

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

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FUR-SEAL INVESTIGATIONS.

In accordance with a provision of the sundry civil appropriation bill approved March 3, 1893, it was made incumbent upon the Fish Commissioner to continue, under the direction of the Secretary of the Treasury, the annual investigations relative to the conditions of seal life on the Pribilof Islands, which had then been carried on during three seasons; and the Commissioner was also charged with the conduct of further observations respecting the life-history and pelagic habits of the fur-seals. The first of the present series of inquiries on the Pribilof Islands was made during the summer of 1890 by Mr. Henry W. Elliott, a special agent of the Treasury Department, appointed under an act of Congress dated April 5 of that year, which provided for a thorough examination into the status of the fur-seal industry on the seal islands of Alaska, so as to make known its relative condition then as compared with 1872. A novel and important feature of Mr. Elliott's work was the construction of a series of maps showing the precise outlines of each of the breeding and hauling grounds. In 1891, and again in 1892, in connection with the preparation of the case of the United States for the Paris tribunal of arbitration, Mr. J. Stanley-Brown, also acting as a special Treasury agent, conducted corresponding observations, including the delineation of rookery areas occupied by seals, for the convenience of which purpose a set of base maps was prepared and lithographed. An innovation on the part of Mr. Stanley-Brown was the photographing of characteristic parts of each of the rookeries, in order to illustrate graphically the distribution and abundance of the seals upon them.

The summer of 1892 was the last preceding the meeting of the Paris tribunal, and the object in still further continuing the examinations was to provide for maintaining a record of all subsequent changes in the condition of the rookeries, especially under the operations of the Paris award, which had not, however, at that date been concluded. It was, therefore, made a part of the mission of the steamer *Albatross* to repeat the observations of Messrs. Elliott and Stanley-Brown, the naturalist of the steamer, Mr. C. H. Townsend, who had had considerable previous experience with the matter, being specially charged with the conduct of this work. He was stationed at the islands from July 11 to August 18, 1893, and was assisted in the photographic work by

Mr. N. B. Miller. The delineation of the rookeries and the taking of the photographs were all accomplished during the period when seal life was most abundantly represented on the islands—that is to say, when the rookeries had reached their maximum development for the season and before the females had begun their search for food. The views, 46 in number, were taken from the same positions as in 1892, and, so far as the weather permitted, at corresponding dates. The observations related mainly to the abundance of seals as compared with the previous season, the number of bachelor seals available for killing, the effects of long-distance drives and of culling, and the results to be expected from a continuance of pelagic sealing. In accordance with the law, the report of Mr. Townsend was transmitted to the Secretary of the Treasury.

The experience of the *Albatross* in previous years, as well as in 1893, has demonstrated that the pelagic habits of the seals can not be satisfactorily studied by means of so large a vessel, if by a steamer at all, about the only opportunities afforded for examining specimens being on the few occasions when a sealing schooner is boarded. To obviate this difficulty during the season of 1894, arrangements were made before the close of the fiscal year to have Mr. A. B. Alexander accompany one of the vessels actually engaged in pelagic sealing during the open period in the Bering Sea—that is to say, after August 1. The importance of such an undertaking will consist in the advantages to be gained from expert evidence in respect to several of the questions which have given rise to controversy, such as the proportions of each sex found at a distance from the islands, the breeding condition of the females there taken, the feeding habits of the seals, the character of their food, etc.

OPERATIONS OF THE STEAMER ALBATROSS IN THE NORTH PACIFIC OCEAN AND BERING SEA.

During the summer of 1893 the steamer *Albatross*, Commander Z. L. Tanner, U. S. N., commanding, was attached to the sealing patrol fleet operating in the North Pacific Ocean and Bering Sea under the orders of the Secretary of the Navy. Her instructions also provided for the customary fishery investigations and for those relating to the pelagic habits of the fur-seal, as directed by Congress, which were to be carried on to the extent permitted by the requirements of this special detail. Through the cooperation of the senior naval officer in charge, a considerable amount of time was allotted to these inquiries, but they were necessarily restricted to that part of Bering Sea within the limits of possible pelagic sealing.

Leaving Port Townsend, Wash., on May 24, 1893, the *Albatross* followed along the course taken by the seal herds and the sealing fleet as far as Unalaska, whence she proceeded by way of Bering Sea and Amukta Pass to Adak Island, of the Aleutian chain, arriving at the latter place on July 1, the beginning of the fiscal year. The object of visiting Adak Island was to learn if one of its harbors, the Bay of Waterfalls, was being used as a rendezvous by pelagic sealers and

although no vessels were found there at the time, there were indications that it had been so utilized earlier in the season. After making an examination of the harbor, a line of soundings was carried southeasterly to latitude $50^{\circ} 03' N.$, longitude $174^{\circ} 30' W.$, in order to ascertain if the deep submarine trough occurring to the eastward and running approximately parallel with the trend of the Alaska Peninsula and Aleutian Islands extended to this point. A maximum depth of 4,002 fathoms was found in latitude $50^{\circ} 28' N.$, longitude $175^{\circ} 10' W.$, and only 2,802 fathoms at the end of the line, the depression being again crossed in 3,794 fathoms on the way back to Amukta Pass, thus demonstrating the existence of the trough in this vicinity. The beam trawl was used in Amukta Pass, whence a line of soundings was run to the Pribilof Islands, which were reached on July 10. Mr. C. H. Townsend, accompanied by Mr. N. B. Miller, was at once landed to begin upon the work of delineating and photographing the rookeries, as elsewhere explained, this task not being finally completed until August 18.

Until near the end of July the movements of the *Albatross* were governed chiefly by patrol duty and by the necessity of rendering incidental assistance in connection with the party on the islands, but some fishery and hydrographic inquiries were conducted, more especially to the northwestward of the Pribilofs. Before the close of the month, however, the investigations were taken up on a more comprehensive basis, and they were continued systematically until September 3, although patrol service remained a necessary adjunct of the work. The plan as carried out provided for regular series of observing stations along 13 lines equally distant from one another and radiating from a common center located midway between St. Paul and St. George islands. The length of each of these lines or radii was 225 miles, the area covered being, therefore, circular in shape and 450 miles in diameter; it extended a considerable distance beyond the border of the shallow platform to the south, east, and southeast of the islands, but the bulk of the work was done inside of the 100-fathom curve, which practically marks the outer limit of profitable fishing-grounds.

The inquiries comprised the customary examinations respecting the depth and temperature of the water; the character, condition, and richness of the bottom; the food-fishes of the region, their distribution, abundance, size, quality, etc., and the additional ones relating to the fur-seal. It was found to be impossible, however, to obtain satisfactory results in respect to the pelagic habits of the seal, which, quickly alarmed at the approach of any object, is especially distrustful of a steamer under way, and the most that could be accomplished was to record the positions of those noticed from the deck. Under the circumstances, therefore, it was not considered expedient for the ship to deviate from the regular courses laid out in connection with the fishery work, and the number of seals observed was undoubtedly much smaller than would have been the case had they been hunted for persistently. Seals were seen along 11 of the 13 radiating lines, the most distant

positions being from 180 to 200 miles from the Pribilof Islands in north-easterly, northwesterly, southwesterly, and southerly directions. With respect to their feeding-grounds in August, Commander Tanner makes the following remarks:

The 100-fathom curve from the one hundred and seventieth to the one hundred and seventy-fourth meridian is a favorite feeding-ground, where scattered seals were frequently observed from the decks of the vessel, a sure indication that it would have been a prolific hunting-ground had we hove to and sent out boats. Next to this region, the largest numbers were observed near the northern extremity of radial No. V, and it soon became evident that the August feeding-grounds were to the westward of the meridian of the Pribilof Islands. Earlier in the season they would doubtless have been found in greater numbers east of that meridian, where their food, composed largely of codfish, would still abound in the shoaler waters of eastern Bering Sea.

The restriction of the fishery work to a period of scarcely more than a month's duration made it necessary to so hasten its progress that the fishing trials could not, in most cases, be conducted with sufficient thoroughness to satisfactorily demonstrate the productiveness of the different grounds examined. Notwithstanding this fact, however, the results obtained have enabled Commander Tanner to reach certain conclusions which it is important to note in this connection. So far as known at present, Baird Bank and Slime Bank, in Bristol Bay, described in previous reports, afford the only profitable cod fishing in Bering Sea on a commercial basis, although this species has also been taken to a slight extent on the Kulukak Ground and is sufficiently abundant along the shores of the Aleutian Islands to supply the local demand. With respect to other parts of the sea, Commander Tanner makes the following statement:

Banks have been reported in various parts of Bering Sea, but we have no data at present that would justify a fisherman in visiting them as a commercial venture. A vessel can anchor anywhere inside of the 100-fathom line and by persistent fishing take enough to "fill the decks," to use a common expression, where a mess for all hands has been caught. The same may be done in calm, smooth weather, when the ship is lying dead in the water, yet the locality might be worthless commercially; and, in fact, such is the case over the greater portion of Bering Sea. The search for cod in paying quantities would be confined to spots where the bottom is free from mud, and a glance at the chart will show the prescribed areas where success would be probable.

First, a stretch of 60 miles or more will be observed ESE. (mag.) of St. George Island, in from 70 to 80 fathoms, coarse sand and gravel, and fine dark sand, near the 100-fathom curve. Another spot having favorable indications lies about 50 miles NE. by N. (mag.) from the island, in 40 fathoms, gray sand and rocky, and fine gray sand. A region of considerable area, having promising features, lies from 180 to 200 miles NE. (mag.) of St. Paul Island in from 20 to 30 fathoms, fine gray sand and shells. A spot about 42 miles N. by W. $\frac{1}{4}$ W. (mag.) from northeast point of St. Paul Island has been reported as a bank, and has favorable indications, in about 40 fathoms, sand and gravel. There are other places between the above spot and Nunivak where a certain degree of success might be expected, although our examination did not develop a particularly rich fauna. There is also a region near the 100-fathom curve, in from 70 to 90 fathoms, fine gray sand and rocky bottom, lying from W. by S. to SW. by W. (mag.) of St. Paul Island, which promises well, although the depth is greater than fishermen are in the habit of resorting to in this region.

The report of the fishery expert, Mr. A. B. Alexander, gives the experience of this vessel in fishing with hand lines from the rail, but in considering the results it must be remembered that the vessel was always under way, frequently drifting rapidly before boisterous winds and heavy seas. The duration of trials never exceeded 20 minutes, and other work was frequently carried on when line fishing was impracticable; hence some of the most favorable localities escaped a fair trial with hook and line.

It is reasonable to suppose that the presence of cod varies with the seasons in the shoal waters of Bering Sea, as in other localities, and that they will be found in greater depths as summer approaches. The *Albatross* has never taken halibut in any considerable quantities in Bering Sea, and none of large size. The conditions under which trial lines have been used were particularly unfavorable for the capture of this slow-biting fish. Trawl lines set on favorable bottom near the 100-fathom line would be an interesting experiment, from which good results might be expected to follow.

