protection seems most judicious and expedient.

WYOMING.

The Yellowstone National Park.—Two investigations have been made in the Yellowstone National Park within the past two years, the first by Dr. David S. Jordan and Prof. Charles H. Gilbert, during September and October, 1889, the second by Prof. S. A. Forbes and Prof. Edwin Linton, during July and August, 1890. These inquiries were instituted chiefly for the purpose of obtaining information to be used in connection with the stocking of certain of the streams and lakes with fishes, a measure which had previously been determined upon by the Fish Commissioner. A peculiarity of the park is the small variety of fishes which inhabit it and the entire absence of fish life over a very large area. The park is drained by tributaries of both the Mississippi and the Columbia rivers, being traversed toward the southwest by the continental divide, which extends in a general northwest and southeast direction. The streams which are devoid of fishes form several small, distinct basins, in each of which it is proposed to plant only one or two species, and at the time of writing this report considerable progress had been made in this direction. Under the conditions which there exist not only may all suitable waters become replete with fishes, but it is expected that the results will afford an interesting study in acclimation, owing to the isolation of the different forms.

The following brief account of the principal characteristics of the park from an ichthyological standpoint is from the report of Dr. Jordan:*

The Yellowstone Park is a high plateau, having a general elevation of 7,000 to 8,000 feet above the sea. Its entire surface, with the exception of the Gallatin Range of mountains in the northwest and some granitic summits in the northeast, is covered with lava, with its varieties of obsidian, rhyolite, etc. This mass of lava covers to a great depth what was previously a basin in the mountains. According to Mr. Hague, the date of the lava flow is probably Pliocene. Its existence was of course fatal to all fish life in this region. Since its surface has become cold, the streams flowing over it, most of them now wholly unaffected by the heat within, have become well stocked with vegetable, insect, and crustacean life, but are for the most part destitute of fishes. The cause of this absence of fishes is to be found in the fact that nearly all the streams of the park, on leaving the lava beds, do so by means of vertical falls situated in deep cañons. Except in the Yellowstone and its tributaries, in Gibbon River and in Lava Creek, no fishes have been found above these falls, and the presence of fishes in the Upper Yellowstone and Lava Creek is doubtless due to the imperfect character of the watersheds separating these streams from others. Outside of the park, the falls in Clark Fork of the Yellowstone exclude fish from that river, and perhaps the Great Shoshone and American Falls in Snake River exclude from the upper part of the stream the fauna of the Lower Columbia. Another supposed obstacle to the spread of fish life in the Yellowstone Park is the presence of the innumerable hot springs, solfataras, and geysers, for which the region is famous.

Dr. Jordan's trip was made somewhat late in the season, and on that account was considerably hurried, but he was, nevertheless, enabled to study the leading points in the problem which had been suggested to him. Yellowstone River and Lake, including all their western tributaries, were examined at many places, and also all the principal streams and lakes of the Madison and Snake River basins. The total number of fishes discovered was 10, of which 2 belong to the *Salmonidæ* (the Rocky Mountain trout and the whitefish), 1 is the miller's thumb or blob, 1 the grayling, 4 are minnows and chubs, and 2 suckers. Nowhere above the falls, except in the Yellowstone and its tributaries, in Gibbon River, and in Lava Creek, were any fishes found. The miller's thumb or blob was very abundant above the falls in Gibbon River, and its presence there is unexplained; but the occurrence of trout in Lava Creek, where they are common, is supposed to be due to the imperfect character in some places of the watershed which surrounds it. The grayling is restricted to the extreme northwestern part of the park. Dr. Jordan describes with much care the peculiarities and distribution of the different species, and the characteristics of all the principal lakes, rivers, and creeks in the park, making his report invaluable as a guide in the stocking of those waters. His conclusions regarding the suitability of certain areas for that purpose are also very important.

*A reconnaissance of the streams and lakes of the Yellowstone National Park, Wyoming, in the interest of the U. S. Fish Commission. By David Starr Jordan. Bull. U. S. Fish Com., IX, for 1889, pp. 41–63, pls, VII–XXII, and one map.

Speaking of the hot springs, solfataras, and geysers, he states:

Although these springs exist in almost every lake basin, cañon, or other depression in the park, we do not think that, in their present condition at least, they would stand in the way of the stocking of the streams and lakes with fishes. The waters of the geysers and other calcareous and silicious springs do not appear to be objectionable to fishes. In Yellowstone Lake trout are especially abundant about the hot overflow from the Lake Geyser Basin. The hot water flows for a time on the surface, and trout may be taken immediately under these currents. Trout have also been known to rise to a fly through a scalding hot surface current. They also linger in the neighborhood of hot springs in the bottom of the lakes. This is probably owing to the abundance of food in these warm waters, but the fact is evident that geyser water does not kill trout. * * * There are, however, numerous springs in the park which discharge sulphurous liquids, very offensive in odor and doubtless fatal to fishes. Most of these springs have but a very slight discharge, and so exert no appreciable influence on the streams. The upper part of Obsidian Creek, between Twin Lakes and Beaver Lake, is the only running stream noticed by us as likely to prove uninhabitable by fishes. An obstacle of equal importance in the lower course of the same creek is the series of three beaver dams, to which the existence of Beaver Lake is due. These, with their covering of brush, must be wholly impassable.

During 1889 and 1890 the following plants of fishes were made in the Yellowstone Park: The eastern brook trout in the Gardiner River and its west fork; the mountain trout in the east fork of the Gardiner River; the California or rainbow trout in Gibbon River; the Loch Leven trout in Firehole River and Lewis and Shoshone lakes; the Von Behr trout in Nez Percé Creek; the lake trout in Lewis and Shoshone lakes; the native whitefish in the Twin lakes and Yellowstone River. None of these waters, except the Yellowstone and Gibbon rivers, and possibly the East Fork of the Gardiner River, were previously inhabited by fishes, and the only species known from the Gibbon River was the little blob or miller's thumb. With the exception of Lewis and Shoshone lakes, in both of which two species were planted, each basin was supplied with only a single species.

The observations of Dr. Jordan proved conclusively that the absence of fishes in certain parts of the park was not due to the unsuitable condition of the waters, although within a few limited areas they may be unfitted for them. However, it was deemed expedient to obtain more positive information relative to the character, abundance, and distribution of the lower forms of life, on which the introduced species would be dependent for their food, as a deficiency in respect to such organisms might necessitate their being supplied by artificial means. Arrangements were made with Prof. S. A. Forbes, director of the State laboratory of natural history of Illinois, and Prof. Edwin Linton, of Washington and Jefferson College, Pennsylvania, to conduct this investigation during the summer of 1890. Prof. Linton, in addition to assisting Prof. Forbes in the general inquiry, was charged with the special study of the parasitic worm which infests so large a proportion of the trout in certain portions of the park, penetrating into the flesh and

rendering it unsightly. Specimens collected by Dr. Jordan the previous year had been examined by him, but observations were desired on fresh material and in relation to the life history of the species.

The party reached the park about the middle of July, and, provided with a very complete outfit, began at once their examinations, which were continued until August 30. The ground gone over was practically the same that had been traversed by Dr. Jordan in 1889, including the Gardiner, Madison, and Yellowstone river systems on the Atlantic slope of the continental divide, and that of the Snake River on the Pacific slope. Collections were made in 43 localities. The principal fishless waters visited were Shoshone and Lewis lakes, the upper Gibbon and its tributaries, the Firehole and its branches, Goose Lake, Twin Lakes, Swan Lake, and Tower Creek. The effects of geyser and hot-spring overflow were studied especially on the Firehole and on Alum Creek, and of the intervention of falls on the Gibbon River and some of its tributaries. The highest waters examined were Mary Lake, having an altitude of 8,200 feet, and a small lake, near Norris Pass, at about the same level. Dredging was carried on in Yellowstone Lake to a depth of 195 feet. The general collection of specimens obtained is very large, and has been sent to the State Laboratory of Natural History, at Champaign, Ill., where it is being carefully studied under the direction of Prof. Forbes. It is considered to be sufficiently complete to explain the biological conditions existing in those lakes, ponds, rivers, and creeks which are devoid of fishes, in such as have only a single species of fish, and again in others supporting from 3 to 8 species each. Awaiting the preparation of Prof. Forbes's report, we are able, in this connection, to present only a few of his preliminary conclusions, which are as follows:

The waters of the park, wherever they were examined, were found to provide a fair amount, and often an abundance, of animal life suitable as food for the ordinary carnivorous fishes, the fishless areas being no less well supplied in this respect than those already containing trout. These observations, therefore, support those of the ichthyologists, that the peculiar distribution of the fishes in this region can be explained alone from its topographical features, which have had no noticeable effect upon the distribution of invertebrates. Collections made both above and below the falls in certain rivers show that these obstructions to fish migrations have in no way interfered with the dissemination of the lower forms. The scarcity of fresh-water mussels and crayfishes is probably due to the chemical condition of the waters, especially in the absence of lime. The former were found only in Cañon Creek, where the living specimens were greatly eroded and the dead shells rapidly decalcified. Crayfishes have also been recorded from only a single stream. No isopod crustaceans were discovered, and amphipods were very irregularly distributed, being very abundant in some places and entirely wanting in others. No phyllopod crustaceans were col-

lected, but they may abound earlier in the season, in temporary pools. Entomostraca were abundant in every situation where they might naturally be expected to occur, copepods largely predominating, except in the smaller ponds. These indispensable elements to the preservation of young fishes were as plentiful in the waters of the park as they are in Lake Michigan and in the deeper lakes of the Wisconsin series.

The greater proportion of animal life found in the streams consisted of insect larvæ, chiefly neuropterous. Caseworms, ephemerid larvæ, and the larvæ of stone flies and *Sialidæ*, which are everywhere excessively abundant, are the main dependence of the trout in waters containing no other fishes. The larvæ of *Chironomus* are very common, and those of *Simulium* are exceedingly numerous in suitable localities. The smaller mollusks, especially species of *Physa*, were also plentiful occasionally. In the deepest waters examined the bottom fauna consisted mainly of a few slender annelids, an abundance of red *Chironomus* larvæ, some small mollusks, mostly *Pisidium*, and occasional specimens of *Gammarus*. By far the most important elements of fish food, however, were the entomostraca for the young and the neuropterous larvæ for the adult fishes.

Prof. Linton was entirely successful in his study of the wormy trout, the history of which he has been able to complete. This instance of excessive parasitism was noticed during the early explorations of the park, and has ever since attracted much attention from tourists and scientific men. The parasite is a species of tapeworm, named *Dibothrium cordiceps* by Prof. Joseph Leidy, and occurs among the viscera, beneath the peritoneal lining of the abdominal cavity, or burrowing in the muscular tissue of the body wall. The only fish which it is known to infest is the native trout of the Yellowstone Park, and it has been found almost exclusively in Yellowstone Lake, in Yellowstone River above the falls, and in Heart Lake. It does not, however, finish its development in the trout, which contain only the larval stages, but requires a second host to complete its life history. The latter is, in part at least, the white pelican, which spends the summer in this region, and breeds on an island in the southeast arm of Yellowstone Lake. All of the birds examined had been feeding on the trout, the only fish occurring in the lake.

