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

By RICHARD RATHBUN, *Assistant in charge.*

FUR-SEAL INVESTIGATIONS.

In the last annual report a brief account was given of the services rendered to the State Department by the Fish Commission in connection with the controversy respecting the sealing question in the North Pacific Ocean and Bering Sea. During the summer of 1891, the steamer *Albatross* was used to convey the Bering Sea commissioners on the part of the United States to and from the Pribilof Islands. On March 15, 1892, she was detailed to take an active part in the sealing investigations, under the orders of the Secretary of the Treasury, in conjunction with the revenue steamers *Corwin* and *Bear*, which service had not been completed at the close of that fiscal year.

During the summer of 1892, and again the following year, a very careful examination was made of the seal rookeries on St. Paul and St. George islands, by Mr. J. Stanley-Brown, then acting as a special Treasury agent. His work included the preparation of a set of base maps of both islands, on which the outlines of the rookeries were delineated, and also the taking of a series of photographs illustrating the distribution and abundance of seals on prominent parts of each of the rookeries. It was considered that the duplication of these graphic records during a term of years would serve to demonstrate any changes that might take place in the conditions and dimensions of the rookeries and, consequently, in the size of the seal herd. The summer of 1893 was the last preceding the meeting of the Paris Tribunal of Arbitration, for whose consideration Mr. Stanley-Brown's results were especially intended; but, appreciating the importance of further observations in the same line, the Secretary of the Treasury recommended to Congress that the work be continued under the direction of the Commissioner of Fisheries. Favorable action on this subject was taken in connection with the sundry civil appropriation bill, approved March 3, 1893, which also provided for investigations by the Fish Commission relative to the pelagic habits and distribution of the fur seal.

The assistant in charge of this division continued to be occupied during the first two or three months of the current year in preparing material for the Bering Sea case, respecting the character and condition of the more important fisheries in foreign countries and the methods there pursued for their protection and improvement.

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

At the beginning of the year the steamer *Albatross*, Commander Z. L. Tanner, U. S. N., commanding, was still on duty under direction of the Secretary of the Treasury, being at Port Townsend, Wash., where she had recently arrived after coaling at Departure Bay, British Columbia. She left the former place on July 1 for Unalaska, but unfortunately (owing to continuous sea service for a long period, much of the time under trying circumstances as regards sea and weather) her boilers were in bad condition, and in several other respects the ship needed a thorough overhauling. Ten days were consumed in making the passage to Unalaska, where it was found imperative to order a board of survey, which found the boilers unsafe for further use. Temporary repairs were begun at once, to permit of the ship's returning to San Francisco, but several weeks were required for their completion.

The unfinished work which the *Albatross* had been expected to carry on was assigned to the revenue steamers *Corwin* and *Rush*, to which Mr. C. H. Townsend and Mr. A. B. Alexander were transferred to serve as naturalists, and also two seal-hunters and the necessary appliances for conducting the investigations. Taking advantage of the delay, Prof. B. W. Evermann, then acting as chief naturalist of the *Albatross*, and Mr. N. B. Miller, laboratory assistant, were dispatched to the Pribilof Islands, where they made a careful inspection of the seal rookeries and obtained an interesting series of photographs bearing upon the same.

On August 3 the *Albatross* left Unalaska, having in tow a British schooner which had been captured while engaged in pelagic sealing in Bering Sea, in contravention of the provisions of the *modus vivendi* then in operation. After delivering this prize at Sitka, she proceeded to Port Townsend and thence to San Francisco, which was reached on September 3. By direction of the Secretary of the Treasury the control of the ship reverted to the Fish Commissioner at the close of August 31, while still upon her passage, having up to that date been in the service of the Treasury Department for a period of 5½ months, during which she visited 26 ports and steamed a distance of 14,848 miles, mostly in northern waters. In order to put the ship in suitable condition for further service it became necessary to provide new boilers and to make many alterations and repairs, which were not fully completed until the following April. Beginning on the 25th of that month, a successful trial trip was made, lasting three days, in the course of which investigations of the sea bottom were carried on off Monterey Bay.

On May 13 the President directed that the *Albatross* be placed under the orders of the Secretary of the Navy, for assignment to duty in connection with the sealing patrol fleet in the North Pacific Ocean and Bering Sea, composed otherwise of certain naval and revenue-marine vessels. It was arranged, however, that her commanding officer should receive his customary instructions relative to fishery and fur-seal investigations, which were to be carried out so far as the special duties

devolving upon the ship would permit. The patrol fleet rendezvoused at Port Townsend, Wash., where the *Albatross* arrived May 24. She finished coaling at Comox, British Columbia, May 31, and proceeded northward by the passage inside of Vancouver Island to the open waters of the Pacific Ocean, where her patrol work began. The vessels of the fleet were so disposed as to cover the track of the seal herd and sealing vessels bound north, but the *Albatross* was given the western or off-shore route, which placed her outside of the usual course taken by the seals, and none were observed between Vancouver Island and Kadiak.

The first sealing vessel was encountered off the southern edge of Portlock Bank, and St. Paul, on Kadiak Island, was reached June 7. From this point, on the following day, the *Albatross* began working to the westward, boarding such pelagic sealers as were met with and warning them, in accordance with the temporary agreement between Great Britain and the United States, to refrain from carrying on their operations in Bering Sea. On arriving at Sand Point, Shumagin Islands, where the sealing vessels often congregate, it was found that none had yet reached that place. Continuing to the westward as far as Amukta Pass, and there entering Bering Sea, the ship proceeded to Unalaska for coal and thence returned to Sand Point, boarding several vessels on the way, one of which proved to be a cod-fishing schooner bound for Slime Bank, off the north side of Unimak Island.

Some time was spent among the Shumagin Islands, and the principal harbors were visited. Mist Harbor, on the east side of Nagai Island, a secure and convenient anchorage, was surveyed for the first time, and advantage was taken by the naturalists at each stop to obtain as much information as possible respecting the fishes and other marine animals of the region. Leaving Sand Point on June 26, the ship proceeded to Unalaska, and thence along the Bering Sea side of the Aleutian Islands, entering the Pacific Ocean through Amukta Pass, near which she was at midnight of June 30, the close of the fiscal year.

Owing to the long delay in port, in consequence of the extensive repairs made necessary by previous service, the *Albatross* was only 75 days at sea during the year, but the distance steamed amounted to 9,610 miles. Prof. B. W. Evermann, who acted as chief naturalist during the first cruise made on behalf of the Treasury Department, left the ship after his return from Alaska in August, 1892. The permanent civilian staff consisted of Charles H. Townsend, naturalist; A. B. Alexander, fishery expert; and N. B. Miller, laboratory assistant. The two former were attached to revenue vessels during the summer of 1892, but were with the *Albatross* during the remainder of the year.