Incidental to the specific objects of the cruise in Bering Sea, attention was also given, as heretofore, whenever the opportunity offered, to the requirements of navigation, in the direction of perfecting the information relative to harbors, coast lines, the passes between the islands, etc. In view of the dangers attending navigation in this region and the limited surveys hitherto made there, this work can not fail to be of great practical benefit, especially considering the number of vessels which now assemble in Bering Sea every season in connection with the fur-seal fishery. With respect to the principal harbor, located at the entrance to the sea, Commander Tanner summarizes his results as follows:

Great difficulty has frequently been experienced in making Unalaska in thick weather in the absence of soundings, and we have from time to time run lines from the 100-fathom curve to Unalaska Bay, which were supplemented after our departure from Unalaska by a line from Priest Rock, off Kalekhta Point, to the north head of Akutan, and thence to Akun, the route usually followed by steamers between Unimak Pass and Unalaska. These soundings, with others we have made in the vicinity of the Fox Islands, will, when plotted on a chart of large scale, greatly assist the navigator, inasmuch as it will make the lead available.

The work in Bering Sea terminated early in September, and on the 9th of that month the *Albatross* left Unalaska bound south. In accordance with the directions of the senior naval officer, a course was first laid along the south side of the Alaska Peninsula as far as Kadiak for the purpose of intercepting, if possible, certain vessels for violation of the hunting regulations. From off Cape Greville, Kadiak, soundings were made to the vicinity of Cape Edgecumbe, Baranof Island, with the object of investigating the circumstances connected with a reported discoloration of the water in the neighborhood of latitude $57^{\circ} 16' N.$, longitude $143^{\circ} 11' W.$, but only deep water and normal conditions were discovered along all parts of the line. Sitka was reached September 17, Port Townsend on the 24th, and the Mare Island navy-yard on the 30th. The control of the movements of the ship by the Navy Department was relinquished on October 16, but the work of repairing and refitting detained her at the navy-yard until the end of the calendar year.

As the appropriation would not permit continuous operations during the winter, the *Albatross* was ordered to San Diego, where a survey of the bay was considered desirable, and where the health of the crew

could best be assured. She reached that locality on January 4, 1894, and remained there until March 27, the examination of the bay being conducted by Mr. N. B. Miller, under the direction of Commander Tanner, and relating to its general fishery resources and its advantages for oyster cultivation. Returning to the Mare Island navy-yard the last of March, Mr. Townsend and Mr. Alexander were dispatched to the Puget Sound region to make inquiries respecting the character and conditions of the sea and salmon fisheries adjacent to the international boundary line in the interest of the joint investigation elsewhere described. On April 11 the ship was again placed under the orders of the Secretary of the Navy for detail to sealing patrol service during the season of 1895, and on April 19 she reached Port Townsend, the first rendezvous of the fleet. Nearly a month was spent in this region, such time as could be spared being given to cooperating with Messrs. Townsend and Alexander in the local inquiries above referred to.

Commander Tanner relinquished his command on May 1, being succeeded by Lieut. Commander F. J. Drake, U. S. N., and on May 17 the *Albatross* proceeded north in company with the flagship, the U. S. S. *Mohican*. The course was first to Unalaska, and thence to Attu Island, at the western end of the Aleutian chain, where Lieutenant Jacobs, United States Revenue Marine, was landed. Returning eastward, an outlook was maintained for the purpose of intercepting any sealing schooners which might approach from the westward with the intention of entering Bering Sea. Stops were made at the islands of Agattu, Kyska, and Atka, and the fishing-grounds in their vicinity were hastily examined. The latter part of June was occupied in patrol duty and in conducting observations relative to the distribution and pelagic habits of the fur-seal to the eastward and the southeastward of the Pribilof Islands, fishing trials being also made in the same connection. The instructions for 1895 contemplated the same combination of fishery and sealing work that had been carried on the previous season.

During the year the *Albatross* had been at sea 138 days, and had steamed 17,269 miles. The number of fishing and dredging stations occupied was 223, and of hydrographic stations 259. The civilian scientific staff consisted of Mr. C. H. Townsend, naturalist; Mr. A. B. Alexander, fishery expert; and Mr. N. B. Miller, laboratory assistant. Mention should also be made of Mr. H. C. Fassett, the captain's clerk, for his efficient services in preparing the charts illustrating the results of the investigations.

The retirement from active service with the Fish Commission, near the close of the fiscal year, of Commander Z. L. Tanner, U. S. N., has been the cause of deep regret, to which the writer ventures to give expression in this connection. Illness, following an attack of grip, made it imprudent for him to risk the exposure or assume the arduous duties attendant upon a northern cruise during the summer of 1894, and hence the action taken, at his own request. Commander Tanner was first assigned to duty with the Fish Commission as in charge of the tempo-

rary dredging steamer *Speedwell* in 1879, which led to his being selected by Professor Baird to supervise the planning and construction, first, of the steamer *Fish Hawk*, and, later, of the steamer *Albatross*, each of which he commanded in succession. The exceptional advantages afforded by these two vessels for marine investigations have, through his energetic and appreciative cooperation, been utilized to the greatest possible extent, the appliances for research have been developed and perfected to a degree not elsewhere approached, and the results accomplished in the lines both of fishery and of deep-sea exploration have greatly surpassed those by any other nation. After an experience of nine years on the Atlantic coast, during which his work extended from Newfoundland to South America, he was especially qualified to enter the comparatively unknown region of the North Pacific Ocean and Bering Sea, with which his name will ever remain associated as the earliest practical exponent of its fishing-grounds and fishery resources. Commander Tanner has in course of preparation an important paper descriptive of the methods of investigation employed on board the *Albatross* and of the history of their development.

JOINT INVESTIGATION OF FISHERIES IN WATERS CONTIGUOUS TO CANADA AND THE UNITED STATES.

On December 6, 1892, an agreement was entered into between Great Britain and the United States for the investigation, by a joint commission of two experts, of the fisheries prosecuted in the territorial and contiguous waters of Canada and the United States, with the object of determining the regulations, practices, and restrictions proper to be adopted in concert for their preservation. The provisions of this agreement, the subjects and territory comprised within the scope of the inquiry, and the work accomplished to the end of the fiscal year 1892-93 were explained in the last annual report. At the close of that year the two representatives, Dr. William Wakeham on the part of Great Britain and Mr. Richard Rathbun on the part of the United States, were at Eastport, Me., having made a rapid reconnoissance of the mackerel fishery northward from New York City. Mr. R. Venning, of the department of marine and fisheries of Canada, accompanied Dr. Wakeham until July 8, and Dr. Hugh M. Smith, of the United States Fish Commission, acted in conjunction with Mr. Rathbun until July 21.

During a large part of July the Commission was engaged in investigating the mackerel in the Gulf of St. Lawrence, having the use for that purpose of the Canadian fishery cruiser *Acadia*, Capt. O. G. V. Spain commanding, by which means all the principal fishing centers were visited in rapid succession, the movements and spawning habits of the fish being studied, and many fishermen interrogated respecting the abundance of the species and condition of the fishery. Returning again to Eastport, Me., a temporary laboratory was established there to provide the means for studying the marine and especially the herring fisheries of Passamaquoddy Bay and adjacent waters. The *Fish Hawk* was detailed to the region to assist in the work, which was carried on

by Mr. H. F. Moore, of the University of Pennsylvania, and Mr. W. O. Kendall and Mr. B. L. Hardin, of the Fish Commission. This party continued its inquiries into November, making observations also respecting the fresh-water fishes in the upper St. Croix River.

By the end of July the members of the Commission had begun the examination of the St. Croix and St. John river basins, which are contiguous to Maine on the one side and to New Brunswick and Quebec on the other. Attention was first paid to the St. Croix River, including the main stream and its two branch systems, together with the interesting chain of lakes which constitute the most conspicuous features of the latter. An important part of this investigation was the survey, by the steamer *Fish Hawk*, under Lieut. Robert Platt, U. S. N., of the extensive beds of sawdust which encumber the upper tidal channel of the river from near the "Ledge" to the Calais-St. Stephen bridge.

The St. John River was next taken up, and all important places along its course were visited from the Bay of Fundy at its mouth to the St. Francis River in the upper part of the main valley. Examinations were also made of the Aroostook and Meduxnickag rivers, the two most important western tributaries of the lower basin lying chiefly in the State of Maine and formerly resorted to by many salmon. This species is the principal one of international concern in both the St. John and St. Croix rivers, in which its numbers have been greatly reduced through the building of dams and the polluting and obstructing influences of factory refuse, although excessive fishing may also have been partly responsible for this result.

After completing the work on the Maine border Dr. Wakeham and Mr. Rathbun proceeded to the upper part of the St. Lawrence River, where they began the examination of the basin of the Great Lakes, their investigations extending westward along the northern sides of Lake Ontario and Lake Erie as far as the Detroit River, where the season's field work was completed about the middle of October.

During November sessions of the Commission were held at Gloucester, Mass., Portland and Eastport, Me., where the testimony of many mackerel and other fishermen was obtained and recorded stenographically. Dr. Hugh M. Smith was present at Gloucester and took part in the examinations.

In the spring of 1894 arrangements were completed for a thorough study, during the succeeding summer and fall, of the natural history of the fishes and the methods and statistics of the fisheries throughout the boundary waters of the chain of the Great Lakes and adjacent regions. The statistical inquiries were to be under the direction of Dr. Hugh M. Smith, the natural-history topics and the relations of the fishes to the different methods of capture employed being assigned to several parties, as follows: Lakes Ontario, Champlain, and Memphremagog, and the upper St. Lawrence River to B. W. Evermann and R. R. Gurley, of the Fish Commission; Barton A. Bean, of the National Museum, and R. H. Hinckley, of Bowdoin College; Lake Erie and Lake

St. Clair to H. F. Moore, B. L. Hardin, and Cloud. Rutter; Lake Huron to J. T. Scovell and D. C. Ridgely, of Indiana; Lake Superior and Lake of the Woods to A. J. Woolman, of Duluth, Minn. Work was begun on Lakes Ontario, Erie, and Huron early in June, Mr. Rathbun also spending some time with the party on Lake Erie during that month, and taking the field for the season just before the close of the fiscal year.

OYSTER INQUIRIES.

MOBILE BAY AND MISSISSIPPI SOUND, ALABAMA.

During February and March, 1894, a survey of the oyster beds of Mobile Bay and Mississippi Sound, Alabama, was made by Mr. Homer P. Ritter, assistant, United States Coast and Geodetic Survey, who had been specially detailed for that purpose, and who was assisted by Mr. W. F. Hill, of the Fish Commission, and Mate James A. Smith, U. S. N., of the steamer *Fish Hawk*. A small steamer, suitably equipped, belonging at Mobile, was employed for the use of the party. The limited time available for the inquiry prevented its being made as exhaustive as will eventually be desirable, but the work was executed in a methodical and thoroughly reliable manner, and, within the limits of the bay, is supposed to have been sufficiently comprehensive in scope to meet the present requirements of oyster fishermen of the region.