The cause of the unusual multiplication of parasites in this locality may be traced to the peculiar combination of circumstances there prevailing. Probably not less than 1,000 pelicans resort to the lake during the summer, and of this number 50 per cent or more are infested with the adult *Dibothrium*, the eggs of which become disseminated through the water, where, after a short development, they are swallowed by the trout. The eggs hatch more readily in warm than cold water, and the former conditions, according to Prof. Linton, are—

Supplied in such places as the shore system of geysers and hot springs on the west arm of the lake, where for a distance of nearly 3 miles the shore is skirted by a hot

spring and geyser formation, with numerous streams of hot water emptying into the lake, and large springs of hot water opening in the floor of the lake near shore. Trout abound in the vicinity of these warm waters, presumably on account of the abundance of food there. They do not love the warm water, but carefully avoid it. Several persons with whom I talked on the subject while in the park assert that diseased fish—that is to say, those which are thin and affected with fleshworms—are more commonly found near the warm water; that they take the bait readily, but are lazy. I frequently saw pelicans swimming near shore in the vicinity of the warm springs on the west arm of the lake. It would appear that the badly infested or diseased fish, being less active and gamy than the healthy fish, would be more easily taken by their natural enemies, who would learn to look for them in places where they most abound. But any circumstances which cause the pelican and trout to occupy the same neighborhood will multiply the chances of the parasites developing in both the intermediate and final host. The causes that make for the abundance of the trout parasite conspire to increase the number of adults. The two hosts react on each other, and the parasite profits by the reaction.

An effective remedy might be found in the extermination of the pelicans, providing they are the only final hosts of this parasitic worm. The relief which might thereby be afforded, however, is not of sufficient importance to justify the destruction of so interesting a feature of the park. The trout in that region is not important as a food supply; the diseased fishes are in most convenient places for capture, and with the increase in fishing will be drawn upon more largely than the healthy ones. The introduction of other species into the lake would, moreover, tend to improve conditions by adding new varieties of food for the trout, thereby probably diverting them more or less from the warm waters and imparting to them a more vigorous constitution. The pelicans would also profit by this new source of food, the trout would suffer less from their attacks, and parasitism would be decreased in proportion.

Other fish parasites were obtained in the Yellowstone Park by Prof. Linton, who has presented three reports treating of these interesting forms.*

COLORADO AND UTAH.

Investigations were conducted in Colorado and Utah during July and August, 1889, by Dr. David S. Jordan, assisted by Prof. B. W. Evermann, Mr. Bert Fesler, and Mr. Bradley M. Davis. The special object of this inquiry was to determine the character of the streams and lakes of the Rocky Mountains and the Great Basin as represented in this State and Territory, the variety and distribution of the food-fishes now inhabiting these waters, and their suitability for the intro-

* On two species of larval Dibothria from the Yellowstone National Park. Bull. U. S. Fish Comm., IX, for 1889, pp. 65–79, pls. XXV–XXVII.

A contribution to the life-history of *Dibothrium cordiceps*, a parasite infesting the trout of Yellowstone Lake. *Idem*, pp. 337–358, pls. CXVII–CXIX.

On fish entozoa from the Yellowstone National Park. (Appendix 5 to this volume.)

duction of species not native to them. The importance of these studies was much increased by the fact that a new hatching station for the *Salmonidæ* was about to be established in the vicinity of Leadville, Colo., a site for the same having already been selected. In Colorado the examinations had reference to four river basins, and were naturally confined for the most part to their upper courses, although on three of the rivers the work was extended beyond the limits of the State. These river basins were as follows: The Platte and Arkansas, tributaries of the Mississippi; the Rio Grande, flowing directly into the Gulf of Mexico; and the Colorado, flowing into the Gulf of California. In Utah, in addition to the Colorado River, the Great Salt Lake and Sevier Lake basins were examined.

According to Dr. Jordan's report* of this expedition, most of the streams of Colorado rise in springs in or above the mountain meadows, while many have their origin in banks of snow, their waters being very clear and cold. In their descent from the snow banks they are brawling and turbulent, often so much so as to be unfitted for fish life. In their course through the mountain meadows the streams have usually a gentle current, and lower down most of them pass to the valleys through deep cañons, which generally, however, present no obstacles to the presence of trout, especially as vertical falls are very rare in Colorado. In the valleys the water grows warmer, fine silt renders it more or less turbid, and at last it becomes unfit for trout, and at the same time suitable for suckers and chubs. During the colder temperature of winter the trout extend their range somewhat down the valleys, but during the summer and fall they are more or less confined to the mountains or the cañons. After reaching the base of the mountains the streams flow with little current over the ill-defined beds across the plains. In some cases placer mining and stamp mills have filled the waters of otherwise clear streams with yellow or red clay, rendering them almost uninhabitable for trout. Parts of the Upper Arkansas and Grand Rivers have been almost ruined as trout streams by mining operations. Dr. Jordan says:

> In the progress of settlement of the valleys of the Colorado the streams have become more and more largely used for irrigation. Below the mouth of the cañons dam after dam and ditch after ditch turn off the water. In summer the beds of even large rivers (as the Rio Grande) are left wholly dry, all of the water being turned into these ditches. Much of this water is consumed by the arid land and its vegetation; the rest seeps back, turbid and yellow, into the bed of the stream, to be again intercepted as soon as enough has accumulated to be worth taking. In some valleys, as in the San Luis, in the dry season there is scarcely a drop of water in the river bed that has not from one to ten times flowed over some field, while the beds of many considerable streams (Rio la Jara, Rio Alamosa, etc.) are filled with dry clay and dust. Great numbers of trout, in many cases thousands of them, pass into these

* Report of explorations in Colorado and Utah during the summer of 1889, with an account of the fishes found in each of the river basins examined. By David Starr Jordan. Bull. U. S. Fish Comm., IX, for 1889, pp. 1-40, pl. I-V.

irrigating ditches and are left to perish in the fields. The destruction of trout by this agency is far greater than that due to all others combined, and it is going on in almost every irrigating ditch in Colorado.

The fishes of Colorado comprise very few species, only 32 indigenous species being enumerated by Dr. Jordan, of which 2 were new to science.

The Rocky Mountain trout, *Salmo mykiss*, is found in all the mountain lakes and streams tributary to the four main rivers, extending down to a point where the summer temperature reaches 60° to 65° F., where it gradually disappears. The mountain minnows, *Rhinichthys dulcis* on the eastern slope and *Agosia yarrowi* in the Colorado basin, accompany the trout in the mountain meadows, not, however, ascending so near to the sources of the streams, but, on the other hand, much farther down their courses. They are eaten by the trout. The blob or miller's thumb is very abundant in the clear and cold waters of the Colorado basin, and is very destructive to the eggs of trout. The suckers extend up the rivers more or less to the point where the trout disappear, and, for the most part, the species are different in the different basins. The species of *Catostomus* and *Xyrauchen* reach a considerable size, but are of poor quality for food. The suckers and the chubs, especially the latter, are very destructive to the trout eggs. The *Ptychocheilus lucius* of the Colorado attains a great size, and in default of better fish assumes economic importance. The bulk of the rich fauna of the Mississippi, as well as most of the Texan fishes, are excluded from Colorado on account of the intervening turbid waters through which they can not ascend.

Three species of the *Salmonidæ* have been introduced into some of the streams and lakes of Colorado, the Eastern brook trout most extensively, the rainbow trout of California, and the landlocked salmon of Maine. Carp ponds have also been established in the State, and Dr. Jordan strongly recommends the introduction of the larger catfishes into the tributaries of the lower Colorado, the entire basin of that river having, besides the trout, only fishes of very inferior quality for food.

Tributary to the Arkansas River are the Evergreen Lakes, a series of trout ponds, wholly or partly artificial, fed by cold streams from the flanks of Mount Massive. One of these streams, having its rise in the largest permanent snow field in Colorado, has been chosen as the site of the new U. S. Fish Commission hatchery. Dr. Jordan states that no better location for that purpose could be desired.

In Utah no permanent streams of any importance, except the Colorado River, occur to the east of the Wahsatch Mountains. West of the divide of those mountains lies the Great Basin, in which the Salt Lake Basin and the Sevier River were examined. In the former 14 species of fish, including the trout, *Salmo mykiss*, were taken, and in the latter 7 species. The trout of Utah Lake are of excellent quality and reach a weight of 3 to 10 pounds. The same trout also occurs in Panquitch

Lake and the upper part of the Sevier River. In all streams like the latter occurring in this basin Dr. Jordan considered that catfishes might be planted to good advantage.

In connection with his description of the many mountain trout observed, Dr. Jordan defines carefully the several varieties or subspecies which he now recognizes, numbering 10 in all. One of these, a new and large variety from the Twin Lakes, has been named *Salmo mykiss macdonaldi*, in honor of the U. S. Fish Commissioner. Five of the varieties mentioned were collected in Colorado and Utah, and nine have been figured in his report.

MISSOURI AND ARKANSAS.

The investigations in these two States, which had been planned for 1888, were taken up in the summer of 1889 by Prof. S. E. Meek, of Coe College, Iowa, assisted by Mr. Louis Rettger and Mr. Frank M. Drew, of the Indiana University. The operations of this party were chiefly limited to the Ozark region of southern Missouri and northern and western Arkansas, in the midst of which, at Neosho, Mo., a hatching station was in course of building by the U. S. Fish Commission. The surface of the country in this region is much broken, although none of the hills reach a very great height. Springs abound and the streams are clear and cold even during midsummer. The bottoms of the latter are rocky, gravelly, or sandy, with little mud, and aquatic vegetation is not abundant. Fishes were plentiful in nearly all of the rivers in Missouri that were visited, but they were scarce in the Mazarn, and especially so in the Caddo and the forks of the Saline. It was reported that large numbers of fishes had been killed in the latter streams by the use of dynamite, and also in the neighborhood of Newburg, Neosho, and Cabool, Mo. Were this pernicious practice of destroying the native fishes to be continued, fish-cultural operations could not have much effect in replenishing the supply, but it is hoped that measures may be taken to prevent it in the future. In the Missouri River basin the Meramec, Gasconade, and Osage rivers were examined; in the Arkansas basin, Neosho River and Spadra Creek; in the White basin, White River, the tributaries about Mammoth Spring, and Little Red River; and in the Washita basin, Washita, Caddo, and Saline rivers and Mazarn Creek.

Mammoth Spring, Arkansas, is one of the largest springs in the United States, flowing about 50,000 cubic feet of water per minute; the temperature of the water ranges from 59° to 62° F., throughout the year. A fish farm has recently been established at this place, and in 1889 they began the rearing of trout which are said to grow rapidly, the conditions being exceedingly favorable for that purpose. The U. S. Fish Commission hatchery at Neosho is situated on a branch of the Neosho River and is fed from a fine spring. The station, however, had

not been completed, and was, therefore, not in operation at the time of Prof. Meek's visit.*

IOWA.