No trawling or hydrographic work was carried on except during the short trial trip off Monterey, in April, 1893. Meteorological and density observations were continued, however, during the entire year, and a record was kept of all surface animal life and drift material observed at sea. Full details of the operations of the ship are given in the report of Commander Tanner, forming an appendix to this volume.

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

By an exchange of notes between the Government of Great Britain and that of the United States, an agreement was reached on December 6, 1892, which provided for the appointment of a joint commission of two experts, one on behalf of each government, to consider and report to their respective governments, jointly or severally, concerning the regulations, practices, and restrictions proper to be adopted in concert, on the following subjects:

1. The limitation or prevention of exhaustive or destructive methods of taking fish and shellfish in the territorial and contiguous waters of the United States and Her Majesty's possessions in North America, respectively, and also in the waters of the open seas outside of the territorial limits of either country to which the inhabitants of the respective countries may habitually resort for the purpose of such fishing.

2. The prevention of the polluting or obstructing of such contiguous waters to the detriment of the fisheries or of navigation.

3. The close seasons to be enforced and observed in such contiguous waters by the inhabitants of both countries, as respects the taking of the several kinds of fish and shellfish.

4. The adoption of practical methods of restocking and replenishing such contiguous and territorial waters with fish and shellfish, and the means by which such fish life may be therein preserved and increased.

It was furthermore provided that—

The commissioners to be so appointed shall meet at the city of Washington within three months from the date of this present agreement, and shall complete their investigation and submit their final reports thereof to the two governments, as herein provided, within two years from the date of their first meeting.

The contracting governments agree to place at the service of the said commissioners all information and material pertinent to the subject of their investigation which may be of record respectively in the offices of the United States Commission of Fish and Fisheries and in the Department of Marine and Fisheries of the Dominion of Canada; and, further, to place at the disposal of said commissioners, acting jointly, any vessel or vessels of either of the said fish commissions of the United States and Canada as may be convenient and proper to aid in the prosecution of their investigation in the contiguous and adjacent waters aforesaid. * * *

The two governments agree that so soon as the reports of the commissioners shall be laid before them as aforesaid, they shall consider the same and exchange views thereon, to the end of reaching, if expedient and practicable, such conventional or other understanding as may suffice to carry out the recommendations of the commissioners, by treaty, or concurrent legislation on the part of the respective governments, or the legislation of the several States and Provinces, or both, as may be found most advisable; but nothing herein contained shall be deemed to commit either government to the results of the investigation hereby instituted.

The two representatives appointed in accordance with the foregoing agreement were, on the part of Great Britain, Dr. William Wakeham, of the Department of Marine and Fisheries of Canada, and, on the part of the United States, Mr. Richard Rathbun, of the United States Fish Commission. Their first meeting was held at Washington, on March 2, 1893, at which Dr. Wakeham was accompanied by Mr. R. Venning, of the same department as himself, Dr. Hugh M. Smith, of the United States Fish Commission, acting with Mr. Rathbun. At this conference,

which continued several days, the scope of the inquiry contemplated by the agreement and the plans for carrying on the necessary investigations were discussed in full, and arrangements were also made for beginning upon the field work as soon as the season was sufficiently advanced.

The waters covered by this agreement are not only very extensive and diversified, but they afford some of the most important fisheries of the world, in the preservation of which both Canada and the United States have a mutual interest. With respect to the open waters of the Atlantic coast it was decided that the mackerel fishery, which is carried on continuously from off Cape Hatteras, North Carolina, to the mouth of the River St. Lawrence, was the only one demanding immediate attention in this connection. At the mouth of the Bay of Fundy, about Eastport, Me., and the neighboring islands, are several marine fisheries which overlap the boundary line. Next come the rivers St. John and St. Croix, flowing in part between the Province of New Brunswick and the State of Maine. Following in succession are Lake Memphremagog, Lake Champlain, the upper part of the St. Lawrence River, and the entire chain of the Great Lakes, except Lake Michigan, which is entirely included within the territory of the United States. A short distance to the westward of Lake Superior are Rainy Lake and the Lake of the Woods, both situated on the northern border of Minnesota and finding an outlet northward into Lake Winnipeg and thence into Hudson Bay. Farther to the west there are no important waters until we reach the Columbia River, where it crosses the boundary into Washington. Finally, on the Pacific side, are the extensive sounds and straits between British Columbia and the State of Washington, still only slightly developed except as regards the catch of salmon.

As it was evident that the members of the joint commission would not have the opportunity of inspecting personally in detail all the fisheries on which they were expected to report, it was arranged on the part of the United States Fish Commission to send out several field parties to make special studies respecting some of the more difficult problems presented. The schooner *Grampus* was detailed to investigate the offshore or purse-seine mackerel fishery from the time of its commencement at the extreme south, as had been done in former years, but in accordance with a more comprehensive plan of operations; an assistant was stationed at Fulton Market, New York, to inspect all mackerel brought there both by the purse-seiners and from the nets along the coast, the owners of many of the latter being also supplied with blanks on which to record their catch of this species; and the assistants at the Woods Hole station of the Commission were charged with the study of the breeding and other habits of the mackerel in the neighboring region, which is especially well adapted for observations of that kind. A party was also established at Eastport, Me., and another on Lake Erie, while the steamer *Albatross* was directed to investigate the boundary waters on the western coast at such times as her regular duties would permit.

The members of the Commission, together with Mr. Venning and Dr. Smith, met at New York on June 2, where they began their inquiries respecting the mackerel fishery. From there they proceeded to Woods Hole, Mass., and thence visited all the more important fishing ports on Cape Cod. Subsequently a few days were spent in Boston and Gloucester, Mass., and Portland, Me. At all of these places interviews were held with the fishermen, the shore apparatus of capture was visited and many mackerel were examined. At the close of the fiscal year the party was at Eastport, Me., from which place it was planned to go to the Gulf of St. Lawrence.

OYSTER INVESTIGATIONS AND EXPERIMENTS.

CHESAPEAKE BAY.

The oyster survey of Mobjack Bay, begun in May, 1892, was continued during most of the following summer, being completed about August 20. The delineation of the oyster beds and of the areas of scattered oysters in the open waters of the bay, by means of the launch *Petrel*, was finished early in July. The dredging work was then immediately taken up by the steamer *Fish Hawk*, Lieut. Robert Platt, U. S. N., commanding, having for its object to determine the actual condition of the oyster beds, including the number of oysters of different sizes to each square yard of bottom. Subsequently the steamer *Fish Hawk* proceeded to Tangier Sound, on the east side of Chesapeake Bay, where extensive investigations had been carried on the previous year, and repeated its lines of dredgings over the principal beds, in order to ascertain what, if any, changes had taken place in their condition during the intervening twelve months. While the dredging work was in progress the launch *Petrel* continued the oyster survey up the four rivers tributary to Mobjack Bay, the East, North, Ware, and Severn. Signal stations had first to be established, followed by a triangulation of the streams as far as was considered necessary, after which the location and extent of the natural oyster beds were determined.