The principal object of the investigation, as stated in the instructions, was to determine the positions, outlines, characteristics, and richness of the different oyster beds, and the location and extent of all areas of bottom which appear to be suitable for oyster-planting, either in their natural condition or after preparation. During the period when the survey was in progress extensive freshets prevailed in the neighboring region, causing the bay to become nearly filled with fresh water, which extended far out into Mississippi Sound. The densities were therefore again observed by Mr. Ritter in the following December, when more normal conditions were found to exist. In his report,¹ which is accompanied by a large chart, showing graphically the results accomplished, Mr. Ritter states:

The investigations were confined principally to the waters of Mobile Bay and the eastern end of Mississippi Sound. The location and extent of the natural oyster beds are shown, as is also the density of the water in the different parts of the bay, showing what it was during a heavy freshet and also after the succeeding protracted drought. The depth of water and nature of the bottom are also indicated wherever examined. * * * From the most reliable information we could gather, and which is borne out by our investigations, the northern limit for oyster growth in Mobile Bay is a line extending from Fowl River on the west to Great Point Clear on the east. The location of the oyster beds as shown on the chart indicates that in the bay the greater part of the natural oyster beds lies between the 6-foot and 12-foot curves. From all the information we could obtain the local impression seems to be that few if any oyster beds exist beyond the 12-foot curve.

¹ Report on a Reconnaissance of the Oyster Beds of Mobile Bay and Mississippi Sound, Alabama, by Homer P. Ritter, assistant, U. S. Coast and Geodetic Survey, Bull. U. S. Fish Com., xv, for 1895, pp. 325-339, pls. 56-63.

The total acreage of the reefs surveyed on the east side of the bay was less than 500 acres, but the oysters are generally large and of fine quality. The known reefs are few, of small size, and considerably depleted, owing doubtless to excessive fishing. Oyster planting is carried on to quite an extent in the southeastern part of this side of the bay, especially in and around the mouth of Bon Secours River and in Oyster Bay. The natural oyster-grounds are more extensive on the west side of the bay, the beds are larger, and at present are in a more flourishing condition. They seem to lie more in the pathway of the fresh waters coming from the large tributaries at the head of the bay, which may produce a more abundant supply of food, although at times these fresh waters may be a source of danger if too long continued. The total area of natural reefs surveyed on this side of the bay was 2,245 acres.

Only a few days could be given to the examination of Mississippi Sound, which for a distance of 15 miles east and west belongs within the State of Alabama, and detailed observations were, therefore, impossible. This territory merits further attention at an early date, its advantages for oyster cultivation suggesting the utility of a careful investigation. The water area embraced within the State, north of a line extending due west from the western end of Grant Pass, is roughly estimated at 35,000 acres, two-thirds of which has less than 6 feet of depth, and the remaining one-third averaging less than 9 feet. That much of that area may be considered suitable for oyster cultivation is borne out by the circumstances that oysters are growing in all parts of it. There may also be added to it no less than 10,000 acres of marsh, which if the occasion should demand might with a comparatively slight outlay for dredging be changed into canals or basins for oyster purposes. Little is known of the southern part of the sound, in which the water is of greater depth.

BEAUFORT, N. C.

During the late spring and early summer of 1894 observations and experiments relating to the oyster were carried on at Beaufort, N. C., by Mr. C. P. Sigerfoos, of Johns Hopkins University, under the immediate direction of Dr. W. K. Brooks. The plan contemplated the utilization of a tract of tide-water marsh land on the Government reservation at Fort Macon, by the damming of one of the creeks flowing through it, in order to control the supply of water as desired and to test its nutrient value to the oyster. Unfortunately these arrangements could not be perfected, owing to the lateness of the season when the work began, but other experiments respecting the feeding of the species were conducted on a smaller scale and with significant results.

Although a complete report upon the investigation has not yet been submitted, it may be said that noteworthy progress was made in the attempt to rear oysters from the egg, a subject to which Dr. Brooks has given much attention, but not to the extent of entirely overcoming the difficulties previously existing in that respect. In connection with

all former experiments it had been impossible to discover any food suited to the larval oysters, or any means of renewing the water without losing the latter, owing to their small size, and they soon ceased to grow, dying of starvation. Mr. Sigerfoos was successful in devising a partially satisfactory method for replenishing the water and in finding that the young will feed voraciously upon a certain kind of alga after it has been finely powdered in a mortar. Under this treatment they grew rapidly for some time and large quantities were carried in good health past the stage where the former experiments met with failure, but after a while the remains of the powdered alga, which were so minute that no way of getting rid of them could be found, caused the water to become vitiated with the inevitable result of destroying the larvæ. It is intended to continue these studies at a future time. A good series of the young attached oysters of all stages from one hour up to maturity were obtained and preserved for examination.

Mr. Sigerfoos also began upon a study of the shipworm (which is quite abundant in this region) from both a scientific and practical standpoint, securing material for a complete life-history of three species. It is expected that important results will be obtained, suggestive of more effective methods of protecting submerged timber against its inroads than are now recognized. A full report upon the subject is in course of preparation; a short preliminary paper on the development of the several forms observed has been published.¹

INQUIRIES RESPECTING THE MACKEREL, MENHADEN, ETC.

MACKEREL.

The investigations respecting the habits and abundance of the mackerel and the fisheries to which this important species gives rise were continued again this year upon the same general plan as in 1893, but on a more elaborate scale and during a greater part of the season. The schooner *Grampus* and steamer *Fish Hawk* were both utilized in connection with this inquiry, and several land parties were employed to study the subject from the standpoint of the inshore fisheries along the entire coast covered by the range of the species. The information sought to be obtained from this series of observations was desired for the use of the Joint International Commission, as elsewhere explained, and the practical importance to the American fishermen of reaching a more complete and definite understanding of all the circumstances connected with the natural history of the mackerel, in relation to the several methods employed for their capture, has long been acknowledged.

Until this work was started by the Fish Commission a few years ago, most of the facts at hand were such as had been obtained incidentally, and it is only within a year or two that the matter has been taken hold of in the systematic and comprehensive manner which it deserves. The

¹The *Pholadidae*; note on the early stages of development. By C. P. Sigerfoos, Johns Hopkins University Circulars, XIV, No. 119, June, 1895, pp. 78, 79.

mackerel fishery has long been the subject of a vigorous controversy, both domestic and international. Each year the same phases are repeated; the fish first appear off our coast above Cape Hatteras, whence they spread rather rapidly toward the north and east as far as Labrador, giving rise to one of the most active and persistent fisheries of the world. Their abundance, within the scope of observation of the fishermen, varies from year to year, and at times the fluctuations are very great, periods of plenty of greater or less duration being followed by others of scant supply, bringing consternation to those whose fortunes are mainly linked with this species.

The improvement of methods for the capture of mackerel has kept pace with the steady development in other lines of industry until it would appear as though the limit of perfection had practically been reached. One of the most important questions of the day is whether, as some affirm, the modern devices are proving too destructive and are causing a depletion, in view of the lessened catch during several years past. To those who are at all acquainted with the history and character of the mackerel fishery, it will be evident that this question can not be answered offhand, and that the published observations respecting the natural history of the mackerel do not meet the requirements of a thorough consideration of the matter. To supply this desideratum so far as possible, has been the object of the inquiries now in progress.

These inquiries have been directed so as to cover at least the more essential features in the history of the mackerel during that part of each season when their presence along the coast becomes apparent through their surface distribution, the only period when they can be fished for. It has been attempted to trace their movements and all the principal circumstances connected therewith from the time of their first appearance in the spring until cold weather causes their return to winter quarters; to learn the extent and relations of the schools, the conditions which accelerate or retard their progress, and the factors which influence their swimming at different depths, whereby the great body of the fish may travel long distances unobserved; to settle definitely their spawning-places and seasons and their habits in that connection; to ascertain the effect upon the schools of the different fishing methods apart from the simple question of the quantity of fish so captured; and from the data thus secured, as well as from statistics of the catch, to determine, so far as possible, if the stock is being decimated and the causes which may be directly responsible therefor.

The schooner *Grampus* started south from Gloucester, Mass., on April 7, to repeat the customary examinations on the southern grounds during the early spring season, but heavy gales retarded her movements in the beginning, as well as interfered with the operations of the fishing vessels. Lewes, Del., was made the headquarters from April 20 to May 10, but the *Grampus* remained constantly with or in the neighborhood of the fleet, as the best means of keeping track of the schools of fish, making a careful series of physical observations at hourly

intervals, towing for mackerel food, and recording all facts obtainable from the fishing captains or by personal observations respecting the positions of the schools each day, their extent, movements, depth, the abundance, size, and condition of the fish, etc. From the extreme south the *Grampus* followed the main body of the fish to the region off New York, and thence proceeded eastward over Georges Bank to Cape Sable and the Nova Scotia coast. Here the mackerel were studied during their progress to the Gulf of St. Lawrence as far as Cape North, stops being made at Shelburne, Liverpool, Beaver Harbor, and North Sidney, in search of such information as could be gained from the local fisheries in the neighborhood of those places.

On June 13, the main part of the down run of mackerel having ended and the spring season closed on the cape shore, the *Grampus* left North Sidney and returned to Gloucester, first passing around the north side of Cape Breton and through the Gut of Canso, in quest of further data. Gloucester was reached on June 25, and the remainder of the month was spent in preparations for a summer cruise on the mackerel grounds in the Gulf of Maine. This work was in charge of Mr. E. E. Hahn, master of the *Grampus*, with Mr. W. C. Kendall as naturalist.

Mr. B. L. Hardin was stationed again this year at Fulton Market, New York City, from April 21 to the last of May, his observations being mainly supplemental to those conducted on board the schooner *Grampus* and directed chiefly toward completing the records bearing upon the early offshore fishery. Every fare landed by the purse-seiners from the southern grounds, as well as all specimens received from the shore fisheries tributary to New York, were inspected by Mr. Hardin, and everything that could be learned relating to their capture and conditions was fully noted. Convenient office and laboratory accommodations were supplied gratuitously by Hon. E. G. Blackford, through whom and the other prominent fish-dealers of the city, Mr. Hardin was afforded the fullest opportunity for the successful prosecution of his inquiries.

Mr. H. F. Moore, of the University of Pennsylvania, was detailed to the study of the shore fisheries from their southern limit at Virginia Beach, Va., to Rhode Island. His work was begun at the south at the commencement of the season, and was carried northward, all of the principal fishing centers being visited, the fishermen interrogated, specimens examined wherever possible, and blanks left to be filled in with daily records of the catch. In this manner a very complete account was secured of the shore relations of the mackerel during the period of their early movements, a subject which had not hitherto been given much attention.

Dr. W. E. Wolhaupter was given the section of coast from Rhode Island to the outer side of Cape Cod, including the important spawning and hooking grounds between Block Island and Nomans Land, and the extensive trap-net fisheries of Vineyard and Nantucket sounds.

The steamer *Fish Hawk* also assisted in the work here during a part of June. The region between Cape Cod and the Bay of Fundy, including the coast waters of Massachusetts, New Hampshire, and Maine, and the Gulf of Maine, was assigned to Capt. A. C. Adams, formerly in command of the schooner *Grampus*, and having a long experience in connection with the mackerel fishery. His inquiries were started at Provincetown on Cape Cod, about the middle of May, and were thence extended along the shores of Massachusetts Bay, Cape Ann, and the coast farther north to Portland, where he was joined by the steamer *Fish Hawk* and Dr. Wolhaupter in the latter part of June. By the close of the year the examination had been carried as far east as Boothbay Harbor.