Prof. S. E. Meek, of Coe College, Iowa, began in the summer of 1889 a careful study of the fishes of Iowa, which was continued, with some intermissions, until into June, 1891. During this period he examined all the rivers in the State tributary to both the Mississippi and the Missouri, and also many of the smaller streams which empty into the former, as well as the principal lakes. Large collections of fishes were made, and upon them and his field observations Prof. Meek has based a very important report,† in which the fishes are classified in accordance with each river basin.

Iowa is situated between the Mississippi and the Missouri rivers. Its surface is comparatively level, rising gradually toward the north and west. Many streams traverse it, the greater number and the larger ones flowing southeasterly into the Mississippi, the remainder southwesterly into the Missouri, the affluents of the former draining more than two-thirds of the entire area of the State. The vast agricultural industry for which the State is so conspicuous has apparently had much to do with changing the character of many of these streams, causing their deterioration and at the same time a decrease in the abundance of the better food-fishes. This is said to have been caused in large part by the breaking up of the original stiff sod of the prairies, which tended to prevent the rapid flowing of the waters after heavy rains toward the river channels, but ditching and underdraining have also been instrumental in this respect. Rivers which formerly had well defined, deep, and narrow channels have widened out and become more shallow, overflowing their banks in the rainy season and losing most of their water during the succeeding months. The soil, loosened constantly for farming purposes, is also readily transported by the rain to fill the streams with sediment, which has caused the rapid disappearance of the trout.

The streams of southwestern Iowa have mostly muddy bottoms, and comparatively few fishes, but elsewhere the currents are generally stronger, the bottom consists chiefly of sand, gravel, and rocks, and fishes are relatively abundant both as to species and individuals. There are very many dams throughout the State, few, if any, of which are provided with fishways, thus greatly interfering with the spawning instincts of many species. There are a number of large and fine springs

*Report of explorations made in Missouri and Arkansas during 1889, with an account of the fishes observed in each of the river basins examined. By Seth Eugene Meek. Bull. U. S. Fish Comm., IX, for 1889, pp. 113-141, plate XLII.

†A report upon the fishes of Iowa, based upon observations and collections made during the years 1889, 1890, and 1891. By Seth Eugene Meek. Bull. U. S. Fish Comm., X, 1890, pp, 217-248.

in some places, which feed small but clear and cool brooks, in which trout have been abundant and in some of which they still exist. Numerous bayous are found along some of the larger rivers, to which the young bass, pickerel, and sunfishes resort, but owing to the greater or less drying up of such places during the summer a great mortality occurs among these species. The practice of seining out these young fishes and planting them in the open streams, which has proved so efficacious in Illinois and other States, was at one time resorted to in Iowa, but it has since been abandoned. If it were again renewed upon a proper scale, it would add greatly to the fishery wealth of the State.

The total number of rivers, smaller streams, and lakes examined by Prof. Meek was 41, and as many of these were visited at several places, and at several different times, it is safe to conclude that the principal chthyological features of the State have been brought out in his report. The greatest number of species of fishes recorded from a single stream was 85 from Cedar River: the smallest, 4 from Boyer River.

WISCONSIN.

During 1890 Prof. S. A. Forbes presented to the Fish Commission an interesting report* upon investigations made in lakes Geneva and Mendota, partly at the instance of Prof. Baird. The work was performed between 1881 and 1887, but the completion of the report had been deferred in the hope of obtaining more material that might throw additional light upon the principal subject of direct practical importance to which the paper relates—the fish mortality in Lake Mendota in 1884. Although no opportunity has yet occurred to add to Prof. Forbes's original inquiries in regard to this matter, it has been deemed advisable not to delay further the publication of his observations.

Lake Geneva, situated in the extreme southeastern part of the State, lies in a trough-like valley of the drift, the southern side of which formed part of the terminal moraine of the great Lake Michigan glacier. It is 7 miles long by 1½ miles in greatest width, and has an extreme depth of about 132 feet. It drains by a small outlet into Fox River, and thence into the Illinois. In his examination of the lake conducted in 1881 and 1887, Prof. Forbes made a very comprehensive study of all its characteristics, running lines of soundings to determine the contour of the bottom, and collecting its animals and plants by dredging and by the use of surface and other nets. While the investigation is not considered as complete, it is one of the most comprehensive and instructive examinations of such a body of water that has yet been made in this country, and may well serve as a model for future studies of the same character. Its usefulness consists in demonstrating very

* Preliminary report upon the invertebrate animals inhabiting lakes Geneva and Mendota, Wisconsin, with an account of the fish epidemic in Lake Mendota in 1884. By S. A. Forbes. Bull. U. S. Fish Comm., VIII, for 1888, pp. 473–487. Three maps and diagrams.

fully the natural conditions of the lake in all its main features, a knowledge of which shows its capacity for fish life, its suitability for the introduction of new species, and the measures necessary for the protection of its fisheries. Most attention in the line of biology was paid to the smaller forms of life, such as the larval and adult insects, crustaceans, mollusks, and worms, which serve as food for fishes, both adults and young.

In his conclusions, Prof. Forbes remarks:

> It is evident that even in a lake of so moderate size as this the smaller inhabitants are quite clearly divided into pelagic and littoral groups, the latter containing the greater number of species, but the former not less numerous in individuals; and a comparison of the results of dredging shows that this difference applies to the animals of the bottom as well as to those swimming freely above it. * * * It is also apparent, from the product of the towing net in deep water under varying conditions, that the pelagic entomostraca avoid the surface by day, whether it be rough or calm, or the weather cloudy or clear; but they do not necessarily withdraw to any great depth, hauls 10 feet below yielding "good" or "large" collections when the sun was shining. By night, on the other hand, the yield at the surface was large, even in a high wind.

The examination of Lake Mendota was made for the purpose of studying a most remarkable mortality among the common perch (*Perca flavescens*) in August, 1884, and was repeated in August of the following year. A study of the lake similar to that of Lake Geneva was also instituted, but upon a less comprehensive scale. The fish mortality began early in July of the former year and continued until about the middle of August, the quantity of fish dying during that period being estimated at above 300 tons. About 90 per cent of the fish which perished were the common perch, after which in numbers came the lake herring, followed by a few other species. Prof. Forbes's studies of the subject were thorough and covered all the questions that could be suggested, including an examination of all the conditions of the lake, both physical and biological, and of the morphological and histological conditions of both the dead and living fishes. It was impossible, however, to arrive at satisfactory deductions respecting the cause of the mortality, Prof. Forbes not having been apprised of its occurrence until it was practically over, and no subsequent opportunity having arisen to study similar phenomena. However, all the facts have been carefully recorded and discussed, and are available for future consideration. The more significant facts connected with the mortality are stated in considerable detail, but they are too long to make more than a brief reference to them in this connection.

A diseased condition of some parts of the viscera was noticed, especially in the herring, but externally the dying fishes seemed to be in good condition. The herring are subject to some mortality of the same character every year, but to a much less extent than in 1884. It is probable that the causes affecting the two species were the same, and it is also possible that the disease is contagious and was taken directly from the herring. The majority of the dead perch were full grown,

no young individuals having been observed. Moreover, the dead and diseased fishes had been feeding almost exclusively on a red insect larva peculiar to the mud of the deep water, while all the healthy fishes observed had been feeding on shallow-water forms.

The mortality, thus, seems to have been limited to the perch that were ranging in the deeper parts of the lake in company with the diseased herring, and observations indicate that such a deep range for the perch is unusual in midsummer. There also seems to be a deficiency in Lake Mendota of the kinds of animals usually selected by the perch as food, according to observations made elsewhere. A heavy flooding rain which occurred not long before the outbreak of the disease may have washed into the lake unusual quantities of organic matter from the swamp beyond Catfish Bay and from the surrounding country. Quite similar cases of destruction of the native fishes are of rather common occurrence in the rivers of Illinois in the hottest weather of the year. They usually, if not always, follow upon flooding rains, and thus occur when the streams are full or overflowing with turbid water loaded with the products of decay.

During the summer of 1890, Prof. C. Dwight Marsh, of Ripon College, began a physical and biological examination of Green Lake, situated in Green Lake County, Wis., for which the Fish Commission supplied one of its deep-sea thermometers for taking bottom temperatures. His investigations will be continued during the summer of 1891, when he expects to publish an account of his results.

INDIANA.

The investigations begun in Indiana by Prof. B. W. Evermann in 1888 were continued by him during the summer of 1890 in the northern and western parts of the State. Considerable work was done at intervals in the vicinity of Terre Haute, both in the Wabash River and in the numerous ponds which occur along its course in this region. During the regular spring rise in the river these ponds fill with water and numerous fishes enter at the same time, but in the summer and early autumn many of the ponds become dry, and great numbers of fishes perish there in consequence. Among the species which are thus destroyed are the black bass and crappie, and other valuable food-fishes. Several hundred specimens in good condition were transplanted to Lake Maxinkuckee by Prof. Evermann. Observations and collections were also made at Bonebank and Mackey Ferry on the lower Wabash River and at several places in the St. Joseph River basin, as follows: Pigeon River, Twin Lakes and Cedar Lakes near Ontario and Lima; Oliver Lake at Valentine, and Elkhart River at Goshen. Material was likewise obtained at Plymouth from the Yellow River, a tributary of the Kankakee, from Lake Maxinkuckee, and from the Tippecanoe River, a few miles south of the lake. Prof. Evermann was assisted in his work by a number of his students at the State Normal School, Terre

Haute, among whom may be mentioned Mr. D. C. Ridgley, Mr. C. S. Hoover, and Mr. C. H. Copeland. A report upon these inquiries is now in course of preparation.

OHIO.

Dr. James A. Henshall, secretary of the Cincinnati Society of Natural History, continued, during the summers of 1889 and 1890, his researches respecting the fishes of Ohio, referred to in the last annual report A complete account of these inquiries is deferred until further observations can be made, but the following brief notice of the work accomplished during the past two years has been furnished by Dr. Henshall:

The watershed of the State of Ohio extends from Ashtabula County, in the northeast corner of the State, to Mercer County, on its western border. The streams north of this ridge flow into Lake Erie, while those south of it empty into the Ohio River. The waters explored in the latter basin were the Ohio, Muskingum, Scioto, and Little Miami rivers and a number of smaller streams. Of the Great Lake Basin, the Maumee and Sandusky rivers and Lake Erie in the vicinity of Put-in Bay were examined. From these various sources 130 species of fishes were obtained out of about 150 known species supposed to inhabit Ohio waters. The only previous efforts in this direction were made by Rafinesque in 1818 to 1820, and by Dr. J. P. Kirtland from 1836 to 1846. The former explored the Ohio River and its tributaries from Pittsburg to Louisville, and described 120 species, of which the existence of about 70 valid species have since been verified. Dr. Kirtland described, from the waters of both basins, even a less number.