The assistants of the Fish Commission who were engaged upon this inquiry were Mr. John D. Battle, in charge, Mr. W. F. Hill, and Mr. B. L. Hardin. As soon as this party returned to Washington the construction of the charts to illustrate the results of the investigation, as well as the compilation of the data relating thereto, were pushed rapidly to completion, and copies of the same, together with the corresponding charts of Tangier and Pocomoke sounds, based upon the surveys of 1891, were supplied, at an early date, to the government of Virginia, to serve as a basis for establishing the outlines of the public oyster-grounds in those parts of the State waters to which they related, after the manner described in the last annual report. A steam launch was also provided for the use of the State party engaged upon this work. That the assistance rendered by the United States Fish Commission in this connection was of great value to the State authorities of Virginia and was duly appreciated by them may be judged from

the following extracts from two letters received during the year from the engineer in charge:

> The steam launch furnished by the United States Fish Commission and the copies of the records of that Commission have alone enabled me to finish the work in Tangier and Pocomoke sounds in a short time.
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> The charts showing the legal boundaries of the natural oyster beds of about half of the Virginia waters have been published. I should never have been able to accomplish this without the assistance rendered by you.

The inquiries respecting the food of oysters and the relations of oysters to their environment, by Dr. John P. Lotsy, of Johns Hopkins University, the plans for which were referred to in the last report, were commenced early in July, 1892, and completed the latter part of September. These researches were carried on in the vicinity of Hampton, Va.

GALVESTON BAY, TEXAS.

In the early part of the summer of 1892 word was received of a sudden and extensive mortality among planted oysters in Galveston Bay, Texas, and an inquiry into the causes thereof was requested. One company alone had made plantings on 480 acres of bottom of empty oyster shells and seed oysters a year or so old, the latter growing rapidly and the beds being in a prosperous condition as late as the close of April, 1892. During May, however, the oysters began to die without apparent cause, and a month later scarcely anything but empty shells were left upon the ground where a yield of over 300,000 bushels had been expected the following winter. The mortality was not confined to this particular planting, but was said to have extended also to the wild oysters in other parts of the bay. In August Mr. John D. Battle was detailed to investigate this matter, and at the same time to make a general examination with respect to the oyster resources of the region, to serve as a basis for possible future inquiries on a more extensive scale. Only a short time was spent upon this work, but considerable information was obtained.

With regard to the question of mortality, the subject was studied from several standpoints. Too great an influx of fresh water has been considered a frequent cause of such destruction. However, the only sources, except seepage and local rainfall, from which a supply of fresh water can reach Galveston Bay are the San Jacinto and Trinity rivers, both of which are relatively small as compared with the main body of the bay. The Trinity drains quite an extensive territory, while the San Jacinto does not, but the fresh waters coming from both of these rivers meet and merge into each other and flow over Redfish Bar into the lower part of Galveston Bay. General inquiries made to ascertain if there had been an unusual rainfall and freshet in these rivers at or just before the period when the mortality on the planted grounds was first noticed afforded negative results. According to the records in the office of the Weather Bureau in Galveston, however, there had been

an average rainfall during April and May, and in March only an inch more than the average. During the same period there had also been some strong northwest and southwest winds.

Although Mr. Battle's visit was made during the dry period of the year, he undertook to ascertain by density observations the point nearest to the planted grounds where fresh water could then be found, both at the surface and the bottom. A line of such observations was, therefore, run up the bay in a general northwesterly direction, from off the foot of Tremont street, Galveston, and over the planted grounds to the mouth of the San Jacinto River, a distance of 25 miles. At the foot of Tremont street the specific gravity was 1.017 at high water, and 1 mile farther, 1.0166. On section 1 of the planted beds it was the same as the last, and on section 8, three-fourths of a mile away, it amounted to 1.0164. Beyond the area of the planted grounds the observations succeeded one another as follows: About 1 mile WNW. of the west end of Pelican Island, 1.0147; about 1 mile SE. of Half-Moon lighthouse, high tide 1.015, ebb tide 1.0142; about 200 yards from Half-Moon light-ship, 1.0144; about 1 mile NNE. of Dollar Point, ebb tide 1.0132; about 2 miles south of Redfish light-house, ebb tide 1.007; Redfish Beacon, 1.0036; about 400 yards SE. of Northwest Beacon, 1.002. Five subsequent stations were made, the last about 1 mile NW. of Red Bluff Buoy, where the water was practically fresh both at the surface and bottom.

Information was furnished to the effect that the water in the bay is never fresher than at the time of year when this examination was conducted, but Mr. Battle is inclined to doubt the correctness of this view as not being based upon scientific observations, and, moreover, the occurrence of any particular freshet having its origin from 25 to 30 miles away might easily escape detection by those living along the sea. Such a freshet would undoubtedly bring the fresh-water point much nearer to the Gulf and might radically affect both planted and natural oyster beds. Even if the salinity of the water is as great at all seasons as it was in August, Mr. Battle thinks his observations clearly demonstrate that it would be the height of folly to plant oysters north of Redfish Bar. Empty shells are much more numerous than living oysters on this bar, and he has no doubt that fresh water was the main factor in their destruction. An oysterman of long experience in this region recalls that oysters have twice been destroyed in Galveston Bay within the past twenty-five years, once by fresh water and again during the great southeast storm of 1875, which lasted several days and swept everything before it.

Mr. Battle next made a critical investigation of the planted beds and of the natural beds nearest to them, with the object of determining their relative condition as to mortality and the character of the bottom. Samples were obtained by tonging from all of the eight sections of the planted ground. The total amount of material brought up was 1½ bushels, which contained 46 adult oysters and 992 spat. The oysters were generally in groups or clusters, seldom single. The living adults

seemed to be in as good condition as those examined on the natural beds, and the spat was still attaching and thrifty. Drawbridge Reef, about 2¼ miles southwest of the planted beds, which was next examined, is one of the best grounds as regards quality of oysters, but it has been overfished. It showed no signs of any special destruction which could be attributed to a late cause. It occupies a stable shelly bottom where the observations were made. On Blind Shoal Reef, another shelly bottom, about a mile northwest of the planted grounds, dead shells were more numerous, which may indicate a greater mortality, and the oysters were not so finely shaped as those on Drawbridge Reef. This bed is nearer the fresh-water point, but the density determinations were as high as 1.0126 and 1.013. The oysters on Half-Moon Reef, judging from the shells, show some deaths which may have been of late date, but not enough to assign any other cause for mortality than that of old age and the usual casualties.