MENHADEN.

From the 1st of March to early in May, 1894, the steamer *Fish Hawk*, Lieut. Robert Platt, U. S. N., commanding, was stationed in the lower Chesapeake Bay investigating the spawning and other habits of the menhaden and making observations respecting the natural history of the other economic fishes of the region, and the fisheries to which they give rise. Mr. W. C. Kendall was on duty as naturalist during the first part of the season, being succeeded later by Dr. W. E. Wolhaupter. The collecting work was carried on by means of seines, fyke nets, gill nets, and the beam trawl, and specimens were obtained from the fishermen wherever possible. In this manner much important information was secured relative to the life-history, distribution, seasons, food, spawning characteristics, etc., of several species. Physical observations relating more especially to the temperature and density of the water were also conducted at frequent intervals during the entire cruise.

The fact seems to have been quite conclusively established, through recent observations, that the menhaden resort to shallow, protected coastal waters, such as bays, inlets, and the lower parts of rivers and creeks, for spawning purposes, and that the young remain for a considerable length of time in the same or similar situations, but persistent investigations have failed to discover the mature fish in the act of breeding. A few specimens have been secured from time to time containing ripe eggs or ripe milt, but ripe individuals of both sexes have never yet been taken together, thus precluding the fertilization and hatching of the spawn artificially, whereby the conditions necessary to that process could positively be ascertained. The *Fish Hawk* was again unsuccessful in regard to the matter this spring, but many interesting observations on the young of different stages and on the adult fish were obtained, and from the evidence supplied by the fishermen and by the condition of the fish it was concluded that the spawning period in the Chesapeake Bay region occurs probably in February or March, or during parts of both of those months.

Mr. Vinal N. Edwards, of the Woods Hole Station, also gave much time during the spring of 1894 to the study of the menhaden question

in the region about Buzzards Bay, where that species is known to spawn abundantly, and where Mr. Edwards has conducted extensive inquiries on the subject during several years past.

TILEFISH.

During a part of July and August, 1893, the schooner *Grampus* was employed, under the immediate direction of the Commissioner, in making fishing trials along the margin of the Gulf Stream slope off the coast of southern New England, New York, and New Jersey, for the purpose of determining the present range and abundance of the tilefish, in continuance of the examinations conducted during the past few years, as described in previous reports. A number of specimens, weighing from 7 to 20 pounds apiece, were obtained, and the reestablishment of the species seems to be assured, although it does not appear as yet to have been restored to its old-time abundance.

TEMPERATURE OBSERVATIONS.

The Fish Commission has continued to receive, through the courtesy of the Light-House Board and the Southern Pacific Company, the daily records of water-temperature observations taken at many seacoast and inland stations, as follows:

Temperature stations on the Atlantic Coast.

Stations of the Light-House Board:

- Coast of Maine: Petit Manan Island, Mount Desert Rock, Matinicus Rock, Seguin Island, Boon Island.
- Coast of Massachusetts: Race Point, Pollock Rip light-ship, Great Round Shoal 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 Shoal 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: Windmill Point, Stingray Point, York Spit.
- Coast of North Carolina: Cape Lookout, Frying Pan Shoal light-ship.
- Coast of South Carolina: Rattlesnake Shoal light-ship, Martins Industry Shoal light-ship.
- Coast of Florida: Fowey Rocks, Carysfort Reef, Dry Tortugas.

Temperature stations on the Pacific Slope.

Stations of the Southern Pacific Company:

- Sacramento River at Tehama and Yolo bridges and Kings Landing, California.
- Feather River at Feather River Bridge, California.
- American River at American River Bridge, California.
- Mokelumne River at Lodi, Cal.
- Tuolumne River at Modesto, Cal.
- San Joaquin River at the upper and lower railroad crossings.
- King River at Kingsburg, Cal.
- Colorado River at Yuma, Ariz.

WOODS HOLE LABORATORY.

The Woods Hole laboratory of the Commission was kept open, as usual, during the summer of 1893. A few investigators arrived there in June, but the largest attendance was during July and August. The laboratory was in charge of Mr. J. Percy Moore, instructor in biology in the University of Pennsylvania. The Commissioner was also present during the most of the season, aiding and advising in the direction of the work, and conducting experiments relative to fish-cultural subjects.

The others in attendance were as follows: Prof. Francis H. Herrick, of Adelbert College; Dr. William Patten, of Dartmouth College; Dr. Bashford Dean, of Columbia University; Dr. John A. Ryder and Mr. H. F. Moore, of the University of Pennsylvania; Dr. E. A. Andrews and Dr. George P. Dreyer, of Johns Hopkins University; Dr. H. V. Wilson, of the University of North Carolina; Dr. Charles B. Davenport, Mr. H. V. Neal, and Mr. Conkling, of Harvard University; Mr. James I. Peck, of Williams College; Prof. D. S. Kellicott, of the University of Ohio; Prof. R. C. Schiedt, of Franklin and Marshall College; Mr. John Y. Graham, of Princeton College; Mr. B. L. Hardin, of the Fish Commission; Miss Elizabeth Cooke, of the University of Chicago; Miss Ida Hyde, of Bryn Mawr College, and Miss M. H. Carter, of Boston.

Of these, Mr. J. Percy Moore, Professor Herrick, Mr. Peck, Dr. Dean, Mr. H. F. Moore, and Mr. Hardin were engaged upon investigations in the interest of the Fish Commission. The remainder were accorded the privilege of the laboratory for carrying on such special biological researches as they desired to undertake on their own account, in accordance with the custom which has prevailed since the establishment of the station by Professor Baird. The presence of such independent workers involves no extra expense upon the Government, and is fully justified both by the private subscriptions from scientific sources which rendered possible the purchase of the land on which the station is located, and by the benefits indirectly derived by the fishing industries from the results of all such inquiries.

The time of Mr. J. Percy Moore was given mainly to the study of the embryology and food of some of the more important market fishes. The station was not opened until after the close of the spawning season of both the menhaden and mackerel in this region, an examination of fresh specimens showing that the season had ended with the former about the middle of June, and with the latter perhaps a week later. From the study of alcohol specimens of menhaden, preserved from day to day by Mr. Edwards during the earlier part of the run, Mr. Moore is led to believe that in the case of that species the greatest spawning activity in the vicinity of Woods Hole occurs between May 15 and June 15, this conclusion agreeing essentially with the results of previous

observations by Mr. Edwards on the spawning conditions of the living fish. Inquiries were also made relative to the spawning of other species, to the age or size at which the menhaden, mackerel, and scup first begin to spawn, and to the anatomy of the adult menhaden, of which a number of drawings were made.

The fishes whose food was studied were the mackerel, cod, haddock, lake, scup, sea bass, weakfish, bluefish, and tilefish. Over 1,000 stomachs of the common mackerel (*Scomber scombrus*), besides a small number of the chub mackerel (*Scomber colias*), were examined. The majority were taken in the neighborhood of Woods Hole the latter part of June and during July and August, when the food was found to consist almost exclusively of surface amphipods, copepods, squids, and sand eels (*Ammodytes*), one or other of these forms or groups preponderating according to locality or time. The stomachs of over 200 individuals brought by the schooner *Grampus* from the coast of Nova Scotia, where they had been captured during the spawning season, furnished interesting results in respect to their habits at such times, as their contents consisted chiefly of bottom living animals, many of which were also discovered in the stomachs of cod and haddock taken in the same localities. Although copepods and appendicularia were abundant at the surface at the same time, as proved by the results of surface towings, these forms were detected in only two of the stomachs.

Mr. H. F. Moore and Mr. Hardin assisted in the study of the mackerel, but they remained at the station only a short time, being ordered to other parts of the coast on Fish Commission work.

Professor Herrick continued his researches on the natural history of the lobster, a work begun in 1889, in preparation for the writing of a complete monograph of the species, to include a discussion of all subjects relative to its structural features, life-history, habits, etc., which are important for consideration in connection with its protection and increase by legislative action and by propagation. The drawings for the report, which are being prepared by Professor Herrick himself, are not only noteworthy for their accurate representation of structural details, but they also exhibit a degree of finish and beauty of execution that will make them a popular object lesson in natural-history illustration.

During this season Professor Herrick also visited the principal lobster-fishing centers along the coast of Maine and Massachusetts for the purpose of extending the scope of his observations and of obtaining materials for study from additional localities. With the assistance of Mr. V. N. Edwards, inquiries were also continued at Woods Hole during the winter of 1893-94 and the following spring to determine the entire range of the breeding period of the lobster—that is to say, the time during which the extrusion of the eggs takes place—as well as other important questions respecting its winter habits. A number of lobster traps were kept set continuously, their contents being removed every

day and each lobster subjected to a detailed examination, all of the points on which information was desired being carefully noted and recorded.

The studies of Dr. Peck related chiefly to the food and feeding habits of the menhaden, which resort in considerable numbers to the region adjacent to Woods Hole, and his report¹ upon the work accomplished must be given a place in the front rank of biologic-economic contributions, both for the thoroughness with which the subject was treated and the uniqueness of the results. But few specimens of menhaden could be obtained at that season in the open waters, and the majority of those examined were from the smaller bays, brackish-water estuaries, and shallow lagoons. The material secured from those sources was quite sufficient to demonstrate the general character of the food, as well as some of its details, and to illustrate the mechanism by which it is taken. The food of the menhaden consists of the unicellular organisms, both vegetable and animal, which swarm in all surface waters, together with the smaller crustaceans and other free-swimming forms which congregate there.

The presence in a region of the brackish, even almost fresh, waters of broad shallow estuaries and inlets, connecting with the sea only by narrow channels, is very important as affecting the kind and abundance of the various microscopic organisms used by this fish as food. The streams tributary to them also bring down a wealth of fresh-water microorganisms of the most important nature, and salt-water forms are carried in with each tide, giving a new intensity to the struggle. These minute organisms furnish directly the food of the menhaden, not only within the limits of the brackish-water inlets and estuaries where the spawn is left to develop, but also wherever the fish is found in the more open coast waters. The whole food supply of this species is obtained by filtering out from the surface stratum of water the organic life there suspended. The observations of Dr. Peck related to the younger as well as to the adult stages of the fish. After discussing the different groups of organisms which were discovered among its food, he adds:

Such being, then, the primitive character of the food supply of the menhaden, its economic relations are very important; it arrives first hand at a food supply which is the most stable, the most abundant and widely distributed of all foods, and yet so unavailable to the majority of other species. The wide distribution and vast extent of the schools of this fish testify to this fact, for no matter how many are aggregated together in a given area the food supply is adequate. At the same time the menhaden comes into no competition with the other food-fishes. * * * Not only, therefore, do the menhaden not compete with other fishes for food, but they themselves form an important factor in the food of other fishes, as has been so often observed in the bluefish, bonito, and squeteague; making available through their own life-history favorable conditions upon which the other economic fishes are borne and satisfied, bringing to them directly an elaboration of this primitive food supply here considered.

¹ On the Food of the Menhaden, by James I. Peck, Ph. D., Bull. U. S. Fish Com., XIII, for 1893, pp. 113-126, pls. 1-8.