The most important food-fishes collected in the Ohio and its tributaries were the black bass, pike perch, sunfish, crappie, fresh-water drum, and several species of suckers and catfish. Those from the Lake Erie basin were the whitefish, lake herring, black bass, pike perch, sauger, and sturgeon, the first-named being the most important commercial food-fish of the State. From this it will be seen that were the fishes of Ohio afforded proper protection during their breeding season, and the pollution of the streams by the refuse and offal of various mills and factories prevented by wise and efficient legislation, a bountiful supply of good food-fishes would be assured to the people of the State that would go far toward supplying the demand for fish food.

KENTUCKY.

During the autumn of 1889 and the spring of 1890, Prof. Philip H. Kirsch, superintendent of public schools at Columbia City, Ind., made an investigation of the streams of Clinton County, Ky., and obtained a very complete collection of their fishes. In his report upon the subject,* Prof. Kirsch explains that this is one of the smallest counties in

* Notes on the streams and fishes of Clinton County, Ky., with a description of a new darter. By Philip H. Kirsch. Bull. U. S. Fish Comm., x, 1890, pp. 289–292.

the State, having an area of only about 206 square miles. It lies between the Cumberland River and the Tennessee State line, its surface being hilly and broken by the deeply-cut valleys of the water courses. The central Poplar Mountain range and other elevations form a watershed, dividing the county into two districts of nearly equal extent; the northern of these drains directly into the Cumberland River, while the other drains into the same river in Tennessee, through Obeys River. The total number of species obtained from all the streams was 33.

In the summer of 1890, Mr. Albert J. Woolman, assisted by Mr. H. W. Monical and Mr. C. O. Chambers, all students in Indiana University, made a very extensive and thorough investigation with regard to the fishery resources of Kentucky, their fieldwork beginning in July and continuing until near the middle of September. All of the principal river systems were visited, and very careful observations were made upon their physical characteristics, as well as upon the variety, abundance, and distribution of their fishes. The observations embraced not only the main stream in each basin but also a greater or less number of its tributaries. In his report* Mr. Woolman gives a detailed description of all of these features, and also has taken pains to incorporate the results of several previous collecting trips to this State by assistants of Indiana University. The collection of fishes obtained was especially large and interesting, and was noteworthy as containing nearly all the known species of darters.

Work was begun near the center of the State, in the Rolling Fork of Salt River, and was carried thence westward to the Green River, Tradewater River, the lower Cumberland and Tennessee rivers, Mayfield Creek, Obion River and the Bayou de Chien, in the extreme southwestern part of the State. Subsequently the party proceeded to the upper Cumberland and Tennessee rivers in eastern Kentucky, the upper Kentucky, Big and Little Sandy and Licking rivers. More work was done in the mountainous regions than elsewhere, leaving some of the lower streams to be investigated at a future time. The greatest number of species of fishes taken in any one basin was 64, in the Upper Green River and its tributaries.

FLORIDA.

During December, 1890, and January, 1891, Mr. A. J. Woolman, accompanied by Prof. Louis Rettger, made an examination of the freshwater streams occupying the western slope of Florida between Charlotte Harbor and the Suwanee River. Beginning operations in the vicinity of Punta Gorda and proceeding northward, the following rivers, together with their tributaries, were visited in succession, namely: Alligator, Peace, Hillsboro, Withlacoochee, and Santa Fe, the last mentioned

* Report of an examination of the rivers of Kentucky, with lists of the fishes obtained. By Albert J. Woolman. Bull. U. S. Fish Comm., x, 1890, pp. 249–288, pl. lx.

being one of the largest affluents of the Suwanee. As comparatively little information has hitherto been obtained regarding the ichthyological features of this region, Mr. Woolman's efforts were well rewarded, notwithstanding that the rainy season had commenced before the party reached the field. The relatively small number of species which inhabit these waters is especially noteworthy, only 12 species having been taken in the Alligator River, 20 in the Peace River, 14 in the Hillsboro River, 16 in the Withlacoochee River, and 17 in the Santa Fe River. Mr. Woolman's report * gives descriptions of the principal characteristics of the rivers, with annotated lists of their fishes.

NEW YORK.

In July, 1889, an examination was made of Lake Ronkonkoma and Great Pond, Long Island, by Mr. Fred. Mather and Dr. Bashford Dean, a part of the collecting outfit and the thermometers having been supplied by the U. S. Fish Commission. An account of this inquiry has been published in the Eighteenth Report of the Commissioners of Fisheries of New York, 1890, pp. 205–217.

Lake Ronkonkoma is situated in the center of Long Island on the top of an extended gravelly ridge of land. It is one of the largest bodies of fresh water on the island, having an area of a trifle over a square mile, and occupies a depression in the drift formation. Many myths are associated with the place, and the lake has been supposed by residents of the vicinity to have a very great depth. The soundings made during the summer developed, however, a nearly uniform depth of only 15 feet, a maximum of 65 feet having been discovered in one place. There are no inlet or outlet streams, the source of its water being underlying springs. The temperature was found to be high, ranging from 75° F. in the deep hole to 77° F. in depths of 3 to 4 feet, and 80° F. at the surface. It was concluded from the observations made that "the balance of fish life in this lake is nearly if not quite complete." Black bass of both species, which were planted some years ago, are now plentiful and have attained a large size. Notes are given on all the species of fishes found, and the commoner forms of invertebrates and plants are enumerated.

Great Pond is at Riverhead, near the eastern part of the island, and although also situated in the drift, differs considerably in character from Lake Ronkonkoma. It drains the surrounding hills and has an outlet flowing into Great Peconic Bay. Its average depth is something over 24 feet, the temperature at the bottom ranging from 65° to 75° F. The pickerel (*Esox reticulatus*) and common sunfish (*Lepomis gibbosus*), absent from Lake Ronkonkoma, are abundant here, but the black bass has never been introduced.

* Report upon the rivers of central Florida tributary to the Gulf of Mexico, with lists of fishes inhabiting them. By Albert J. Woolman. Bull. U. S. Fish Commission, x, 1890, pp. 293-302, pls. LII, LIII.

WOODS HOLL LABORATORY.

Nearly all of the important food-fishes occurring in the Vineyard Sound region spawn during the spring or winter months, and as the Woods Holl Station has not generally been occupied for scientific purposes until about July 1 of each year, the study of their breeding habits and of the development of the young has, for the most part, been neglected. The pressing demands of fish-culture have been met from time to time by the temporary employment of specialists in the proper seasons for such investigations, but nothing in the way of a thorough and continuous series of observations relative to these subjects has hitherto been attempted. Among the forms respecting which information is most urgently desired at present are the cod, sea bass, scup, tautog, mackerel, menhaden, lobster, and oyster, but there is not a food species common to this coast an account of whose life history and spawning habits would not contribute something to the welfare of the fisheries by suggesting either methods of propagation or suitable measures of protection.

In order that scientific studies bearing upon these subjects might be continued at all seasons, Dr. H. V. Wilson, a graduate of Johns Hopkins University, was appointed in May, 1888, resident naturalist at the Woods Holl Station, in charge of the biological laboratory. Within the past two years Dr. Wilson has completed a very important monograph on the embryology of the sea bass, and has also collected much material illustrating the development of the egg and larval stages of the cod, scup, tautog, and other species of fishes as well as of some crustaceans. He has also made some progress in the study of the development of sponges, preliminary to a proposed visit to the coast of Florida, where it is intended to investigate the life history of the commercial forms. A complete series of the eggs and embryos of the Atlantic salmon, obtained at the Maine station of the Fish Commission, has likewise been prepared by Dr. Wilson for future examination. The surface nets have been in constant use in the vicinity of Woods Holl, under his direction, and Mr. H. G. White, a draftsman, has been employed during a portion of each year to make drawings of the larval fishes secured by this means. A more complete account of the results of Dr. Wilson's inquiries is given under the heading of "Special Investigations."

Mr. V. N. Edwards has continued his field observations respecting the different fishes which inhabit the Vineyard Sound region, keeping a careful record of the time of approach and disappearance of the migratory species, of the breeding and feeding habits of all forms, and of the growth of the young from day to day. He has also experimented successfully with the hatching of several common fishes, and has demon-

strated practically the best methods by which their artificial propagation may be accomplished.

The steamer *Fish Hawk* was at Woods Holl during a part of the summer of 1889, and made several collecting trips for the purpose of securing material desired for examination. This station was also the headquarters of the schooner *Grampus* during both summers, while engaged upon the physical inquiries respecting the mackerel-grounds off the adjacent coast, as described elsewhere, and Prof. Libbey and the members of his party were given the necessary accommodations in the laboratory for working upon the materials and observations obtained on each cruise.

Many important additions have been made to the laboratory equipment, and the facilities for research are now much better than they have been at any previous time. The aquaria have also been maintained upon a proper basis, and while supplying the requirements of the investigators for the preservation of living specimens, they are equally appreciated by the public, which is given free access to the building at all hours. The greatest desideratum at the station is the lack of a good collection of scientific books, but this has been met in part by the courteous action of the Marine Biological Laboratory in placing its fine working library at the service of the Fish Commission. Books are also obtained when needed from the Boston Society of Natural History, and from Washington, and the principal technical journals treating of biological subjects have been subscribed to.

During the summer months of each year the laboratory has been occupied by a relatively large number of scientific men, some of whom have been employed by the Fish Commission in making special investigations, while others were given such facilities as they required for conducting whatever researches they desired to make. The Commissioner was also present during a part of both seasons. Seventeen investigators were in attendance during 1889, and 14 during 1890. Below is given a brief summary of the work performed by each, the principal topics pertaining to the operations of the Fish Commission being again referred to under special headings.

SUMMER OF 1889.

During this season Prof. W. K. Brooks, of Johns Hopkins University, was occupied chiefly with a study of the life history of the common starfish, the most dreaded enemy of the oyster beds on the New England coast, whose breeding habits it is very desirable should be carefully determined. He also paid some attention to the natural history of physalia and salpa, surface organisms which are sometimes very abundant in the vicinity of Woods Holl.

Prof. F. H. Herrick, of Adelbert College, best known for his joint memoir with Prof. Brooks on the Embryology and Metamorphosis of the Macrura, soon to be published by the National Academy of Sciences,

began for the Fish Commission an exhaustive inquiry into the development and spawning habits of the lobster, one of the most interesting marine forms now being propagated artificially at the Woods Holl Station. He also collected material bearing upon the embryology of other crustaceans inhabiting this region.

Prof. Edwin Linton, of Washington and Jefferson College, who has been engaged for several years in a study of the entozoan and other worm parasites of fishes, was employed to continue his field researches and to make additional observations in respect to this subject. Fish diseases, so far as they have been investigated, appear to be almost entirely the result of parasitism in one form or another, and it is, therefore, very important that the relations of these low organisms to their respective hosts should be made out with as much care as possible.

Dr. C. F. Hodge, of Clark University, was at Woods Holl during the first part of the summer, and afterwards joined the steamer *Fish Hawk* as naturalist in connection with the oyster investigation. While at the station he was occupied in making observations upon the feeding habits of larval lobsters, and in attempting to rear them through their free-swimming stages, during which period they are subject to great mortality.