Finally, the character of the bottom on the planted beds was tested by means of a sounding pole, which showed it to be generally soft, and in some places very soft. The pole would usually go down very easily a distance of 10 to 12 inches through the mud before it reached a harder substratum. Several times shells were felt at a depth of 10 or 12 inches, apparently resting on this substratum. Judging from the softness of the bottom and the mud-stained condition of the shells, Mr. Battle is led to believe that mud has been a factor which will account in part for the destruction of the planted oysters. The general trend of the currents over these beds is southeast and northwest. One may readily conceive that strong northwest winds, which have a sweep down the bay from the mouth of San Jacinto River, would affect objects lying on the bottom in shallow water. It would naturally impart a motion to them and cause them gradually to sink. It is reasonable to suppose also that this disturbance would make the water very thick with suspended mud, especially that part of it near the bottom and immediately surrounding the oysters, and if continued for any length of time would result in great injury to the beds. Southwest winds would have a similar but less effect, for the reason that they do not have the same sweep.

Comparing the general character of the bottom of the natural beds with that of the planted grounds, it will be found that the former are much more stable, owing to the yearly accretion of shells on which the living oysters grow. The plantings already made on the artificial beds, amounting to 400 bushels to the acre, may possibly furnish a foundation which will render the bottom more stable and result in the formation of a continuous oyster bed in the course of time, and the chances of success in that direction would be greatly heightened by the addition of more shells.

Within 1½ miles of the planted area are located mills for the manufacture of creosote. It had been conjectured that the refuse from these mills might have been responsible for at least a part of the mortality

above referred to. An examination of the piles of neighboring wharves, however, showed the presence of adult oysters and spat in a flourishing condition, as well as an abundance of other forms of life which are generally found in such situations. The pungent odor of creosote was very strong under the nearest wharf, but it did not seem to affect the welfare of the oysters there, although they appeared to Mr. Battle to leave an astringent taste in the mouth. A sample of the water and specimens of oysters from the wharves were afterwards subjected to chemical examination in Washington, without discovering the presence of creosote or of any other poisonous matter.

Besides the inquiries above referred to, Mr. Battle also located approximately all of the natural oyster beds in Galveston Bay. There are none in the deeper parts of the bay, probably owing to the soft character of the bottom, but they are situated on shoals, from which, in some instances, they have encroached on the adjacent soft bottom by yearly accretion. Except for the preponderance of this soft bottom the conditions seem favorable for oyster-culture south of Redfish Bar, in case the water is never fresher than in August for any length of time. The only enemies known are the drill, conch, and drumfish, no harmful starfishes, it is asserted, finding their way to the oyster beds.

SEA ISLE CITY, N. J.

In the last annual report reference was made to experiments by Prof. John A. Ryder, of the University of Pennsylvania, respecting the collecting of oyster spat in accordance with an entirely new method, which promised excellent practical results. Formerly, while a member of the scientific staff of the Fish Commission, Professor Ryder's energies were directed chiefly toward the solution of this important and perplexing problem, which involves the prosperity of a large proportion of our coastwise population. His work was then carried on mainly at St. Jerome Creek, Maryland, and at the Woods Hole station of the Fish Commission, and, although fair success was met with, it fell short, for some reason, of the practical benefits which had been anticipated.

During the season of 1891, taking advantage of the facilities afforded by the marine station of the University of Pennsylvania at Sea Isle City, N. J., Professor Ryder started upon a new series of experiments differing radically from any he had tried before. The incidental expenses of the work that year were met by the university. During the next summer, 1892, coöperation with the Fish Commission was accepted to the extent of paying for the appliances and supplies necessary to conduct the work upon a larger scale.

The following extracts from letters written by Professor Ryder in May and June, 1892, will serve to explain his plans:

I propose this summer to conduct a series of experiments on a wholly new line. I think most of us have been mistaken in our way of looking at the question. I want, this year, to produce from 30 to 60 bushels of seed oysters to the square rod. I have already experimented far enough at Sea Isle to show that such an estimate is not

extravagant. * * * I firmly believe that the culture of oyster spat or seed is as practicable as bee-culture, and that it may be profitable also. I believe that the production of spat or seed oysters can be carried on in concentrated or condensed form, and that it may and will become a distinct industry from that of oyster planting. It will inevitably come to this, and will be as scientific and precise in its knowledge of conditions as bee-culture.

I have just returned from a visit to Sea Isle City to inspect my last year's experiments in oyster-culture. I find, to my surprise, that spatting is already in progress there, and I inclose with this a young oyster which I should judge was already three weeks old. These results, together with my Chesapeake Bay observations made in 1880, prove that the spatting period extends over four or five months. My method of working there has resulted in the development of what I believe must eventually be the method of rearing spat on a large scale for commercial purposes on an apparatus that will cost 30 cents per square yard. The yield from the very small plant already in use promises the first year from 1 to 3 bushels of seed oysters per square yard, ranging from 2 to 2½ inches in length. The method is, in fact, applicable where the bottom consists of ooze and is unfit for planting, and will enable the oystermen of New Jersey to reclaim thousands of unused acres of riparian territory. My plan is essentially the creation of an artificial bottom or bed which shall be at all times accessible for cleaning, sorting, spawning, and growing oysters to marketable dimensions. It also makes it possible to use the whole spawning season, four or five months, with clean shells for the whole time. Moreover, there is no loss of shells in the mud, so that shells once brought to the bed can be used until they have caught spat. This does away with the wasteful results of sowing shells on the bottom.

Since I have returned I have visited Sea Isle and met one of the oystermen there, who is very much interested. He told me that if he could do on a more extensive scale what I succeeded in doing there last year on a small scale, he would not hereafter need to import seed from the Chesapeake. He will supplement my work with experiments of his own. This, from a practical man who has been in the business for many years, is, it seems to me, a pretty strong indorsement.

The framework for holding the cultch and breeding oysters was constructed in the early part of July, 1892. It consisted of six squares of No. 16 galvanized-iron wire netting, each 1 rod square and having a 2-inch mesh. These squares or frames were supported on cedar piles driven into the soft mud and jointed with stringers of light pine. The entire outfit was very cheap, costing only a little over $60, inclusive of the oyster shells planted upon it, and will last for two or three years without repairs. This apparatus was arranged in the wide tide-water ditches which had been cut to drain the land about the laboratory at Sea Isle City. The wire screens were placed about 6 to 8 inches below high-water level, so that when covered with 30 to 50 bushels of clam and oyster shells as cultch, together with a few adult oysters to furnish the spawn, the top of the bed was nearly uncovered at low tide. The idea was to have the cultch as near the surface as possible, in order that the fry might have a proper chance to set.