Dr. Dean, who had carried on successful experiments during the spring respecting the artificial hatching of the sea sturgeon (*Acipenser sturio*) on the Delaware River, continued at Woods Hole the detailed study of the material collected and preserved at that time.

The subjects pursued by the independent investigators were mainly as follows: Dr. Andrews, the anatomy of certain annelids; Dr. Patten, the structure, physiology, and development of the horseshoe-crab; Dr. Schiedt, the anatomy and physiology of the oyster, an interesting conclusion based upon some of his experiments being that the presence of great quantities of minute algæ in the water is unfavorable to the life of oysters, the gills and palpi becoming so clogged as to interfere with the freedom of ciliary action, causing the animals practically to starve because of a superabundance of food; Professor Kellicott, the marine rotifera and infusoria; Dr. Ryder, the habits and life-history of a fresh-water polyp and the bathymetric relations and distribution of the foraminifera; Miss Carter, the micro-organisms affecting the alimentary canal of the mackerel and other fishes, a new field of study of probably great economic importance as well as scientific interest; Miss Hyde, the physiology and mechanism of the respiratory movements of the horseshoe-crab, and the ontogeny of several forms of jelly-fishes; Miss Cooke, the physical factors in the modification of the form and life phenomena of the lower animals; Mr. Graham, the development of the sea bass.

The season's work will result in the preparation for publication of at least 23 papers, all of scientific value and several of great economic importance.

Mr. Vinal N. Edwards, who has been attached to the station at Woods Hole since 1871, has continued his regular natural-history observations throughout the year, keeping a daily record respecting the presence, movements, etc., of the different fishes occurring in the region. In this connection the catches made by the local fishermen are closely examined and seines and other nets are constantly employed by him for this special purpose. Mr. Edwards has also conducted important investigations relative to the mackerel, menhaden, and lobster, as described elsewhere.

The season of 1894 was opened on June 4 by the arrival of Mr. J. Percy Moore, who was again designated to take charge of the laboratory, with instructions to begin upon a special study of the embryology and spawning habits of the common mackerel. Investigations relative to the natural history of the mackerel in connection with the fishery for that species off the southern coast of New England by Dr. Wolhaupter and Mr. Edwards were already in progress at this place, as elsewhere explained. Before the end of June the following additional investigators had also arrived: Mr. W. E. Castle, of Harvard University; Mr. Ulric Dahlgren, of Princeton College; and Mr. N. R. Harrington, of Williams College.

INVESTIGATIONS OF INTERIOR WATERS.

COLUMBIA RIVER BASIN.

The last annual report contains an account of investigations made during the fall of 1892, in accordance with two provisions of the act of Congress approved August 5, 1892, relative to (1) the character and extent of the obstructions to the ascent of salmon in the Clarke Fork of the Columbia River, and (2) the advisability of establishing a hatching station for salmon in the eastern part of the State of Washington. As this work was not completed at that time, it was taken up again during the summer of 1893 by Prof. B. W. Evermann, assisted by Drs. C. H. Gilbert, O. P. Jenkins, and W. W. Thoburn, of Stanford University, and by Mr. C. Rutter, of Long Pine, Nebr.

The primary objects of this inquiry were (1) to ascertain the location and character of all obstructions, natural and artificial, which seriously interfere with the movements of salmon and other important fishes in the principal streams of the Columbia River Basin; (2) to determine the past and present distribution of salmon throughout the basin, as indicating, in a measure, the extent of their depletion; (3) to locate definitely the spawning-grounds of the salmon and ascertain to what extent the species enters the different streams for spawning purposes; (4) to examine all available sites, especially in the State of Washington, with respect to their adaptation for salmon-hatching operations; and (5) to make a general study of the fish fauna of the basin.

In view of the wide extent of the Columbia drainage and the perplexing nature of many of the problems presented by the salmon question in that region, it was found to be impossible to cover the ground in one season as thoroughly as is desirable, or to arrive at more than tentative conclusions respecting the special points on which information is most urgently required. The waters examined were the Snake River at many points and 11 of its tributaries; the Pend d'Oreille River or Clark Fork, from Albany Falls, Idaho, to the international boundary; the Upper Columbia at Kettle Falls, and the Colville and Spokane rivers; and the Lower Columbia River in numerous localities from Pasco, Wash., to its mouth.

The results of this investigation were embodied in a report to Congress by the Commissioner of Fisheries, under date of May 31, 1894, the same being supplemented by a detailed description by Professors Gilbert and Evermann, of the work accomplished during the seasons of 1892 and 1893.¹ According to the Commissioner:

The area of distribution [of the salmon in the Columbia River Basin] is approximately 90,000 square miles. This immense tract is drained by innumerable streams of clear, cold water, into which the salmon enter for the purpose of spawning and

¹The Salmon Fisheries of the Columbia River Basin, by Marshall McDonald, United States Commissioner of Fish and Fisheries; including a report upon investigations in the Columbia River Basin, with descriptions of four new species of fishes by Charles H. Gilbert and Barton W. Evermann. First issued August 27, 1894, as Senate Mis. Doc. No. 200, Fifty-third Congress, second session, and reprinted in Bull. U. S. Fish Com., XIV, for 1894, pp. 153-207, pls. 13-25.

up which they ascend till their progress is stopped by falls or other obstructions which they can not surmount. These waters furnish the feeding-grounds of the young salmon during their early life, which is spent in the fresh waters. Their migration seaward does not begin until they are at least a year old and have attained a length of from 8 to 10 inches. These streams are the nurseries of the great salmon fisheries of the Lower Columbia. From each goes out every year a colony more or less numerous, to swell the aggregate of young salmon necessary to repair the waste by natural casualty and by capture. The area of natural distribution has not as yet been very materially abridged. Certain streams, such as the Bruneau and the Boise, have been obstructed by dams near their mouths, but the vast extent of waters still accessible to salmon and affording suitable breeding and feeding grounds indicates that we must look to other causes to explain any ascertained deterioration in the salmon fisheries of the Columbia.

The investigations made by Professor Evermann and the parties under his direction establish conclusively the fact that there has been a very great reduction in the number of salmon frequenting the headwaters of the Columbia River and its tributaries. This decrease is more notable in the main river. * * * There is no reason to doubt—indeed, the fact is beyond question—that the number of salmon now reaching the headwaters of streams in the Columbia River Basin is insignificant in comparison with the number which some years ago annually visited and spawned in these waters. It is further apparent that this decrease is not to be attributed either to the contraction of the area accessible to them or to changed conditions in the waters which would deter the salmon from entering them. We must look to the great commercial fisheries prosecuted in the lower river for an explanation of this decrease, which portends inevitable disaster to these fisheries if the conditions which have brought it about are permitted to continue.

The principal recommendations of the Commissioner are as follows:

The initial step in attempting the restoration of the salmon fishery is to restrict and regulate the net fishing. The restriction that may be put in force with the least hardship to the fishermen is the shortening of the season of net fishing. The use of pounds, gill nets, traps, and seines in the lower river, from the Cascades to the mouth, should be limited strictly to the months of May, June, and July. The wheels should not be permitted to take salmon prior to the middle of May, so as to permit the salmon which have entered the river in April the opportunity to pass up to the headwaters. A further close season for wheels should be established from the 1st of August to the 10th of September, so as to provide for the uninterrupted spawning of the August run of salmon. There does not at present appear sufficient reason to prohibit the wheel fishing during the balance of September and during the month of October. Protection for the salmon which have thus been enabled to reach their spawning-grounds should be afforded by a close season during the months of September and October, covering the streams in Washington, Oregon, and Idaho, to which the salmon resort for breeding.

Should the policy above outlined be adopted by these States and the requisite measures to carry it into effect be enacted and enforced, it will be possible for the United States Fish Commission and the State commissions to greatly enlarge their fish-cultural operations and to prosecute them under much more satisfactory and economical conditions than at present. Until the States interested adopt measures to restrain net fishing, so as to permit a portion at least of the salmon entering the river to pass up to their spawning-grounds, it is not deemed wise or expedient to attempt to increase or extend the work of artificial propagation of the salmon.

The report of Gilbert and Evermann discusses the conditions found at each of the localities visited, the physical and natural-history features, the impediments to the movements of salmon, of which the principal ones are illustrated, and the advantages for fish-cultural operations presented by the waters in different parts of the basin. While good

sites for a hatching station occur in the Upper Columbia and on the Snake River and other tributaries, the investigations failed to show that spawning fish could be obtained in sufficient numbers in the neighborhood of any of those visited to make them suitable for that purpose. Their conclusions are as follows:

In summing up the facts brought out by these investigations it may be said, first, that the absence of salmon from the Pend Oreille River is not necessarily due to the presence of falls in that stream, but to other causes, chief among which is the excessive catching of salmon in the Lower Columbia; second, that while it is true that the salmon are shut out by falls and dams from a large area, especially in the Upper Snake River basin, and that these limitations are increasing as the streams become useful for irrigation and mining purposes, it is nevertheless certain that the decrease in the salmon has been even greater, and that the accessible waters suitable for spawning purposes are still more than ample to meet present needs; and, third, that the desirability of establishing another salmon hatchery at some point in the Columbia basin will depend largely upon the nature of the fishery legislation in the States of Washington, Oregon, and Idaho.

It must be understood, however, that our knowledge regarding the present abundance of salmon, their relative abundance as compared with former years, and the location and extent of their spawning-grounds, is of the most general kind. While valuable so far as it goes, the information which we now possess upon these important questions is chiefly useful in indicating the nature of the investigations which must be carried on for several seasons before a thorough understanding of the salmon question can be reached.

The study of the Columbia River was again taken up early in the season of 1894, by Professor Gilbert, who proceeded to Astoria on March 20. Three weeks were spent in the field at that time, chiefly at Astoria and on the fishing-grounds in the lower part of the river, in making observations on the runs of both the quinnat and blueback salmon, but the river was also ascended as far as Lewiston, Idaho, with stops at The Dalles, Riparia, and Starbuck. The work was resumed June 1 by Professor Gilbert, with three assistants from Stanford University, and its scope was extended to include a reconnoissance of the Klamath, Rogue, and Umpqua rivers, for the purpose of determining the relation of their faunas to that of the Sacramento on the south and the Willamette on the north. This inquiry was still in progress at the end of the fiscal year.

IOWA, NEBRASKA, SOUTH DAKOTA, AND WYOMING.

The acts of Congress approved July 28 and August 5, 1892, directed that investigations be conducted respecting the advisability of establishing fish-hatching stations at suitable places in one or more of the States above named. This work was commenced in the fall of 1892 and was completed during the summer and fall of 1893, having been under the immediate direction of Prof. B. W. Evermann. The inquiries were twofold in nature, relating (1) to the physical and natural-history characteristics of the waters of the region, in order to determine their conditions as to the existing fish supply, as well as their suitability for stocking with species not indigenous to them and their requirements in that respect, and (2) to the advantages presented by different localities for fish-cultural operations.

A previous acquaintance with the general hydrographic features of the four States made it possible to restrict the investigations mainly to certain areas in each, outside of which it was evident that little information could be gained that would be of material advantage in reaching the desired results. Most attention was therefore given to the northeastern part of Iowa, the northern and central parts of Nebraska, the southeastern part of South Dakota, and the eastern part of Wyoming, including the Black Hills region in the two States last mentioned.