Mr. James I. Peck, of Johns Hopkins University, was engaged to investigate the habits and distribution of the young of the scup and sea bass, two of the principal food-fishes of the Vineyard Sound region. His observations were made both in the field and with the aid of the aquaria.

Johns Hopkins University was represented at the station by four independent workers, Dr. E. A. Andrews, Mr. T. H. Morgan, Mr. S. Watase, and Mr. R. P. Bigelow. Dr. Andrews investigated the anatomy and development of certain annelid worms, and Mr. Bigelow the comparative histology of the discophore medusæ, and the habits and the physiology of physalia. The researches of Mr. Morgan were mainly in the direction of the phylogenetic life history of jelly-fishes, of which he examined specimens of *Cyanea artica*, *Aurelia flavidula*, and *Pelagia*, but also paid some attention to the development of pycnogonids, of which three species are found in this region. Mr. S. Watase continued his studies, begun in 1888, on the structure and relationship of the eyes of crustaceans and echinoderms. Preliminary reports on this subject had previously been published by him.

Mr. W. McM. Woodworth, Mr. C. B. Davenport, and Mr. E. R. Boyer were present as representatives of Harvard University. Mr. Woodworth was chiefly interested in tracing the development of a small parasitic planarian which infests the gill lamellæ of the king crab; Mr. Davenport, in studying the structure and development of marine and fresh-water polyzoa, and of *Bopyrus palæmonites*, the latter being an isopod parasite living on the common prawn (*Palæmonites vulgaris*);

and Mr. Boyer in investigating the embryology of a common minnow (*Fundulus heteroclitus*).

Mr. B. H. Waters and Mr. C. W. Stevens, of Princeton College, gave their attention to inquiries of a general character, while Prof. A. A. Wright and Mr. M. J. Greenman, who were in attendance for only a short time, were occupied in securing miscellaneous collections of marine animals for Oberlin College and the University of Pennsylvania, respectively.

SUMMER OF 1890.

During the summer of 1890 Prof. F. H. Herrick continued his investigations, begun the previous year, respecting the life history of the lobster. Prof. H. C. Bumpus, of Brown University, was also present during the spring months and gave attention to the same species, his studies having special reference to the length of time the eggs are carried by the parent lobster before hatching. Mr. R. G. Harrison and Mr. J. L. Kellogg, of Johns Hopkins University, worked conjointly on several problems relative to the habits and fixation of oyster spat, and the latter also took up the study of the anatomy and life history of several bivalve mollusks, including the more common edible species, such as the quahog, soft clam, scallop, and mussel. Mr. George H. Field, also of Johns Hopkins University, continued the inquiries commenced by Prof. Brooks in 1889 on the development of starfishes, and extended his observations to other species of echinoderms. Mr. E. G. Conklin, of the same institution, studied the embryology of *Urosalpinx* and *Crepidula*, two gastropod mollusks, of which the former is the so-called oyster drill, second only to the starfish as to the amount of damage which it inflicts upon the oyster-beds of southern New England.

Dr. E. A. Andrews investigated the structure and development of the eyes of annelid worms, and the growth of a small nemertean (*Meckelia*). Dr. R. P. Bigelow, who was attached to the schooner *Grampus*, in addition to the physical observations assigned him, made large collections of surface animals in the region of the Gulf Steam, which occupied his attention while the vessel was in port. Prof. William Patten, of the University of North Dakota, was interested in the study of the sense organs of crustaceans and of the horseshoe crab, and Mr. W. McM. Woodworth continued his observations upon the parasitic planarian which lives on the gills of the latter species. The development of teleostean fishes was studied by Dr. Thomas G. Lee, of Yale University, and general inquiries were carried on by Mr. W. C. Prime, of Princeton College.

SPECIAL OBSERVATIONS AND EXPERIMENTS.

The Cod (*Gadus morrhua*).

In the last annual report an account was given of the efforts that had been made to increase the supply of cod on the southern New England coast and of the success with which this experiment had been attended. The evidence since obtained in regard to this matter is even more gratifying, and the expediency of continuing the propagation of this species upon as large a scale as possible can no longer be denied. In fact, the observations which are being made from year to year upon the habits of marine fishes tend to prove that they are nearly all much more susceptible to human influences than has generally been supposed, and we feel justified in predicting for this branch of fish-culture a more brilliant future than has usually been accorded to it.

The number of cod fry planted in the Vineyard Sound region prior to July 1, 1889, was about 38,000,000, to which may now be added 5,800,000 for the season of 1889–90, and 36,200,000 for the season of 1890–91, making a total of over 80,000,000 down to the close of the last fiscal year. For the details of the hatching work reference should be made to the fish-cultural report of the Woods Holl Station, but it is interesting to note in this connection that the 36,200,000 embryos deposited in 1890–91 were obtained from the eggs of 587 fish, caught chiefly on Nantucket Shoals, although a few were taken off Marthas Vineyard and No Mans Land. The season during which ripe eggs were secured lasted from November 17, 1890, to February 7, 1891, each fish yielding from 11,000 to 238,000 eggs at a stripping, but some of the fish were handled more than once. The period of incubation ranged from 216 to 762 hours, according to the temperature of the water, which varied from 32° to 49° F.

The observations of Mr. V. N. Edwards during the past two years have shown not only that the young cod have continued to be abundant at the proper seasons, but also that the larger fish enter the inner waters in considerable numbers. In the autumn of 1889 cod of two sizes were plentiful; the smaller, measuring 12 to 13½ inches long, were considered to be yearlings, while the others, from 18 to 22 inches long, were supposed to be 2-year-olds. Fish 1½ years old, captured in the spring, measured 15 inches. The 2-year-old cod were abundant all along the Massachusetts coast south of Cape Cod, and off Block Island, during the fall of 1889, and over 1,000 individuals of this age were secured by the schooner *Grace* during one day's fishing. They were also taken by the tautog fishermen in Vineyard Sound and Buzzards Bay, and 16 were captured in a fyke net which had been set in the Great Harbor of Woods Holl for twenty years, the first time that any of this size have been known to occur in these waters.

During April, 1890, young cod measuring from 1¼ to 2 inches long, were very plentiful all along the shores, and were taken by Mr. Edwards in his small collecting seine. The latter part of the month they had entered Woods Holl harbor and had become common around the wharves. In May large fish, weighing from 5 to 15 pounds apiece, made their appearance in these waters in very large numbers, and were abundant in Buzzards Bay from Cuttyhunk to Quisset, and in Vineyard Sound from Robinson Holl to Falmouth Heights. The fishermen caught them in their fish traps, and they also entered the lobster pots, something previously unheard of. A small funnel-shaped bass trap set on the shore off Nonamessett Island caught 23 of these large cod on May 3, 15 on the 5th, and 8 on the 6th of the same month. They were the first cod ever taken in that locality. From the latter part of October until the end of November, 1890, fish of good size were abundant throughout Vineyard Sound and Buzzards Bay and in the neighboring regions. October 31, Mr. Edwards reported that since the 20th of the month all the tautog fishermen in the sound and bay had been catching codfish every day, measuring from 15 to 20 inches long. On November 18, he stated that individuals weighing from 5 to 10 pounds each were very plentiful in Vineyard Sound, and also occurred in Buzzards Bay. They were also said to be abundant at the same time on Nantucket Shoals and off Cape Cod. During the latter part of the month the boats were obtaining from 75 to 90 good-sized cod at each tide off the mouth of Edgartown Harbor, and sometimes as many as 100 off Nantucket Bar. There is no record of this species having been captured previously in either of these localities. On April 30, 1891, Mr. Edwards reported that codfish were more abundant in the Vineyard Sound region than they had been for thirty-five or forty years, and some of them were of large size.

On November 24, 1890, Mr. Willard Nye, of New Bedford, Mass., reported that during the same fall codfish had been more numerous than for many years in the shoal waters at the mouth of Buzzards Bay and to the westward. They have been caught, he states, in the traps from Salter Point off Narragansett River, Buzzards Bay, as far to the west as Seaconnet Point, and at many places inside of Buzzards Bay, which is something new even to the oldest inhabitant. The fish taken in shoal water are of two sizes, one averaging about 4, the other about 6 pounds, each. They are both school cod and do not have the red color of the so-called rock-cod, stragglers of which are caught every year in shallow water. Cod fishing in Buzzards Bay has been a rarity for a great many years.

On December 3, 1890, Mr. George A. Griffin, wrote from Wakefield, R. I., to the effect that codfish had been very plentiful during the fall off Narragansett Pier and Point Judith. They had formerly been abundant there, but have been very scarce during the past 20 years.

Granting that the increase of codfish, indicated by the above and previous announcements, has resulted from the hatching work of the U. S. Fish Commission, and that fact seems now to have been settled beyond any question, it is interesting to note the extent of sea coast which can be covered from a single station without the need of making a wide distribution of the fry, as nearly all of the plantings have been made in the immediate vicinity of Woods Holl. As to the increase recorded on Nantucket Shoals and off the outer coast of Cape Cod, it is impossible to say at present whether this was brought about by the operations at Woods Holl or at Gloucester, but it is probable that the plantings made from the former station were instrumental in this respect, to some extent at least. As the Fish Commission has not had the means of obtaining careful observations regarding the presence and abundance of young fish north of Cape Cod, there is less positive information at hand to show the outcome of the hatching work at Gloucester, but there is every reason to believe that it has been entirely successful. One instance of the survival and growth of the young planted from that station has been reported as follows: Writing from Kingston, Mass., July 26, 1889, Mr. H. M. Jones stated that he had had forty years' experience in fishing in the waters adjoining Plymouth Harbor, but certain schools of fish, which he describes as having white bellies and dark spots on the back, had appeared during the summer, and were entirely new to him. They averaged 4 pounds in weight, and had been plentiful all summer. Although he considered them to be cod, they differed from those ordinarily found in that vicinity. A specimen forwarded to Washington was found to represent the variety of cod propagated at the Gloucester Station, and there seemed to be no doubt that these schools had originated in the plantings made from that place.

During the winter of 1890–91, Dr. H. V. Wilson began the study of the embryology of the cod, in connection with the hatching operations at the Woods Holl Station, and before the end of the year he had made considerable progress in this work.

The Sea Bass (*Serranus atrarius*).

The experiments with respect to the spawning of the sea bass made at Woods Holl in 1888 and 1889 were continued by Mr. Edwards during 1890. From 4,270,000 eggs obtained during May and June of the latter year, 3,890,000 embryos were secured, an exceedingly large percentage, showing that the propagation of this species could be carried on without difficulty. Ripe fish were first taken on the spawning-grounds off Hyannis on May 10, and eggs were obtained as late as June 23, in the vicinity of Woods Holl. Ripe milters, according to Mr. Edwards, are found two weeks in advance of ripe females, and he reports the same also with respect to the scup, mackerel, and squeteague. If sea bass are held in the traps over thirty-six hours their eggs are always found to be dead when the fish are examined.