The experiments of the first year, 1891, afforded very encouraging results, as at the end of eleven months some of the spat had attained a length of 3 inches and would have made cullings or good plants. In that year they obtained as many as 30 to 40 bushels of seed to the square rod, including the old shells to which they were attached. At this rate the possibility of growing seed from cultch thus treated may be considered as having been successfully proved, and at the end of the

first half of 1893 the original square bed had been transformed into an almost solid oyster bank. In 1892 the six new frames were not in place until later in the season and the results were consequently not so good, but the experiment attracted much attention among the oyster-growers of the neighborhood.

The satisfactory outcome of Professor Ryder's experiments induced the legislature of New Jersey to appropriate $5,000 annually for three years to supplement his work upon a practical scale. In discussing the manner in which this sum could best be expended Professor Ryder has expressed himself as follows respecting the method which he would prefer to see tried:

If any action is to be taken in the matter, sites should be selected, under intelligent direction, at different points in the State at once, and work begun to carry out the experiments on a large, practical scale. If successful, this investment by the State of $5,000 per year will be an absolutely insignificant sum in comparison with the resulting development of an industry worth millions of dollars per annum to her citizens.

My plan, based partly upon the experimental results of the past obtained by myself and others, is something like the following: First of all, having obtained a suitable place where oyster spatting is known to occur naturally and abundantly, and where the salinity of the water is about right, or somewhere between 1.014 and 1.022, according to a standard hydrometer, a site is to be selected for the establishment of the plant, which should be in complete working condition not later than the 25th day of June next. This site should be of such a character as will enable the construction of an inclosure or pond on a pretty large scale, say half an acre at least. It might even be that a pond would have to be excavated near the shore; but in any event the plant should be so arranged that, under the given conditions, the most economical plans of construction could be followed. This pond should be completely shut off from all direct tidal connection with the sea while in use, and lie, if possible, in a perfectly accessible position from all sides, somewhat higher than sea level, though it should be possible to fill the pond from the sea if necessary.

The pond, which we will designate A, should represent an area, say, of from one-half to 1 acre, with a platform resting upon piles, quite near the surface of the water. This platform is formed of galvanized netting, 2-inch mesh, costing 3 cents per square yard, and supported on piles and stringers. It will hold a layer of oyster shells 3 or 4 inches thick, or 40 bushels to the square rod, or from 800 to 1,600 bushels of oyster shells, according as the size of such a pond and platform equals one-half or 1 acre. This is our nursery for clean oyster shells, clam shells, potsherds, tiles, or anything that young swimming oyster "fry" will cling to in order to grow into the condition of the young oyster, or "spat," as it is called.

There should be another platform, B, of an area of one-fourth acre, covered thickly, say, with 100 to 200 bushels of adult spawning oysters, and the whole immersed, say, 6 inches or 1 foot below extreme low water. This area should also have a ledge of heavy planking constructed all round it, so as to prevent the "fry" of the oyster during its floating stage from being wafted away by the tides and lost. Where a natural oyster reef exists the platform would not be needed, since such a reef near by would amply supply the millions of fry that would be required for our experiments.

Next there must be a wind engine and tank for pumping the sea water through pipes from all parts of the area B, and from near the surface, where the floating or swimming "fry" is very abundant. This sea water, charged with its oyster "fry," is then carried to the far side of the pond A. The water then flows from outlet pipes toward escape pipes and back to the sea. In this way, with only slight provisions for filtration, and perhaps a tank under the wind engine for allowing the coarsest

sediment to subside, billions of oyster "fry" can be pumped from the area B through the mass of shells covering the platform A.

The best possible conditions could be maintained and the shells could be kept clean in the pond A by overhauling them by hand from time to time, giving each one a shaking in the water, so as to always present clean surfaces for spatting during the six to eight weeks within which that occurs. With such a plant, costing about $1,000 to $2,000 for its first installation, I would expect that something of permanent value might come, and that such establishments would become the basis for more extensive enterprises controlled by private capital.

The device here described provides many things in the best and cheapest form, though it is not assumed that the plan may not be greatly improved and perhaps modified as a result of practical experience. The aims to be sought are: (1) A vast amount of surface in the form of clean shells supported upon a platform, placed in position about the 1st day of July, when (2) the wind engine may be started to pump the water charged with "fry" from the bed of adult spawning oysters. (3) The "fry" should be pumped from the surface, where it swims for a time. This, I think, is an important point. Past experience shows that the passage of the "fry" through a pump does not injure it. With such a plant, and in the light of past experiences at Sea Isle, especially the season of 1891, for every bushel of shells put into the nursery I should expect a bushel of seed. Past experience shows that this seed will, in the space of twelve months, reach a size of 2½ inches. This estimate I believe to be a fair one, and since the installation or plant is practically a permanent fixture, the possibility of conducting such establishments as permanent nurseries for the production of seed oysters for planting is seen to be a practical matter awaiting a practical test. Oysters are like potatoes; they will stay just where you plant them. The only one of their stages that is locomotive is the "fry" or swimming stage. With such a device as the above we get the maximum possible spatting capacity from an abundant source of fry production. That source should be at least 200 bushels of adult spawners—better still if it were 2,000 bushels. This last number of spawners should yield at least 600,000,000,000 of fry. This vast multitude of young oysters pumped through 800 to 5,000 bushels of shells should yield an abundant supply of spat capable of growing into "plants" or seed oysters, fit for restocking exhausted beds.

The time may come, as it already has in parts of the country, where oyster and clam shells can not be obtained in sufficient quantity to serve as the "cultch" or nidus upon which the "fry" is to attach itself. When this happens it will be an easy matter to produce a cheap kind of tile or earthenware by machinery, in curved flakes somewhat like the oyster shell itself in shape, that can be "burned" or "kilned" somewhat after the manner of bricks. This material could be produced in vast quantity and very cheaply for the purpose of furnishing the foundations for the "spat" or seed oysters in these oyster nurseries of the future. The experiments conducted under my direction at Sea Isle for the past two years, on behalf of the United States Fish Commission, have served to show what the probabilities of artificial oyster-seed culture may some day become when pursued with sufficient capital and energy.

PACIFIC COAST.

While it has been impossible during the past year to undertake any extensive investigations or experiments respecting the subject of increasing the oyster supply on the Pacific coast, observations upon the temperature and density of the water in places supposed to be favorable to oyster growth have been made whenever the opportunity permitted. Such inquiries, continued from year to year, as they have been in the past, will ultimately yield information of great value to those desirous of attempting the establishment of new oyster plants from one

source or another. There are several bays along that coast which seem to be suitable for the introduction of Atlantic stock, and it is now proposed by the Fish Commission, as soon as the necessary arrangements can be perfected, to make a small planting of the eastern species, probably at Willapa Bay, Washington, where the character of the bottom and salinity of the water appear to favor the success of such an experiment. Great interest is now manifested along the entire extent of the Pacific coast in respect to the oyster question in general, and letters requesting advice as to where the best seed can be obtained or as to the conditions necessary to insure the growth and welfare of this mollusk are constantly received.