According to Professor Evermann's report,¹ there is no State west of the Mississippi which has a greater number of excellent fish streams than Iowa. Upon the first settlement of the country these numerous streams teemed with many of the most valuable river fishes, including both species of black bass, the wall-eyed pike, pickerel, white bass, fresh-water drum, channel cat, mud cat, and several species of suckers and sunfishes; while trout were abundant in the clear, cold streams in the northeast part of the State. Many of the streams are still well supplied with these species, and under proper regulations the rivers and lakes of Iowa can be made to yield annually an enormous amount of valuable and nutritious food-supply to the people of that State.

While the Platte and some other rivers of Nebraska are shallow and filled with shifting sands, there are many deep and important streams in which valued food and game fishes abound. The collections made show that this State is not inferior to neighboring States in the variety and abundance of its fish life. Among the food-fishes of most importance are the channel cat, mud cat, buffalo, several species of suckers, sturgeon, the large-mouthed black bass, the wall-eyed pike, and the sauger. In the small lakes in the northern part of the State and in some of the streams the large-mouthed black bass is abundant, and in some of the colder streams, particularly at Long Pine and Bazile Mills, trout were quite plentiful, the plants having been made by the Nebraska Fish Commission.

South Dakota does not differ greatly from Nebraska in its streams and the fishes which they contain. The larger streams in the eastern part of the State and the numerous lakes in the eastern and northeastern portions are well supplied with valuable food-fishes and the amount taken annually from these waters is of no small importance to the people of that State. The half of the State lying west of the Missouri River is but poorly supplied with permanent streams, and many of these are more or less alkaline, and in consequence not inhabited by many species of food-fishes. The numerous species of spiny-rayed fishes, among which are found nearly all of the better game fishes of the Mississippi Valley, are scarcely represented at all in the waters of this State west of the Missouri. The few species there which possess any food value are three species of catfish, a few suckers, and one or

¹The Fishes of the Missouri River Basin, by Barton W. Evermann, ichthyologist of the U. S. Fish Commission, and Ulysses O. Cox, professor of biology in the Mankato, Minn., State Normal School. Report U. S. Fish Com. 1894, pp. 325-429.

two of the larger species of minnows. This is particularly true of the southwestern part of the State, in which occur the Mauvaises Terres or Bad Lands. The only region in the western half of the State which has really excellent streams is the Black Hills.

The Black Hills constitute a mountain island, with heavy pine forests and clear, cold streams, surrounded on all sides by plains with alkali soil, shallow, uncertain streams, and limited vegetation. All the streams of the Black Hills, unless contaminated by mining operations, are clear, pure, and cold, and well suited to trout, though trout do not occur in any of them naturally.

The streams of Wyoming belong to two very different types. Those of the northwestern and western parts of the State are, in many cases, excellent trout streams. The eastern and southern portions are not well supplied with permanent streams. Many of them dry up into isolated pools during the summer, and all are more or less alkaline. There are no trout in these streams, and other food-fishes are few in species and individuals. The only species in eastern Wyoming that are of any importance as food-fishes are three species of suckers, three of catfish, a few minnows, and the wall-eyed pike, which, however, is of rare occurrence. In Green River, in the southwestern part of the State, are found the large Cyprinoids, characteristic of the Colorado River Basin, and which are of some commercial importance.

The total number of fishes now known from the Missouri River Basin is 140; of these, 42 may be regarded as food-fishes of more or less importance. Some of these are game fishes, but it is the pond and river species whose cultivation will result in the greatest good to the Missouri River States.

The investigations bearing directly upon the selection of hatchery sites included the examination of more than 100 springs, at each of which the temperature, character, and volume of water were determined and the surrounding topographic features were considered with special reference to fish-cultural needs, such as the location of buildings, laying out of ponds, the supplying of water by gravity, railroad facilities, etc. In his report to Congress, transmitted on January 24, 1894,¹ the Commissioner recommended the establishment of only one station to supply the needs of Iowa, South Dakota, and Nebraska, the same to be devoted to the rearing of those species which are indigenous to the waters of the region, with some attention paid to trout, the cultivation of which should be a minor feature in the development of the station. Manchester, Iowa, was subsequently selected for the site as furnishing the best combination of facilities for that purpose. It was furthermore suggested that the station under construction at Bozeman, Mont., would be able to supply the requirements of the State of Wyoming.

Professor Evermann was assisted in this investigation by Prof. U. O. Cox, Mr. Cloudsley Rutter, and Prof. R. G. Gillum.

¹ Senate Mis. Doc. No. 53, Fifty-third Congress, second session.

TENNESSEE.

In compliance with act of Congress approved August 5, 1892, providing "for investigation and report respecting the advisability of establishing a fish-hatching station at some suitable point in the State of Tennessee," the necessary inquiries to that end were conducted in September and October, 1893. The observations were limited to the eastern part of the State, as it was known that the conditions required for such a station as was contemplated were most likely to be found there. Many of the streams of that region are suitable for trout, but the majority are better adapted to the various species of pond and river fishes, and eastern Tennessee is especially noteworthy for its numerous large springs. More than 30 of the latter, together with their surroundings, chiefly in the vicinity of Greeneville, Cumberland Gap, Knoxville, Marysville, Athens, Cleveland, and Chattanooga, were examined with reference to their suitability for the purpose in question.

A careful study was also made of a number of streams in the same region with respect to their character and volume, the physical features of the adjacent country, and the abundance and distribution of their fishes, special attention being paid to the food and game species, of which there are a large number of varieties. The principal game fishes are the small-mouthed black bass, the "jack salmon" (*Stizostedion vitreum*), and the speckled trout, the first two occurring in the larger streams, the last in the small, colder ones that flow down the mountain slopes on the eastern boundary.

Only four of the springs examined were found to approximate the requirements of the proposed hatching station, two of these being in the neighborhood of Cleveland, one near Greeneville and one near Athens, the last offering the greatest natural advantages, but being somewhat distant from a railroad station and source of general supplies. A report upon the question of site was transmitted to Congress in January, 1894, and was printed as Senate Miscellaneous Document No. 52, of the Fifty-third Congress, second session. In this the Commissioner reserved his opinion respecting the choice of a location until additional inquiries could be made, but recommended action favorable to the establishment of a station. A general report upon the results of the investigation is in course of preparation. The examinations were conducted by Professor Evermann, assisted by Dr. R. R. Gurley, and by Dr. J. T. Scovell, of Terre Haute, Ind.

OHIO, INDIANA, AND MICHIGAN.

During July and August, 1893, a detailed examination of the Maumee River basin, including its principal lakes and tributary streams, was made for this Commission by Prof. Philip H. Kirsch, fish commissioner of the State of Indiana, assisted by Mr. W. S. Blatchley, of Terre Haute, Ind., and Mr. Charles Beeson, of the Indiana University. This basin covers a considerable area in the northwestern part of Ohio, and

also extends over portions of Hillsdale and Lenawee counties, Mich., and of Steuben, Dekalb, Allen, and Adams counties, Ind., embracing in all a territory of about 7,500 square miles. The main river, formed by the confluence of the St. Joseph and St. Mary rivers, at Fort Wayne, Ind., flows in a general northeasterly direction a distance of 96 miles to Toledo, where it empties through Maumee Bay into Lake Erie, of which it is the most important side tributary. The water is rather clear in the main stream and its larger affluents, but more or less turbid in the smaller branches, owing to their clay channels; in all of the lakes visited it was remarkably clear and pure. Examinations were made in the Maumee River proper, in the neighborhood of Fort Wayne, Ind., and of Antwerp, Cecil, Defiance, Grand Rapids, Waterville, and Toledo, Ohio.

The other waters studied were the St. Joseph River and seven of its tributaries, including Fish Lake and Cedar Lake; St. Marys River, Gordon Creek, Lost Creek, Tiffin River, and Devils Lake; Auglaize River and four of its tributaries, and Beaver Creek.

This water system was found to be exceedingly rich in variety of fishes, the total number of species observed having been 87, more than is known from any other river basin of the same size. The list includes 8 species of catfishes, 9 of suckers, 25 of minnows (*Cyprinidae*), 9 of sunfishes and basses, and 16 of perches. Over 30 species are of value for food, the most important of these being the two species of black bass, the grass pike, and the wall-eyed pike. Crayfishes and mussels are rather common in all parts of the basin; snails are plentiful, and shrimps were obtained in several streams.¹

INDIAN TERRITORY.

In May, 1894, Prof. S. E. Meek, of the Arkansas Industrial University, began an investigation of certain streams in the southeastern part of Indian Territory, along the line of the St. Louis and San Francisco Railroad between Fort Smith, Arkansas, and Arthur, Texas, this work being continued into the next fiscal year. Two of the most important rivers of that region are the Poteau and the Kimishi, both rising in the Ozark Mountains between the Arkansas and Red rivers, the former flowing north into the Arkansas, the latter south into the Red River. In the upper two-thirds of their courses they drain a mountainous sandstone region, their currents being swift and the bottom generally rocky. The Poteau River, below the town of the same name, occupies a deep and rather broad channel, with an occasional rocky shoal, the current being sluggish and causing it to partake somewhat of the nature of a lake. Examinations were made near the mouth of the river and in the vicinity of Poteau. The fishes of the Kimishi River were

¹ Report upon investigations in the Maumee River basin during the summer of 1893, by Philip H. Kirsch, commissioner of fisheries for the State of Indiana. Bull. U. S. Fish. Com., xiv, 1894, pp. 315-337.

studied in the neighborhood of Kimishi and Goodland. Collections were also obtained from the Red River at Arthur, Tex.

These waters were found to be very rich in fish life, both as to species and individuals, the total number of species observed being 58, including the following important food varieties: Channel cat or white cat (*Ictalurus punctatus*), blue cat (*Leptops olivaris*), little green pickerel (*Lucius vermiculatus*), crappie (*Pomoxis annularis*), several species of sunfish, large-mouthed black bass (*Micropterus salmoides*), sauger (*Stizostedion canadense*), and fresh-water drum (*Aplodinotus grunniens*).¹

MINNESOTA.

In the spring of 1894, the services of Prof. U. O. Cox, of Maukato, Minn., were secured to make a study of the small lakes in the neighborhood of Worthington, Nobles County, with special reference to the habits of the buffalo-fish which had been reported as running in exceedingly large numbers into the sloughs and other shallow waters about those lakes during their spawning season of 1893. The run did not occur, however, as anticipated, but observations were made on the fishes generally of the region, and a report upon the subject is in course of preparation.

THE GREAT LAKES.

Lake Erie.—During the summer of 1893, investigations were conducted along the south shore of Lake Erie, from Port Clinton, Ohio, eastward to and including Niagara River as far as the falls, by Mr. A. J. Woolman, of the Duluth High School, assisted by Mr. D. C. Ridgley, of Delphi, Ind., and Mr. E. M. Hasbrouck, of Washington, D. C. This work was carried on primarily for the purpose of securing information desired by the Joint International Commission, elsewhere referred to, and comprised the collecting of data relative to the commercial fisheries at the principal fishing centers, as well as the customary observations respecting the natural history of the fishes occurring along the lake shore and in the more important streams tributary thereto.