That the planting of embryo sea bass, as well as scup, in the shallow waters south of Cape Cod would undoubtedly be attended with good results, is well illustrated by an experiment made by Mr. Edwards in 1890. In June of that year he liberated about 50,000 fry of each of these species in the so-called Eel Pond at Woods Holl, a shallow tidal basin having an area of only a few acres. On November 7, while seining in the pond, he caught thousands of both species, the smallest measuring 2 inches long and the largest 4½ inches. During most of the same month they were observed passing out in large schools through the narrow outlet from the pond, becoming very common in the harbor at Woods Holl, but occurring nowhere else. Sea bass young placed in Eel Pond during the spring of 1889 apparently remained there continuously until the fall of 1890, when they had attained a length of 10 to 11 inches.

The embryology of the sea bass has been worked out in a very complete and satisfactory manner by Dr. H. V. Wilson, assistant in charge of the Woods Holl laboratory. A preliminary notice of his researches was published in the Johns Hopkins University Circular, vol. IX, No. 80, 1890, and the final report in the Bulletin of the Fish Commission for 1889.* Very instructive and important results were obtained by Dr. Wilson, and his observations throw much additional light on the origin and structure of many organs, the developmental history of which has been only imperfectly understood. His explanation of the derivation and function of the lateral line is especially interesting.

The Spanish Mackerel (*Scomberomorus maculatus*).

On June 14, 1891, the steamer *Fish Hawk* was temporarily detached from the oyster survey in Tangier Sound and was detailed to carry on investigations respecting the hatching of Spanish mackerel in the vicinity of Cape Charles City, Virginia. Similar inquiries and experiments had been made in the lower Chesapeake Bay during several previous years ending with 1885, but the work had never been conducted on a large scale, and only a comparatively small number of fry had ever been obtained at any one time. The rapid diminution in the abundance of this valuable food species, reported from year to year, had again called attention to this subject, and rendered it of considerable importance that additional and more positive information should be obtained. Lieut. Robert Platt, U. S. Navy, was charged with the fish-cultural operations, and the services of Mr. J. Percy Moore, an assistant in the University of Pennsylvania, were secured to conduct the scientific observations, with the view of supplementing the studies previously made by Prof. John A. Ryder, and published in the Fish Commission Bulletin for 1881. The principal work mapped out was to de-

* The Embryology of the Sea Bass (*Serranus atrarius*). By Henry V. Wilson, Ph. D., assistant U. S. Fish Commission, Bull. U. S. Fish Commission, vol. IX, 1889, pp. 209-277, pls. 88-107.

termine suitable places for obtaining the spawning fish, the means necessary for securing them in good condition, and the apparatus best adapted to the hatching of the eggs. The scientific inquiries were to be directed chiefly towards ascertaining those facts respecting the natural history of the parent fish and of the embryos which could be turned to practical advantage in the artificial propagation of the species. The work continued until the end of July, 1891, and, therefore, only the progress made during the last half of June belongs appropriately to this report.

The vicinity of Cape Charles City was found to offer good facilities for the work, but breeding fish in suitable condition were very difficult to obtain. By the ordinary methods of capture in the pound nets, the fish are held in captivity over night, and those which do not spawn before morning (they are supposed to be mainly nocturnal spawners) are subjected to so much pressure and rough handling when the nets are emptied on the next day that, as a rule, they lose not only what ripe eggs they contain, but also many immature ones. An attempt was made to secure them by means of gill nets, but only a few were so taken, and the nets were almost invariably torn by sharks and gars. It is suggested that several pound nets might be run exclusively for the benefit of the hatching work, in which case they could be hauled at night, and in such a manner as to retain the spawning fish in good condition.

It was ascertained that the ovaries of this species mature slowly and not at the same rate in all parts. Consequently, ova in very different stages of development were found in the same fish. The largest number of ripe eggs taken from a single fish at one time was 60,000. The movements of the schools were much influenced by the physical conditions of the water and atmosphere, but precisely to what extent was not determined. The fry were planted soon after hatching, and it was found impossible to keep them alive in the small compass of an aquarium for more than a week at the most. As young fish, especially alewives, are very abundant at the surface at this season, it is considered that the embryo mackerel stand a poor chance of escaping such enemies while in their earliest and most helpless stages, and it is suggested that some means of confining them along the shore might prove advantageous in case the hatching work should be undertaken upon a large scale.

The tidal or cod jars were employed successfully for this species. The eggs were found to be buoyant in the bay water of ordinary density, but sank and afforded poor results if the water became too brackish. Up to July 1, 1,090,000 fertilized eggs had been taken from 30 female fish, producing 366,000 embryos, which were planted in the vicinity of Cape Charles City. The length of time required for hatching after the eggs had been impregnated was about twenty-four hours.

The Mackerel (*Scomber scombrus*).

Mr. Edwards continued at Woods Holl, in 1890, his experiments with regard to the hatching of this species which had been conducted during 1886, 1888, and 1889. From 768,000 eggs, 688,000 embryos were obtained. About 2,000,000 eggs taken from fish which had been dead a short time proved worthless. During November, 1890, small mackerel, measuring from 8 to 11 inches long, were unusually abundant in Woods Holl harbor, and about 5,000 were caught with hook and line from the Fish Commission wharf. Some adult specimens were also captured at the same place and others in a fyke net set by Mr. Edwards, the first time they had been so taken.

The Scup (*Stenotomus chrysops*).

About 396,000 fry were obtained from 443,000 eggs of this species at the Woods Holl station during June, 1890. The eggs are buoyant and hatch in from three to five days. Ninety-five per cent of all the scup taken at this period were milters. After remaining in the traps over twenty-four hours, the females are never found to contain any ripe spawn. An account of an experiment on the planting of young scup in Eel Pond during the summer of 1890 is given in connection with the sea bass.

The Squeteague (*Cynoscion regale.*)

The artificial propagation of this species was first attempted at Woods Holl by Mr. Edwards in June, 1890, when 237,000 eggs were hatched in 3 to 4 days with a loss of only about 10,000. The eggs are buoyant. Nineteen out of twenty of all the squeteague taken were milters, and ripe males occurred as late as June 30, but nearly all the females had spawned before that time.

The Tautog (*Tautoga onitis*).

From 808,000 eggs of the tautog, secured by Mr. Edwards at Woods Holl during June, 1890, 732,000 embryos were obtained. The eggs are buoyant and hatched in from 3 to 5 days. On June 29, 1890, about 50,000 fry were planted in Eel Pond, where young fish were abundant in the following November. They did not attempt to escape from the pond, but stowed themselves away in the eelgrass. This species is said to be growing less abundant every year on the southern coast of New England.

The Cunner (*Ctenolabrus adspersus*).

The eggs of the cunner are buoyant and very transparent; about 26 are contained in a linear inch. About 50,000 eggs of this species obtained May 22, 1890, were hatched at Woods Holl on the 5th day, with a loss of only 5,000. The tidal cod jar was used, the temperature of the water being 56° F.

The Atlantic Salmon (*Salmo salar*).

In the fall of 1890, after completing his monograph on the sea bass, Dr. H. V. Wilson paid a short visit to the Fish Commission station at East Orland, Maine, where he made careful preparations of a series of embryos of the Atlantic salmon, illustrating different stages in their growth. This material will serve as the basis for the study of the development of the species.

The Flounders (*Paralichthys dentatus* and *Pseudopleuronectes americanus.*)

The two most important flounders which occur on the southern coast of New England are the common flounder, *Paralichthys dentatus*, and the flatfish or winter flounder, *Pseudopleuronectes americanus*. Both of these species, which have a very extended range, are now regarded as valuable food products, and both are sent to market from the Woods Holl region. Nothing is positively known regarding the breeding habits of the former, except that it does not spawn in the shallow water near the shore, but the ripe eggs of the latter may readily be obtained there in large quantities. Experiments regarding the hatching of this species were taken up by Mr. V. N. Edwards in the spring of 1888, and were continued by him during 1890 and 1891. The spawning season begins early in February and lasts until late in April. During the spring of 1890 Mr. Edwards obtained 5,800,000 eggs from 87 fish, the same yielding over 4,000,000 fry; in 1891 71 fish produced 4,680,000 eggs and 3,350,000 fry, the proportion of eggs hatched in each case being about 70 per cent. The length of the period of incubation varied from 400 to 600 hours, the temperature of the water ranging from 32° to 46° Fahrenheit. The fry were liberated in from 1 to 5 days after hatching. The eggs are adhesive and sink. Several different methods of handling them were tried, but the best success was obtained by spreading them thinly on panes of glass and placing them in a current of water in the hatching boxes. If allowed to accumulate together they adhere in masses, and under such conditions a very large percentage, if not the entire lot, soon dies. In some cases, Mr. Edwards found that the eggs had hardened up in the fish, and when pressure was applied they came out in one solid body. Under such circumstances the eggs do not ripen and the fish itself generally dies.

This species can be caught in large numbers in the harbor of Woods Holl and in the neighboring waters during the spawning season. During the more severe winter weather, however, they retreat to the deeper parts of Vineyard Sound and Buzzards Bay. The earliest spawners have been obtained in the upper parts of Waquoit Bay, in the town of Falmouth, where they are said to appear every season at the first thaw in February. Later in the spring they can be taken in the vicinity of Woods Holl. Dr. Wilson found it difficult to keep the young flounders alive for any length of time in the aquaria, but early in May, 1890, they were abundant at the surface and were captured in the tow net.

The Sand Dab (*Pleuronectes maculatus*).

On May 12, 1890, Mr. Edwards secured about 100,000 eggs of this species, which, in a temperature of 51° to 54° F., hatched on the fifth day, with a loss of only 10 per cent. The tidal cod jar was used for this purpose. The eggs are buoyant, and about 24 are contained in a linear inch.

The Four-Spotted Flounder (*Paralichthys oblongus*).

Of this species, 50,000 eggs were obtained on May 15, 1890. They are of the same size as the eggs of the sand dab, are also buoyant, and hatched in the same length of time, but with a loss of 50 per cent. The tidal cod jar was employed.

The Lobster (*Homarus americanus*).

In previous reports accounts have been given of the successful attempts made to hatch lobster eggs which had previously been removed from the swimmerets of the parent, but at the same time attention was called to the difficulty of rearing the embryos in captivity, owing to their propensity to devour one another, notwithstanding great care was exercised in supplying them with proper food. On this account the embryos have generally been planted when only a few days old, but it is considered that much better results could be accomplished by confining them in tanks until they had reached an age of 4 or 5 weeks, when they are better able to protect themselves against their enemies.