EUROPEAN METHODS OF OYSTER-CULTURE.

The last annual report contains a reference to important studies respecting oyster-culture in France, made for the benefit of the Fish Commission during the summer and fall of 1891 by Dr. Bashford Dean, of Columbia College, New York.[1] Before the close of that year Dr. Dean extended his inquiries on the same subject to Spain and Portugal, and during the one just past he has visited Italy, Germany, Holland, Belgium, and England on a similar mission. A report upon the results of his observations in those several countries, accompanied by many instructive illustrations based upon photographs made by himself, has recently been received and published.[2] It will prove of great interest to all the practical oystermen of this country who are desirous of improving the condition of their industry. Dr. Dean's field inquiries were conducted with great care, strict attention being paid to all important matters of detail; and in the preparation of his report he has taken exceeding pains to present in a concise form the different subjects of which it treats, without omitting, however, anything essential to their complete understanding.

The reasons for extending these researches to other countries than France are explained by Dr. Dean as follows, in the introduction to his last paper:

> The methods in use along the ocean coast of France are, in general, similar to those of the neighboring countries. It has, however, seemed important to understand the cultural modifications rendered necessary by changes in climate, shore characters, and saltness of water. Local conditions may not unnaturally have favored one particular locality to such a degree that methods of culture there in use might prove of little value in other and even neighboring regions. By general comparison a more distinct idea may be obtained of the actual character and extent of artificial culture. Thus may be seen by what manner and means one country of Europe has taken advantage of the practical successes of a neighboring one, has modified processes to suit local conditions, found by experiment to what limits imported methods may be carried, and succeeded or failed in securing the most judicious governmental aid in obtaining concession of cultural lands and in preserving the natural supplies of spawning oysters.

[1] Report on the Present Methods of Oyster-Culture in France, by Bashford Dean. Bull. U. S. Fish Comm. for 1890, pp. 363–388, plates 68–78.

[2] Report on the European Methods of Oyster-Culture, by Bashford Dean. Bull. U. S. Fish Comm. for 1891, pp. 357–406, plates 75–88.

The industry is discussed by Dr. Dean separately for each country, comprising in each case an account of the distribution and characteristics of the natural beds, of the methods employed in cultivation, in the production of seed and the rearing to adult size, and of all other matters bearing upon the subject of oyster production and preservation. The importance of the suggestions contained in this report, as well as in the preceding one, can not be overestimated, and it is sincerely to be hoped that the oyster interests of this country will be materially advanced thereby. Some of the more significant of Dr. Dean's conclusions are quoted herewith:

It would appear, for example, that the degree of density of the water is one of the most important factors influencing the spawning and fattening of the oyster. * * * The density of the water recorded in the best spawning-grounds of the French coast is practically that of the spawning-grounds of Italy and of northern Europe. * * * The specific gravity of the water in regions of maximum production throughout Europe appears to be uniform at about 1.023 in the case of the "flat" oyster (*Ostrea edulis*), and at about 1.021 in the case of the Portuguese species (*Ostrea angulata*). The influence of warmth is not to be underestimated in regard to the time and degree of spawning.

The amount of spat occurring annually in a region appears to be directly in proportion to the number of spawning oysters in that region. This is by no means a novel suggestion; it is one, however, that has been repeatedly impressed upon the writer. The older idea, it will be remembered, is that banks can never be exhausted, on the ground that the few oysters left by the dredgers will, by the annual spawning of several millions of young, cause a very rapid regeneration. That the banks regenerate is true, but the process is shown to be slow and beset with many difficulties. * * * It should be noted that only in those places in Europe where the natural bulk of spawning oysters is actually maintained does a great quantity of spat occur regularly; also that where the number of spawning oysters is equal, the percentage of spat will be notably greater if the spawning oysters are little disturbed.

The amount of oyster food appears to be notably characteristic of a locality whose normal food value is represented by conditions of warmth, density, and richness in the organic and inorganic salts, which serve to rapidly generate the oyster-food organisms. Should this natural food value of a locality be a high one, culture has demonstrated empirically that the number of oysters that may be reared is exceedingly great. It would appear that the number of oysters to be fattened is directly proportioned to the food normal of the locality and to the volume of water which passes over the bed. The actual size of a natural oyster bed is limited by other reasons than that of a failure of the food supply in the neighborhood. * * *

The system of stated oyster reserve has been the key to the success achieved by the French and Dutch industries, and has alone rendered it possible for these two countries to supply the entire seed market of Europe. To obtain seed oysters by collectors is shown to be possible only when a regular yearly fall of spat is thus assured. Proximity to a large stock of spawning oysters is one of the imperative conditions of artificial production, a condition that has been too often lost sight of in experiments made along the Atlantic coast of the United States. Collectors in Europe are placed on no river bank or sunk in no stream save where the culturist is fairly sure of a set that will be at least profitable. If experiments in artificial production are to be made in the United States, the suggestion given by European oyster-culture is to secure for the purpose a particular part of beach, near the line of low water, where spat has been found to regularly occur. If a trial demonstrates that the locality is favorable, the European culturist would then gradually and carefully expend his money in the purchase or preparation of a more extended area for collecting and would study to provide the most suitable form of collector. * * *

There can be no doubt that artificial production would succeed in American waters. The question is the practical one, whether it would, on an extended scale, be less costly than the price of natural seed. This can only be determined by experiments in a favorable locality. * * * The phase of European oyster-culture that has as yet no equivalent with us at home is that of the extreme value of land at particular points. * * * The general need in the United States for area in which to extend oyster-culture can hardly be regarded as immediate. At points, however, where local cultural conditions are exceedingly favorable to rapid growth or fattening, it would seem a practical measure to bring into cultivation extended shore strips near the zone of low-water mark by use of tidal parks of the least costly type.

* * * * * * *

In those countries alone where government has absolutely preserved supplies of spawning oysters does seed-culture flourish. The permanent closure of a small natural oyster-bearing area has apparently done what has not been done by a close season of the "R"-less months. * * * That the absolute reservation of oyster-bearing land will have an immediate and important influence upon the production of seed in neighboring areas is a proposition which European experience seems to demonstrate; and the writer would suggest, as in his former report, that the matter of reservation seems far more pertinent to the needs of the American industry than any attempts at artificial production. * * * Reservation is clearly a governmental duty, whether State or local. The matter is not a new one, and the condensed experience of Europe merely emphasizes what, with various modifications as to tenure, time, and degree, the authorities on this subject in the United States have already advised.