These inquiries were preliminary to more extensive investigations planned for the season of 1894, and which were taken up early in June by Mr. H. F. Moore, Mr. B. L. Hardin, and Mr. Rutter. During the balance of the fiscal year this party was engaged in a study of the fishes and the market fisheries in the region about Kelley Island and the Bass Islands, making personal examinations and also securing testimony from the fishermen concerning the methods, history, and conditions of their industry.

Lake Huron.—Corresponding inquiries on this lake were also begun in June, 1894, by Dr. J. T. Scovell, assisted by Mr. D. C. Ridgley. The work was commenced at the lower end of the lake and was carried thence northward.

¹A list of fishes and mollusks collected in Arkansas and Indian Territory in 1894, by Seth Eugene Meek, Ph. D., associate professor of biology and geology in the Arkansas Industrial University. Bull. U. S. Fish Com., xv, 1895, pp. 341-349.

Lake Ontario and St. Lawrence River.—Coincident with the inquiries on Lake Erie and Lake Huron during the summer of 1894, investigations of a similar character were begun about the middle of June with respect to Lake Ontario and the upper or boundary part of the St. Lawrence River, by Professor Evermann, assisted by Mr. Barton A. Bean, of the United States National Museum.

During the same month Professor Evermann also made an examination of several springs located near together in the vicinity of Sterlingville, N. Y., which had been recommended as suited to the needs of the proposed hatching station recently authorized by Congress for the State of New York. The volume of water supplied, its character, temperature, etc., were determined, and observations were made relative to the adjacent stream known as Black Creek; but the distance of this place from Lake Ontario was found to be a serious objection to its selection for the purpose in view, especially as it was intended to utilize the station chiefly for the propagation of lake fishes.

POLLUTIONS IN THE WABASH RIVER, INDIANA AND ILLINOIS.

In view of complaints made by the fishermen and other residents along the Wabash River at and below Terre Haute, Ind., the House of Representatives, by resolution dated April 30, 1894, requested the Fish Commission to investigate and report the extent of damage done to the food-fishes in the Wabash River by reason of the discharge into said river of the overflow and waste products of the oil wells located in the city of Terre Haute, and what steps, if any, are necessary to prevent further destruction of the fishes in that river by the polluting agencies referred to. The examinations required to ascertain the correctness of the statements relative to the conditions said to prevail in the region in question, the injury done to the fishes thereby, and the character and origin of the polluting influences, were made during the middle of May, by Prof. S. A. Forbes, director of the Illinois State Laboratory of Natural History, and indicated a state of affairs sufficiently serious to suggest and invite remedy.

Subsequently, the services of Mr. Arthur N. Talbot, professor of municipal and sanitary engineering in the University of Illinois, were secured to determine the amount of waste matter, deleterious to fishes, discharged into the river at Terre Haute, and the measures best adapted to disposing of it. The results of his observations were satisfactory in demonstrating that the waste products could readily be prevented from reaching the river without imposing any unreasonable or excessive charges upon the industrial enterprises which are responsible for their production. The reports of Professor Forbes and Professor Talbot were submitted to the House of Representatives on July 13, 1894.¹

¹House of Representatives Miscellaneous Document No. 196, Fifty-third Congress, second session.

Omitting the detailed statements based upon the testimony which he obtained, the report of Professor Forbes is as follows:

I have the honor to report, concerning the alleged injury to fishes in the Wabash River by overflow and waste from oil wells at Terre Haute, that in accordance with your instructions I went, May 15, to Marshall, in Clarke County, Ill., near the Wabash, spent May 16 and 17 along that river in and near the towns of Darwin, Old York, and Hutsonville, returned to Marshall on the evening of the 17th, and went thence to Terre Haute, where I remained until the forenoon of May 19, at which time other engagements compelled my return to Champaign.

I made personal observations of the condition of the river with reference to the contamination of its waters by coal oil or its waste products, and collected a mass of evidence concerning the pollution of the river at different times and under different circumstances, and likewise concerning the effect upon the fish. The time at my disposal was too short to permit a complete investigation, and I shall be obliged, consequently, to limit myself to a preliminary report.

As a general result of this investigation, I reached the conclusion that there can be no doubt of a considerable pollution of the river at Terre Haute by the oil wells and gas works connected with it, having the effect to injure fish for a distance of at least 40 miles down the river, and the consequent effect to diminish, and in some places practically suspend, the fishing industry, and to decrease or stop the sale of fish.

There are at Terre Haute three separate sources of pollution—the oil wells, the fuel-gas works, and the illuminating-gas works. In the absence of the general manager of the oil wells, who was out of the city during my visit, I was not able to get personal knowledge of the nature and amount of the objectionable materials which the waters of the Wabash may receive from these wells. I learned, however, from other reputable citizens—especially from the officers of the gas companies, so related to the oil business as to be thoroughly intelligent with reference to it—that there are three of these wells in the city now in operation. Their entire product, I am told, is used at the fuel-gas works, for the manufacture of gas distributed to the city, and at the works of a tool company, where the oil is used as a fuel.

The oil, after being pumped into large tanks, is steamed some time for the purpose of causing a separation of the water and other impurities, which settle to the bottom of the tank. This "B. S.," so called, is then drawn off into the sewers, and reaches the river by way of the main city sewer, a 5-foot brick sewer opening into the river at the foot of Eagle street. The present product of these wells, and the exact nature and amount of this contamination, I was not able to ascertain at the time. I was informed, however, by men who should be acquainted with the facts, that it is much greater than that from the gas works, and that occasional overflows of the wells have occurred, the oil then, of course, escaping into the river. Since my return to Champaign I have received a letter, in reply to inquiries addressed to Mr. S. M. Reynolds, the general manager of the Guarantee Oil and Gas Company, controlling these wells, in which he informs me that the entire product of the three wells is about 45 barrels per day, of which "not one-thousandth of 1 per cent finds its way into the waters of the Wabash." Further investigation will evidently be needed on this point. I may add that Mr. Reynolds volunteers the fullest information with regard to the situation and every opportunity to inspect the works personally.

The second source of contamination is the waste from the fuel-gas works, an establishment situated two blocks from the river and emptying the washings of the gas and other waste directly into the main brick sewer above described. I was shown this sewer connection, and saw also the liquid waste escaping. It is received in a large open tank, the surface of which is covered with a coating of slushy tar, while the water runs off, carrying an iridescent oily or tarry material in suspension. The stream of water, running at the time rapidly through the trough, was perhaps 8 or 9 inches across by an inch in depth. It is possible that there are other sewer

connections at this establishment or additional waste not seen by me. At the mouth of this sewer, which was nearly submerged by the water at the time of my visit, I found a continuous outpouring of oily and tarry materials into the river, which formed, at a distance of 50 feet below, a practically continuous film alongshore about 10 feet wide, with irregular patches extending farther out.

The wind at the time of my visit was blowing across the river from the west, with the effect to hold this floating film against the eastern bank. In an eddy just below the projecting mouth of the sewer was a triangular patch of black tar about half an inch thick and some 3 feet on each side. The amount of tar in the water here is shown by its accumulation in a thick layer at the water's edge, on the sides of barges, etc. A belt of this hard oil tar, three-fourths of an inch thick at its lower edge, had formed on the hull of a cabin boat, according to the owner's statement, within a month since it was cleaned away.

The third source of contamination is the illuminating-gas works, situated on the bank of the river at the foot of Swan street. In these gas works, according to the statement made to me independently by the superintendent of the works and by a workman whom I encountered there, the material principally used in making the gas is what is known as "naphtha oil," brought by rail from Whiting, Ind. From these gas works, I was told, only the washings of the gas escape into the river. These are received in an open iron tank, the overflow from which, as it runs rapidly down the bank, forms a rivulet about a foot wide and an inch deep. At this point a film similar to that from the fuel works was formed on the surface of the water, apparently containing, however, less tarry material. The current inshore is here slower than above, and the film was continuous for about 20 feet out from the bank at a distance of 50 feet below the point of entrance.

As we rowed across the river, about a quarter of a mile below these lowest gas works, small patches of this oily surface coating could be recognized halfway across the river, and the odor was strong for a considerable distance out. On the opposite side of the river there was neither appearance nor smell of this contamination of the surface. It would appear from information collected concerning the oil wells that this waste which I saw was derived entirely from the gas works, that from the wells coming off in quantities and at intervals only, as the tanks are emptied.

Going above the Eagle-street sewer, all appearance of pollution from these sources disappeared within a few rods, and, thence, as far upward as I went, I saw no signs of it on the water, and could get none of the characteristic odor from the driftwood or other water-soaked debris alongshore. The city waterworks are, in fact, situated on the river bank within the city limits above the mouth of this sewer, taking the water through an iron pipe which extends about a third of the way across the river; and here, as I was told by workmen in charge, no trouble is ever experienced with oil or tar or any similar substance. From this I judge that the fish occasionally taken above the town, which taste of oil, have recently come up from below, and that all important contamination of the river by these oil wastes is to be looked for at Terre Haute itself.

The time of my visit was said to be an unfavorable one for an estimate of the amount of pollution apparent at the towns below, since, although the river had begun to rise, it was coming up but slowly and was still below the medium stage. High-water mark is 28 feet, and the river stood at 8½ by the gauge on the wagon bridge at Terre Haute. I was also repeatedly informed that the damage is much the worst in the spring, when the ice breaks up with the spring rise of the stream.

I saw, however, some slight but unmistakable evidence of present contamination as far down as Darwin, 23½ miles below; and again, less evident, but still recognizable, at Old York and Hutsonville, the latter 48 miles by river from Terre Haute. At the place first mentioned I saw on the still water, at the mouth of a small creek opening into the river, a continuous film of an oily appearance, measuring probably 2 square rods, with flakes or patches of a thicker, blackish, tarry film, from mere specks to half an inch or more across. This was pointed out to me as the characteristic

evidence of pollution, and had, in fact, the same general appearance as the film above described at Terre Haute. The peculiar odor of this tarry material was easily obtained, in almost any eddy along the bank where fine drift had accumulated, by raking up a little of this from the bottom, and the same odor could occasionally be got from the bank by standing at the edge of such an eddy when the wind was blowing across it. It was universally said, however, by those with whom I talked, that at this time of year, and especially under conditions existing, these appearances were at their minimum.

I systematically questioned over 20 men at Terre Haute, Marshall, Darwin, Old York, and Hutsonville, examining them separately, and making full notes of their statements at the time. Although it was not possible for me to take sworn evidence, a comparison of these various statements with each other leaves no doubt of the substantial accuracy of most of them. They include reports from fishermen, business men, fish-dealers, and those who have bought and cooked damaged fish, as well as statements from the Fuel Gas Company, superintendent of the Gaslight Company, the city engineer of Terre Haute, and other prominent citizens. I may summarize the statements with respect to injuries to fish by saying that this whole mass of evidence, together with an indefinite amount of general conversation by others, was to the effect that the fishing industry along Wabash River has been practically destroyed at Terre Haute itself, and badly injured for at least 50 miles down the stream—beyond which my visit did not extend—by the presence in the water of oily and tarry waste, traceable to the oil wells and gas works, one or both, at Terre Haute.