During 1890 and 1891 the hatching work was continued at Woods Holl on a moderate scale, and at the same time careful experiments were made to discover some way of keeping the larvæ in the aquaria without the great mortality which has hitherto occurred. Mr. V. N. Edwards also made some interesting observations regarding the eggs and the size at which the adult first becomes mature, and important studies respecting the breeding habits and life history of the species were undertaken by Prof. F. H. Herrick, of Adelbert College, and Prof. H. C. Bumpus, of Brown University. Prof. Herrick first turned his attention to this matter during the summer of 1889, and in the following year arrangements were made with him to prepare a comprehensive monograph covering the entire subject, which will probably require several years for its completion. Prof. Bumpus was at the station in the spring of 1890. Preliminary reports have been published by Prof. Herrick in the Johns Hopkins University Circular No. 80, 1890, and No. 87, 1891, the latter containing the two following papers by him, namely: "Notes on the habits and larval stages of the American lobster," and "The reproductive organs and early stages of development of the American lobster."

From the inquiries made up to this date some very valuable deductions have been reached. The fact that the eggs laid during the summer are carried by the parent until the following spring or summer before hatching, a conclusion reached by the writer from his experiments in 1885, has been proved conclusively. During 1889, eggs were

laid from June 20 to July 15, and probably later; and in 1890, from July 1 until about August 20, according to the observations made. Lobsters do not breed readily when confined in close quarters. One female kept in a small aquarium for about eight weeks extruded eggs which were somewhat abnormal in their condition, and in the course of a few days they were scratched off by her from the swimmerets. The hatching period at Woods Holl occupies about eight weeks, beginning about the middle of May and continuing until near the middle of July, but it varies somewhat. In 1890 the last lobster with light-colored spawn (about ready to hatch) was taken July 7, and on the same day the Gay Head fishermen obtained the first lobster of the season with dark-colored or newly laid eggs.

Prof. Herrick considers that the lobster does not breed annually, judging from the immature condition of the ovaries at the time of hatching of the eggs attached to the swimmerets, and by the large percentage of non-egg-bearing females taken in the winter and spring. In April, 1889, 21 per cent of all the lobsters caught at Woods Holl by Mr. Edwards were females with eggs; in May, 19 per cent, and in June only about one-half of 1 per cent, the larger proportion of the eggs having hatched previous to, or during the early part of, the last-mentioned month. In the course of these observations it was also noticed that the females somewhat exceeded the males in numbers.

Freshly laid eggs are very dark green in color, but toward the next spring they become much lighter, owing to the partial consumption of the yolk. The adult lobster may molt soon after its eggs are hatched (most commonly in the early summer) or not until fall, and possibly at any other time when not carrying eggs. The frequency of the fall molting has been referred to elsewhere. Prof. Herrick is inclined to think that, after becoming sexually mature, lobsters do not, as a rule, molt annually. From six to eight weeks are probably required to produce a fairly hard new shell. At the time of hatching the larval lobster also molts for the first time, the delicate skin being cast off with the shell. This is a critical period in its history, and in connection with the work at Woods Holl large numbers die at this stage through inability to pass the first molt. The young swim at the surface for six or eight weeks, when they attain a stage which bears a general resemblance to the adult, although differing from it in many details. The larva at this age both walks on the bottom and swims at the surface, but when it reaches the next stage, it leaves the surface entirely.

During the early spring of 1890, Prof. Bumpus succeeded in hatching lobster eggs prematurely by placing them in running water, of which the temperature had been elevated artificially to that of the sea water in June. The young made their appearance in a very few days. Other eggs from the same lobster retained in water of normal temperature did not develop appreciably during the same period. The young produced in this way seemed strong and hardy and no fatal results

attended their transfer to water of ordinary temperature. In fact, they were kept for twenty-four hours in a temperature as low as 32° F. without injury. The expediency of resorting to this method is, however, questionable, on account of the extra trouble and expense of manipulation where the work is carried on upon a large scale. Experience has taught that in nearly all fish-cultural operations it is best to conduct them under natural conditions as far as possible.

The observations made by Dr. C. F. Hodge, during the summer of 1889, respecting the feeding of young lobsters in confinement, while not successful from a practical standpoint, furnished some interesting facts regarding the larval habits of this species. The stomachs of specimens, about one month old, taken at the surface in Woods Holl harbor, contained fragments of copepods and of the larval stages of crabs, showing, so far as these examinations go, that their normal food at this age consists of active crustacean forms having the same pelagic habits as themselves. In the aquaria they were supplied with all sorts of food, both animal and vegetable, which it was conjectured might be suited to their tastes and needs, including surface towings brought in from the harbor. They did not appear to touch anything of a vegetable nature or any preparations made from flour. They will eat almost any character of animal food if suitably prepared, but while some kinds seem to be beneficial to them, others are more or less harmful, the yolks of hard-boiled eggs and freshly coagulated milk belonging to the former category. When well supplied with nutriment they rapidly gorge themselves, and it was found necessary to take much pains in dividing the solid particles, which should be neither too fine nor too coarse, to insure their proper feeding and prevent their becoming entangled in the loose tissues. In none of the trials, however, did more than a small percentage of the larvæ survive for any considerable length of time. They appeared to rest mainly upon the bottom of the aquarium at night, but rose toward the surface whenever a light was brought near them. In the daytime, also, they feed chiefly on the bottom, and are apt to spend much of their time there even when not so occupied.

Dr. Hodge is inclined to believe that the difficulties in the way of raising young lobsters in the aquaria do not arise entirely from their feeding habits, but are due in part to other causes, not at present understood. He experimented upon the effects of light, of temperature, of the conditions of the water, etc., but without producing any modifications in his results. Larvæ confined in floating cars off the wharf, moreover, fared no better than those kept in the laboratory. It has been suggested that a minute protozoan, which constantly swarmed about the living young, and completely infested their dead bodies, may to some extent have been instrumental in their destruction, a matter that could readily be determined by a sterilization of the water, but it is improbable that such a widespread mortality could result from such a cause.

Between April 16 and June 13, 1890, 723 lobsters furnished 8,317,000 eggs yielding 4,511,000 embryos. Between April 28 and June 30, 1891, 4,353,000 eggs were obtained from 482 lobsters, and from these 3,533,000 embryos were secured. The proportion of eggs hatched in 1889 was about 51 per cent; in 1890, 54 per cent; and in 1891, 81 per cent. The greatly increased percentage in the last-mentioned year was due to greater skill in the handling of the eggs, and to the exclusive use of the automatic shad jar, which is better adapted to the treatment of lobster eggs than any other apparatus yet employed for that purpose. Observations made in 1890 tended to show that the lobster eggs did not hatch in the apparatus until the temperature of the water had risen to between 54° and 59° F. This fact, however, needs to be corroborated.

During the seasons of 1890 and 1891, Mr. V. N. Edwards kept a careful record respecting the sizes of all breeding lobsters which he handled, and the number of eggs furnished by each. The results obtained are exceedingly interesting, and indicate that a larger proportion of the lobsters begin to spawn at an early age than has generally been supposed. These facts are shown in the following table:

Table showing the number of eggs to lobsters of each size, seasons of 1890 and 1891.

Size.	No. of lobsters.	No. of eggs.	Average No. of eggs to each size.
8 to 8¾ inches	23	149,226	6,480
9 to 10 inches	344	2,642,291	7,600
10 to 11 inches	553	5,763,542	10,400
11 to 12 inches	226	3,095,037	13,600
12 to 13 inches	50	907,330	18,000
13 to 14 inches	9	208,590	23,100
Totals	1,205	12,766,016	10,594

The averages given in this table do not represent the total numbers actually extruded by the females, as in a large percentage of the specimens many of the eggs had been removed by one cause or another before the lobsters were captured. Eels, cunners, and other small rapacious fishes are undoubtedly responsible for much of this destruction. The extreme range in the number of eggs recorded for each size was as follows: In specimens measuring from 8 to 8¾ inches, 3,000 to 12,000 eggs; 9 to 10 inches, 3,000 to 16,500 eggs; 10 to 11 inches, 3,000 to 21,000 eggs; 11 to 12 inches, 3,000 to 24,000 eggs; 12 to 13 inches, 6,000 to 30,000 eggs; 13 to 14 inches, 15,000 to 36,000 eggs.

Over one-fourth of the breeding lobsters were between 9 and 10 inches long, and nearly one-half between 10 and 11 inches long. Only 59 were taken whose size was above 12 inches, and none exceeded 14 inches. It may, therefore, be concluded with respect to the Vineyard Sound region that the average size of the breeding lobsters is much

less than it was ten and twenty years ago, and that much more than half are now under the legal limit of 10½ inches prescribed by the Massachusetts fishery regulations. The search for egg lobsters has also disclosed the fact that the abundance of lobsters is still rapidly decreasing on this coast. During the season of 1890, 59 lobsters with dead eggs were taken, and among the females above 10 inches long caught in this vicinity there was an average of only about 1 with spawn to 12 without spawn. In November, 1890, with 175 traps set, the catch averaged 2 lobsters, measuring 10½ inches and over to each trap per day. There was also an average of 1 egg lobster to every 7 lobsters taken. In February, 1891, 5 traps averaged 1 10½-inch lobster and 10 small lobsters per day. In April, 1891, 400 traps set in the bay and sound averaged about 100 lobsters per day, measuring 10½ inches and over, and about 10 egg lobsters. In May the average per day was 1 large lobster to every 2 traps. Small lobsters were also less abundant than in previous years. At Monomoy, where lobsters were formerly very common within a mile of the point, the fishermen are now required to go nearly to the Nantucket shore to set their traps. The catch in 1890 was only about half that of the previous year.

During October and November, 1890, Mr. Edwards made some interesting observations on the fall molting of lobsters which indicate that the habit of shedding at this season is more common than has generally been supposed. Eight specimens were measured, and the increase in size in each instance, ranging from one-half to 1½ inches, was found to be as follows: From 5 to 6 inches, from 5½ to 6½ inches, from 7½ to 8 inches, from 7¾ to 8½ inches, from 8 to 9 inches, from 8½ to 9¼ inches, from 9 to 10½ inches, and from 11 to 12 inches. The rate of growth seems, therefore, to vary considerably, even among individuals of approximately the same size.

In the fall of 1890 Mr. F. N. Barrett, editor of the American Grocer, New York, called the attention of the Commissioner to the fact that in the canned-lobster trade cans were often found in which the contents had turned black and were unfit for eating. This circumstance had created considerable prejudice against this product, especially in the foreign markets. Many causes had been assigned for the phenomenon, none of which, however, were based upon an investigation of the actual condition of the spoiled goods. Several cans containing the blackened lobsters were sent to Washington, and were placed by the Commissioner in the hands of Dr. William Gray, microscopist of the Army Medical Museum, for analysis. Dr. Gray's studies upon the subject have not yet been completed, but in the discolored patches of muscular tissue he has found a species of bacillus apparently undescribed, which is probably responsible for the changes observed in the color and condition of this product.

Edible Mollusks.