PHYSICAL INQUIRIES.

OFF COAST OF SOUTHERN NEW ENGLAND AND THE MIDDLE STATES.

As it was found impossible to continue during the summer of 1892 the elaborate series of observations carried on during the previous three years respecting the temperature and other physical observations off the southern coast of New England, it was decided to have the schooner *Grampus* make a thorough search for the tilefish in the localities where it had abounded before the astonishing mortality in 1882, which seemed to have effected its extermination. Predicting its return upon the results of the physical inquiries recently conducted, it was confidently expected that at least a few specimens would be captured, and such proved to be the case. During the several trips made between the region off Marthas Vineyard and the latitude of the Delaware capes, 8 specimens were secured by means of cod trawls, some of them of very fair size. The investigations of 1892, as well as those of the previous three years, were in charge of Prof. William Libbey, jr., of Princeton College, the Commissioner of Fisheries also taking an active part in the work and accompanying the *Grampus* in its earlier trips.

The following notice of the results accomplished during the past three years has been prepared by Professor Libbey:

During the summers of 1890 and 1891 work was continued in the same area of water off the southern New England coast as in 1889, the same limitations, east and west, and north and south, being observed, except that in 1890 the lines run by the Coast Survey steamer *Blake* extended 20 miles farther out to sea than usual, or a total distance of 150 miles.

As the steamer *Blake* could not be spared for this purpose in 1891, the parties upon the schooner *Grampus* and the Nantucket New South Shoal light-ship were the only ones in the field. As it was considered inadvisable to make a regular series of observations over the entire area this year, such lines were chosen as would serve to bring out the essential character of conditions supposed to exist. Each line run, however, was equivalent to one that had been utilized in previous years, but the distance between the lines was greater. The schooner *Grampus* occupied 148 stations along 13 such lines, making a total of about 1,500 serial temperature observations of the water and over 300 determinations of its specific gravity. In the same connection over 11,000 hourly meteorological observations were recorded. The light-ship party was on duty from July 3 to August 17, during which time it made 500 serial temperature and 250 specific-gravity observations of the water, besides a special series of over 1,000 hourly determinations of specific gravity. The hourly observations respecting meteorological conditions by this party amounted to 17,000. The total number of observations made in 1891 was, therefore, 32,000, as compared with 39,000 the previous year, when three parties were at work.

The relations of the Gulf Stream to the Labrador current, as brought out by this study, are especially interesting because of their bearing upon the migrations of schools of fishes. The region off the southern coast of New England was chosen for this inquiry because it was supposed that the contrasts between the currents would be more distinctly shown there from the fact of their being forced closer together by the projection of the mainland to the southeastward from its general curve. This expectation was realized in the course of our investigations.

The 50° curve of temperature obtained by plotting the observations made at the different stations has been an interesting one from the beginning. It has been the means of demonstrating the fact that there are two sets of conditions under which these two distinct bodies of water come into contact. It will be convenient to speak of these two portions of the main current of the Gulf Stream separately under two headings, namely, the upper portion and the lower portion.

Upper portion.—The boundary between the cold and warm waters at the surface is very seldom a straight line, perpendicular to the surface of the water. It marks the position of the resultant of all the forces at work. Of course the general position of the boundary will be determined by the velocities of the two bodies of water and their direction when they come in contact. If we leave out of consideration, for the present, the wind as an effective agent in the production and directing of the ocean currents, we find that in addition it becomes a most potent factor in the causation of the changes which are produced in the position of the boundary line at the surface. The winds certainly sway the surface waters of these currents one way or another; it may be for miles in one direction or the other; just as they may retard or reenforce them in their general direction.

The winds which blow over this portion of the North Atlantic may, for convenience, be divided into two classes. One may be said to blow in a southeasterly direction and the other in a northwesterly direction. The general tendency of the first group or summer set will be to drive the warmer waters at the surface toward the coast, thus forcing them above the colder waters of the Labrador current. The other or winter set may be considered to have the opposite effect upon these waters, and the final position reached after a cycle is completed will depend on the relative velocities of the winds. It is not denied that there are other factors which enter into this result, or that this position is not affected by the physical characters of the waters, viz, their relative temperatures, densities, etc., but it is claimed that, after due allowance is made for these other factors, the winds are the most active causes of the daily and seasonal variations which take place in the position of this boundary.

While these motions may equalize one another and the resultant position remain the same from year to year, it is supposable that there may be an excess in one or the other of these directions for a series of years, with the result that the boundary

will be carried far from its normal position in one direction or the other, and thus mask the true position of the main body of one or the other of these currents to a very considerable extent.

Lower portion.—It might be expected that in this position only the general causes which produce and modify the currents in the oceans could bring about any change in either their velocity or their direction. But there is no doubt that the cumulative effect of long-continued impulses, as described above, resulting in each case in a gain in one or the other of these directions, will ultimately be felt, and the result will be seen in a change of position of the main mass of the current. When these changes are brought about, they are of such a character as to evade detection, unless the averages of many observations are carefully studied, when the change in the position of the resultant becomes manifest. The contrast between these two portions of the current are seen in the apparently more flexible character of the upper portion as compared with the lower, the former being characterized by rather rapid changes in position, the latter by much slower motions.

The 50° line indicates very clearly the changes which take place in the relations of these currents. During the time when we were engaged upon this study its predominant shape was that of an inverted letter S, the lower part of the inverted letter representing the main body or lower portion of the Gulf Stream. Neither the 40° line nor the 60° line shows any great deflections under any circumstances, thus apparently indicating that they are well within the boundaries of each of the main bodies of their respective currents.

A study of the temperature profiles obtained in 1891 showed that the general relations of the currents had remained the same, but it was noticed that during the greater part of the time the curved bend of the lower part of the 50° line touched the edge of the continental platform, covering it completely from the depth of 70 fathoms to that of 120 fathoms in different places. This had occurred once or twice in 1890, but it was then believed to be rather an accidental feature than otherwise.

A comparison of the profiles of the three years revealed the fact that there had been a progressive motion during that period toward the shore. In 1889 the lower portion of the curve did not touch the edge of the continental platform at any point within the area we were studying. In 1890 this portion of the curve touched the continental edge both at Block Island and off Nantucket Island in the latter part of the season, and in 1891, as has been said, it touched along the whole edge of this portion of the platform during the greater part of the summer. The change which was thus produced in the temperature at the bottom along this edge of the continental platform was in the neighborhood of 10°, an item of considerable importance.