Although three experienced fishermen gave some evidence that fish were killed in winter under the ice by accumulations of this waste, I was not fully satisfied that this was true. There can be no doubt at all, however, that they are largely rendered inedible, catfish and buffalo most frequently, but no species escaping wholly. The game fishes, the sheepshead, and the so-called pike perch are seemingly least liable to the injury. It is a curious fact, repeatedly stated to me, that the whole body of a fish may not be impregnated, but that the parts about the fins are most likely to be affected. The fact that catfishes are so much more susceptible in this particular than other species is explained by the fishermen, in part, by their naked skins. There is considerable reason to believe that fish which would otherwise pass upstream are kept below by this pollution, and as it unquestionably extends everywhere during seasons of overflow, it may easily have a serious effect upon the eggs and young. The contamination is, indeed, the most marked during the first two months of the season after the breaking of the ice, a time when fishing operations are most active, and coincident likewise, in part, with the spawning seasons of some important species. There is no doubt that the heavier portions of this waste settle in still water, and thus permeate the mud and drift accumulations on the bottom in a way to make it possible that they may have an injurious effect on the invertebrate animal life of the river, on which fish largely depend for food. Its accumulation in and beneath the ice in winter, testified to by several of my witnesses, should be taken into account in considering the importance of its effects.

It seems to me quite impossible to make a definite intelligent estimate of the ratio of damage or the amount of loss which this contamination of the river has caused. It has unquestionably compelled a considerable number of men to abandon fishing, and has reduced the income of others endeavoring to make a living by that business. Statistical information is, however, quite beyond my present reach, and I am equally unable to make any definite recommendations as to remedial measures. This last is evidently a question for an engineer rather than for a zoologist.

Respecting the fuel gas company, I beg to say that the president of the company, Mr. H. P. Townley, gave me every desired opportunity to examine their works, and assured me that they would be glad to do anything that we might indicate to correct any trouble due to their waste. The superintendent of the gaslight company, Mr. M. N. Diall, was also communicative, but seemed to attach but little importance to the waste from their works.

I trust that the foregoing will serve your purpose as a preliminary report and as a guide to further investigation if such is desired.

I send you herewith a copy of my notes of statements made by the various persons whom I examined systematically, together with bottles of the waste from the two gas works at Terre Haute and a small package of the tarry deposit from a barge in the river there. This barge had been cleaned off within a month, and a deposit of the thickness sent you had collected there since that time.

Following is the report of Professor Talbot:

In accordance with your instructions to make an investigation with respect to the amount of waste matter deleterious to fishes which empties into the Wabash River from the oil wells and gas works at Terre Haute, Ind., and to report upon the same with recommendations relative to the proper disposition of said refuse, I have the honor to report that I spent July 5 and 6 in Terre Haute, returning July 7, and that the amount and condition of the wastes at the oil wells, the fuel gas works, and the gaslight works are as follows:

1. *Oil wells.*—Only three wells produce oil. These are controlled by the Guarantee Oil and Gas Company. The oil is pumped into wooden tanks, where the process of steaming and subsidence separates the oil from the water and its impurities. The water is of limestone origin, and its impurities are much the same as those from the artesian wells in the locality. As much of these impurities as may properly be discharged into the sewer either settle in the river or at once mingle and diffuse with the water within a short distance of the mouth of the sewer, it is probable that their effect upon the fishes is comparatively small and not worth considering. It is the escaping oil and tarry matter which is to be avoided.

The product of two of the wells contains but little water. The third, however, discharges twenty times as much water as oil. At the time of my visit this third well, located near the Phoenix Foundry, was undergoing repairs, and the overflowing water and oil were flowing through an open ditch to the sewer, no effort being made to prevent the waste. While the flow of water may have been augmented somewhat by the increased amount of ground water due to the change of casing, the flow was probably less than during the process of pumping. I made weir measurements of the discharge, and calculate that the flow was at the rate of 0.0189 cubic feet per second, equal to about 12,200 gallons per 24 hours, or, say, 240 barrels in 24 hours. Of this I estimate that about 5 per cent is oil, perhaps 12 barrels per 24 hours.

Mr. Reynolds, the general manager of the Guarantee Oil and Gas Company, stated that this is the first time that repairs of this kind have been made to this well, and intimated that this is a very infrequent occurrence, adding that considerations of economy prevent the waste of oil.

The other wells were being pumped and the whole product was received in the tanks. There was visible evidence that there had been waste into the sewer, and testimony taken shows that not infrequently there is leakage and waste of a few barrels of oil, which is allowed to flow into the sewer. It was even stated that at times when it was inconvenient to tank the oil the whole flow of the wells passed into the sewer.

Of the amount of oil which escapes with the "B. S." at the time of the discharge of that waste I have no means of ascertaining. Judging from the means of separation and the care taken in the operation, there is considerably more than is necessary. The amount of this oil reaching the sewer probably would not usually be more than a barrel a day. There must, however, be times when the waste is considerably greater than this.

2. *Fuel-gas works.*—The second source of pollution is the works of the Citizens' Gas and Fuel Company, which uses oil in the manufacture of its gas. The overflow from the tar barrel and the washings from the "scrubber" are caught in a tank, from which, after the tar and oil are roughly separated by subsidence, the waste flows into the sewer. Owing to inadequate facilities for subsidence and to careless-

ness in operating, the quality of this waste is inexcusably bad, a large amount of oil and tar escaping with it.

By weir measurements the amount of waste discharged from the subsidence tank and escaping into the sewers was at the rate of 0.173 cubic feet per second, equal to 112,000 gallons per 24 hours, or about 2,150 barrels. It was impracticable to determine the amount of oil and tar contained in this, but the samples show that it must be at the rate of several barrels per day.

While these works are not now running during the night, it is probable that, except in the summer months, the total discharge for 24 hours is greater than indicated above.

3. *Illuminating-gas works.*—The discharge of waste from the works of the Terre Haute Gaslight Company is from a pipe on the bank of the river near the works. It is of much cleaner quality than the preceding. The discharge was at the rate of 43,000 gallons per 24 hours. Of this the oil did not amount to more than a few gallons a day. From what could be seen, I judge that little pollution comes from this source.

The discharge from the oil wells and the fuel gas works is into the city sewer, known as the canal sewer, which empties into the Wabash River at the foot of Eagle street. Samples taken from the sewer at three different points show a strong indication of oil, and even near the outlet, where sewage discharges down an incline with a velocity of 10 feet per second, at the rate of 2,000,000 gallons per day, the oil quickly comes to the top and floats along down the bank. The very marked coating of oil on the walls of the sewer shows that the discharge of oil must have continued for a considerable time and that it has been at different stages of the river.

It may be said that the total amount of oil discharged into the river is not large when compared with the oil received by other streams, and that the waste is not relatively as large as that from some oil wells and refineries. However, the refusal of the oil to diffuse with the water makes its presence, even when intermittent, very perceptible, and the results are far different than would be the case with diffusing liquids.

It is fortunate that this very principle of nondiffusion makes the separation of this refuse from the ordinary washings very easy, and hence the method of avoiding its discharge into the river is simple and inexpensive. The only process needed is that of separation by subsidence, carrying out more thoroughly and completely the method now used at both the oil wells and the fuel gas works.

The situation is such that no pumping or extra labor is necessary beyond the watching, the proper drawing off of oil and waste, and the occasional cleaning of the tanks. Contrary to what might be expected, there will be no necessity for expensive processes such as are used in sewage purification works.

The recommendations I would make relative to the disposition of the refuse are that the oil and tarry waste be not allowed to reach the sewer or the river, and that this waste be separated from the unobjectionable waste water by the process of subsidence in tanks. The difference in specific gravity is so marked that the separation of the water will not be difficult.

At the oil wells a tank at least 12 feet deep and 16 feet in diameter should be sunk in the ground to such a depth as to catch all overflow from the wells and all leakage from tanks and pipes and waste from loading. The inlet should be so made that the inflow will not agitate the liquid in the tank. A perforated partition will direct the proper distribution of the liquid. The outlet pipe should project well into the tank 3 or 4 feet above the bottom of the tank and be so perforated as to obtain an even draft from the liquid without causing any perceptible current in the tank. It should then be carried to the level of the inlet and connected with the discharge pipe. By this process the water will be carried away and the oil and heavier matter held in the tank. Care must be taken to draw off the oil and waste at the top as fast as it accumulates and to clean the bottom as often as necessary.

In drawing off the "R. S." from the steaming tank, sufficient time for the discharge must be given, that the flow through the separation tank will be

slow. Negligence in this matter and any overcharging of the tank will result in inefficiency. A second and smaller tank may be used if it is necessary to continue operations when this tank is being cleaned.

At the fuel-gas works a separation or subsidence tank, in addition to the one now in use, is very desirable. This may be similar to the one described for the oil wells. The depth should be 12 feet and the diameter 16 feet. It should be designed so that the inflow will be evenly and smoothly distributed, with partitions arranged so as to prevent currents, and with the outlet pipe placed 5 feet above the bottom and extending two-thirds the way across the tank and so perforated as to permit an even flow. The outlet pipe will discharge near the level of the inflow, and all the ordinary water and washings will flow off by gravity. The oil waste at the top and the tarry waste at the bottom may be emptied when necessary.

Some repairs and modifications of the tank now in use are desirable, and proper attention to its cleaning and operation will be necessary.

The expense of following out the recommendations made will not be great. Wooden tanks, partitions, and drains are suitable for the purpose. The waste products obtained will be of some commercial value, and at least will not be difficult to dispose of. The location is such that the tanks may receive and discharge the liquid without pumping.

To summarize my report, I may repeat:

(1) That oil waste escapes from the oil wells and from the fuel-gas works into the Wabash River in noticeable quantities, although the total amount is not large.

(2) That this waste may readily be separated from the waste water by inexpensive subsidence tanks.

I ship by American Express to-day a sample taken from the flow from the well of the Phoenix foundry; a sample of sewage from the canal sewer on Ninth street, near Sycamore, which receives the waste from the oil wells; a sample of sewage from the mouth of the sewer at the foot of Eagle street; a sample of the waste which passes into the sewer from the works of the Citizens' Fuel and Gas Company, and also a sample of the waste from the works of the Terre Haute Gaslight Company.

DISEASES OF FISHES.

Dr. R. R. Gurley continued during the year his researches respecting the parasites and diseases of fishes. His paper on the Myxosporidia or protozoan parasites, which are the cause of considerable mortality among fishes, was finished early in the year, although assigned a place in the annual report for 1891-92, the publication of which was at that time not completed. Several cases of disease and mortality among the eggs and young fish at some of the hatching stations were made the subject of investigations, the most important being furnished by the station at Northville, Mich., where, during the spring of 1894, a very high death rate occurred among the yearling and two-year-old brook trout stored in the ponds at that place. Dr. Gurley was sent to the station and remained there several weeks, but despite the comprehensive scope of his inquiries the true cause of the difficulty failed to be discovered, or, at least, no effective remedy was found. The diseased fishes were infested to a greater or less extent with well-known parasites of two or more varieties, but it could not positively be said that they were the chief instrument of death, even if they were concerned in it at all.