Mr. R. G. Harrison and Mr. J. L. Kellogg, of Johns Hopkins University, were employed at the Woods Holl laboratory during the summer of 1890, under the direction of Prof. W. K. Brooks, to investigate certain natural-history problems relative to the oyster and other edible mollusks, and bearing upon their artificial cultivation. They worked conjointly on the embryology of the oyster, and made experiments respecting the effects of density, temperature, sunshine, etc., on the oyster larva during its free-swimming and fixative stages. They also collected material for a study of the trematode parasites of the oyster and other bivalves, Dr. Brooks having been led to believe that these organisms may have been instrumental in causing the deterioration of oyster beds in some cases. The general investigation of the anatomy, histology, and embryology of lamellibranchs was taken up by Mr. Kellogg and was conducted by him in accordance with modern methods of biological research. It is expected that these inquiries will furnish many important facts regarding the morphology of the common edible bivalves which will be of service to the fish-culturist. They will be continued during the summer of 1891. Dr. Wilson has also, during his investigations at Woods Holl, recorded many valuable observations respecting the breeding habits and organs of the long clam, quahog, mussel, and scallop.

Sponges.

Preliminary to a study of the life history of the Florida commercial sponges, which it is intended shall soon be taken up, Dr. H. V. Wilson began at Woods Holl, in the summer of 1890, an investigation of the breeding habits of certain species occurring in that vicinity. His observations were continued during the following winter and spring, most attention being paid to a silicious form which is common on the wharf at the Fish Commission station. Dr. Wilson found that during the summer and early fall this species, instead of reproducing by means of eggs, does so asexually through the formation of internal buds or gemmules, solid oval bodies which swim about by means of cilia. Similar means of reproduction have been detected in the fresh-water sponges and in the genus *Chalinula*. The formation of these gemmules in the silicious species referred to, the character of the swimming larvæ, and its metamorphosis into the adult sponge, were carefully studied by Dr. Wilson, who, judging also from observations made at the Bahama Islands, is led to believe that this method of propagation is common among marine sponges. Should this hold true with the commercial species, three possible methods of accomplishing their artificial cultivation would thereby be presented, namely, by means of the eggs, by means of the gemmules, and by cuttings. All the practical experiments made in this direction up to the present time have dealt only with the cuttings, and while that method may still prove to be the more satisfactory one, the others might present certain advantages in any attempt to improve the grade of sponges or to distribute them over new grounds.

DISEASES AND PARASITES OF FISHES.

Fishes are subject to a variety of diseases, some of which are local and unimportant, having little or no effect upon the general condition of the fish, while others assume a very serious character, becoming even epidemic in their course and causing the mortality of immense numbers of individuals. But little attention has been paid to the nature or pathology of such diseases or to their treatment, and an important field is, therefore, open for investigations in this direction. It is well known that a large percentage of the disorders which have been observed among fishes is due to parasitism of one sort or another, and as biologists have long been interested in the natural history of the parasites so concerned, much information has been secured regarding the structure and the development of these organisms. This branch of research must, in fact, precede the more special consideration of the relations of the parasites to their hosts and their effects upon the latter; but the time has come when not only the amount of material collected seems ample to begin upon a full investigation of this more practical phase of the subject, but also when the demands for accurate information regarding it have become sufficiently urgent to necessitate its being taken up without delay. Dr. Revere R. Gurley has recently been assigned to the study of these problems.

The parasites which infest fishes belong to both the animal and vegetable kingdoms, and some fishes even are parasitic on others. The groups of crustaceans and worms furnish the greatest variety of known parasitic forms, the former occurring generally on the exterior of the body or in the mouth cavity, the latter in or among the viscera and in the tissues. A majority of these, however, seem to be entirely harmless, but many produce a diseased condition of greater or less extent, and some at least must eventually prove fatal. The protozoan parasites, called psorosperms, give rise to large excrescences on the exterior of the fish, making it very unpresentable in appearance, and undoubtedly soon causing death. Among fresh-water fishes most harm is probably effected by low forms of plants, which often result in a very widespread mortality, as in some of the large northern lakes. Their attacks are not confined to the adults, but extend also to the younger stages and the embryos as well as to the eggs, and in the artificial hatching apparatus they often cause much destruction. A great mortality also occurs among fishes, which has not been traced to parasitism, and of the true nature of which we are still ignorant. One instance of this character is noticed elsewhere in this report, in the account of Prof. S. A. Forbes's observations at Lake Mendota, Wisconsin.

The long-continued investigations by the Fish Commission on the Atlantic coast of the United States, especially in the vicinity of Woods Holl, Mass., have afforded the means of collecting and studying the crustacean and worm parasites of marine fishes under exceptionally

favorable conditions. A few papers bearing upon the former group have appeared in the publications of the Fish Commission and U. S. National Museum from time to time. In 1884 Prof. Edwin Linton, of Washington and Jefferson College, began an exhaustive inquiry respecting the entozoan worm parasites of fishes, which has been continued down to date. Three general papers on this subject have been printed in the annual reports of the Commission for 1886, 1887, and 1888, and a special account of a parasite of the tiger shark in the last-mentioned report. The protozoan parasites occurring on *Cyprinodon* in the Vineyard Sound region, and on cyprinoid fishes in Ohio, have also been discussed by Prof. Linton in the Fish Commission Bulletin for 1889. The entozoan parasites of the trout collected by Dr. Jordan in the Yellowstone Park, in 1890, were referred to Prof. Linton for investigation, and the following year he accompanied Prof. S. A. Forbes on an expedition to the same region, where he was able to study the same forms in a fresh condition and to trace their development through the pelican. An account of his researches in respect to this subject will be found under the heading of the Yellowstone National Park.

The attention of the Commission has been called to several instances where young trout kept in confinement have become blind. Specimens in this condition were carefully examined by Prof. Linton, but no trace of parasitism was discovered. The eyes were congested and there appeared to be an unusual amount of pigment in the choroid coat and in the vicinity of the crystalline lens. It seems probable, therefore, that the trouble arose from some external conditions surrounding the fish, and which affected only the eyes, as the specimens were otherwise in good condition.

COLLECTIONS, PREPARATION OF REPORTS, ETC.

The laboratory established at the Central Station in Washington at the close of the fiscal year 1889 has, up to the present time, met the principal requirements of the work of this division, but it is rapidly becoming overcrowded and furnishes insufficient accommodations for taking proper care of specimens obtained in the investigations now in progress. Very large collections have been received during the past two years, resulting mainly from the explorations of the steamer *Albatross* in the North Pacific Ocean and in Bering Sea, from the oyster surveys along the Atlantic coast, and from the inquiries respecting the lakes and rivers. While it is not proposed to retain permanently in the Fish Commission building more than a type or working series of the specimens thus obtained, yet a considerable time must elapse before any extensive collection can be fully studied and the reports bearing upon it prepared for printing, and ample storage and working space is therefore required for the accommodation of this branch of research.

The study of the fishes has progressed rapidly under the care of Dr. Tarleton H. Bean, the ichthyologist of the Commission, and through

the coöperation of Dr. David S. Jordan and Prof. Charles H. Gilbert, of Indiana University. As elsewhere explained, the fresh-water fishes have been mostly worked up at the last-mentioned institution, and the marine species recently collected by the *Albatross* on the Pacific coast have been sent there to be classified and described by Prof. Gilbert.*

Considering the invaluable assistance received from this source during the past four years, the acceptance by Dr. Jordan of the presidency of the Leland Stanford Junior University is to be regretted in the immediate interests of the Fish Commission, and yet, through his assurance of continued coöperation, the opportunity will now be afforded to make a thorough investigation of the fishery resources of California, a region which has been much neglected in that respect.

Arrangements are now in progress for the study by specialists of high standing of many of the groups of oceanic animals which are richly represented in recent collections from the Pacific coast. This will be done without expense to the Government, and will insure the preparation of a very valuable series of reports upon the more important biological features of the fishing-grounds now in course of examination by the *Albatross*. The higher crustaceans from this region, such as the crabs and shrimps, are now being studied by Mr. James E. Benedict and Miss M. J. Rathbun, of the U. S. National Museum.

Very large collections of fishes and marine invertebrates have been transferred to the custody of the National Museum, and many sets of duplicate natural-history specimens have been distributed for educational purposes, either directly by the Fish Commission or through the medium of the National Museum. The following institutions have been thus supplied: Ohio State University, Columbus, Ohio; Museum of Comparative Zoölogy of Harvard University; Indiana University, Bloomington, Ind.; State Normal School, Terre Haute, Ind.; Purdue University, Indiana; Syrian College, Beirut, Syria; Clark University, Worcester, Mass.; University of South Carolina; Ottawa University, Ottawa, Kans.; Lawrence University, Appleton, Wis.; Muhlenberg College, Allentown, Pa.; University of Wisconsin, Madison, Wis.; High School, Council Bluffs, Iowa; New Orleans University, New Orleans, La.; Woman's College of Baltimore, Baltimore, Md.; Superintendent of schools, Olean, N. Y.; State Agricultural College, Corvallis, Oregon; South Jersey Institute, Bridgeton, N. J.; Dakota Univer-

* A preliminary report on the fishes collected by the steamer *Albatross* on the Pacific coast of North America during the year 1889, with descriptions of twelve new genera and ninety-two new species. By Charles H. Gilbert. Proc. U. S. Nat. Mus., XIII, pp. 49–126, 1890.

A supplementary list of fishes collected at the Galapagos Islands and Panama, with descriptions of one new genus and three new species. By Charles H. Gilbert. Proc. U. S. Nat. Mus., XIII, pp. 449–455, 1891.

Descriptions of thirty-four new species of fishes collected in 1888 and 1889, principally among the Santa Barbara Islands and in the Gulf of California. By Charles H. Gilbert. Proc. U. S. Nat. Mus., XIII, pp. 539–566, 1891.

sity, Mitchell, S. Dak.; Massachusetts Agricultural College, Amherst, Mass.; Nebraska Institute for the Deaf and Dumb, Omaha, Nebr.; St. John's College, Annapolis, Md.; Pennsylvania State College, Centre County, Pa.; Brooklyn Training School, Brooklyn, N. Y.; Mount Vernon Seminary, Washington, D. C.; High School, Bridgton, Me.; Missouri Valley College, Marshall, Mo.; Columbia College, New York, N. Y.; Louisiana State University and Agricultural and Mechanical College, Baton Rouge, La.; State Normal School, Milwaukee, Wis.; High School, Springfield, Mass.; K. K. Naturhistorisches Hof-Museum, Vienna, Austria; British Museum, London, England.

A scheme of exhibits to illustrate the objects and work of this division at the World's Columbian Exposition at Chicago has been prepared in accordance with the directions of the Commissioner. It is proposed to use in this connection actual specimens and appliances where they will serve appropriately, and also models, relief maps, charts, and drawings. The principal subjects to be represented are the following: The economic features of the fauna and flora of the seacoasts and of the lakes and rivers, including the embryology and life history of the more important food-fishes; the general hydrography of the Atlantic and Pacific coasts, and the location, configuration, and principal characteristics of the oceanic fishing-grounds; the lake and river basins, and the distribution, past and present, of fresh-water fishes; the vessels and apparatus used in the investigation of fishing-grounds; laboratories for the study of aquatic life and of fishery problems; temperature, and other physical conditions and variations affecting the distribution of fishery products, and publications bearing upon these different topics.

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