The effect produced by this change in temperature and its relations to the work of the Fish Commission can be seen to best advantage by reference to a very interesting problem in biology with which it has a direct connection. At a conference held in Washington with the Commissioner of Fisheries the results obtained were carefully discussed. We saw very plainly that if the same rate of motion held good during this year the whole of the continental edge, or at least that portion of it with which we were most directly concerned, would be covered with this warmer water. The idea was then suggested that if such were the case the conditions for the reappearance of the tilefish would be established if environment meant anything in the problem. In the years 1880 and 1881 this recently discovered fish had been found in considerable numbers upon the area we were studying, and had attracted so much attention among fishermen that preparations were made to take it upon a commercial scale for the New York and Boston markets during the ensuing season. Unfortunately, however, in the spring of 1882 the water from Cape May to Nantucket became covered with countless millions of this fish in a dead or dying condition. From that time the tilefish (*Lopholatilus chamæleonticeps*) disappeared from this area entirely, and all attempts to find it since then have been unsuccessful. The cause of its disappearance became a sort of biological puzzle.

The fish had previously been caught in a depth of water varying from 60 to 130 fathoms. Its feeding-ground being at the bottom would therefore occur just at the edge of the continental platform. It is probably a tropical deep-sea species, judging from its relationships, which had migrated northward through favorable inducements offered by an enlarged feeding-ground opened up in that direction. It is noteworthy that the temperature at which it was caught (50° to 58°) could only be established on the New England coast and at the edge of the continental platform by just such an invasion of warm water as has been described above. It is only necessary to conceive the whole of the continental edge from Florida to Nantucket thus overflowed by this warm band of water to see how the regular feeding-ground of a tropical species could be extended so that the fish could follow it throughout the whole of this largely increased area.

It was agreed to test these theoretical conclusions during the summer of 1892. In July the Commissioner and myself went out in the schooner *Grampus*, south of Marthas Vineyard, to the area which seemed to promise a reward for our labors. We found the temperature conditions right, set the cod trawls and caught the tilefish. During the remaining portion of the summer I spent considerable time tracing out the limits of the area over which the temperature of 50° and above could be found, using the trawl lines at the same time to ascertain if the fish were there. We found them all the way to the Delaware capes, and were satisfied that though they were not numerous they had taken advantage of the changed conditions to reoccupy this area.

WATER-TEMPERATURE STATIONS.

The Light-House Board and the Southern Pacific Company have continued during the year the taking of daily water-temperature observations for the benefit of the Fish Commission at the following places:

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, Wolf Trap Bar, 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 King's 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 was opened as usual for biological researches on July 1, 1892, but several of the workers arrived and were given the necessary facilities for carrying on their studies during June. The laboratory was in charge of Dr. James L. Kellogg, of Johns Hopkins University, and the Commissioner was also present during most of the season, giving personal direction to such parts of the investigations as were undertaken for the Fish Commission. The total number of investigators in attendance, not including the regular employés of the Commission, was fourteen; of these, two were engaged in the study of special subjects for the benefit of the Commission. The work carried on by each may be summarized as follows:

Dr. James L. Kellogg was occupied mainly with the study of the spawning and early habits of the common scallop or pecten (*Pecten irradians*), the younger stages of which were found attached in great abundance to ulva in the Acushnet River, near New Bedford, Mass. The breeding season of this species occurs during May and June in this region, and is probably of shorter duration than in the case of many other important food mollusks. During June the young were observed to present very slight variation as to size, and during the two succeeding months the growth was not rapid. The attachment to ulva was by means of a well-developed byssus, the occurrence of which in the first stages of growth has been recognized for some time. The byssus-forming gland, which was carefully studied, was found to remain functional until the latter part of August, when it became atrophied, and in the adults all traces of it have disappeared. Late in August the shell in many instances reaches a diameter of two-thirds of an inch, but considerable differences then exist with respect to size. The method of byssus attachment was determined in both the young pecten and the black mussel, and it was made out that in each of those species the byssus could be thrown off at will, the animal crawling about by means of its foot and reattaching. A vestigial organ, probably a nonfunctional byssus organ, was discovered in the young of Yoldia, another form of Lamellibranch.

The practical bearing of the results of Dr. Kellogg's observations relate to the artificial propagation or transplanting of the scallop, which, during its attached stage, could be transported conveniently in immense numbers with slight danger of loss. Moreover, if reared in confinement, a suitable collector could readily be provided for the attachment of the young, thereby obviating the difficulties attending the handling of large quantities of fry in a free condition. Studies were also conducted by Dr. Kellogg relative to the morphology and physiology of several bivalve mollusks.

Prof. Francis H. Herrick, of Adelbert College, Cleveland, Ohio, continued his observations, begun in 1890, on the development and the life-history of the lobster. As previously announced, Professor Herrick is preparing for the Fish Commission a comprehensive report upon the

natural history of this important marine invertebrate, which will be based chiefly upon his own studies now in progress, and is designed especially to present that class of facts regarded as essential in perfecting the methods of its propagation and providing for its better protection by means of legislation.

Prof. H. V. Wilson, of the University of North Carolina, nearly completed during the summer his inquiries relative to the development of certain sponges, which he had previously carried on at Woods Hole and at the Bahama Islands. These studies were partly undertaken with the view of using them as the basis for experimental operations in Florida respecting the cultivation of the commercial sponges, but this work has been deferred for the present owing to Professor Wilson's resignation from the service of the Commission. The report upon his observations, received during the year, has been published in the Journal of Morphology.[1]

Dr. William Patten, of the University of North Dakota, was engaged upon the study of the sense organs in the horseshoe crab (*Limulus*), supplementing his observations on structure by many interesting physiological experiments to determine their functions. These related in part to the sensibility of this animal to changes in temperature, a subject of great importance in respect to fishes, which it is hoped will soon be taken up. Certain points concerning the annelid worms were studied by Dr. E. A. Andrews, of Johns Hopkins University; the development of the group of mollusks known as chitons was observed by Mr. Maynard M. Metcalf, of the same university; and Dr. James I. Peck, of Williams College, was occupied in preparing a systematic paper on the pteropods and heteropods collected during recent explorations of the steamer *Albatross*.

The following persons were also present at the station: Mr. H. McE. Knower and Mr. Lefevre, post-graduate students of Johns Hopkins University, collecting and studying the surface life of the region; Mr. J. Y. Graham and Mr. Farr, of Princeton College, engaged in the study of the anatomy of several local fishes and invertebrates; Prof. E. R. Boyer, of the public schools, Chicago, collecting fishes and marine invertebrates for instructional purposes; Mr. W. McM. Woodworth and Mr. C. B. Davenport, of Harvard University, the latter investigating several forms of hydroids, in continuation of observations begun the previous season.

The schooner *Grampus*, which was employed during the summer months in conducting investigations along the outer margin of the continental platform south of New England and New York, made its headquarters at Woods Hole, and Professor Libbey, in direct charge of that inquiry, occupied quarters in the laboratory during the intervals between the different trips. The steamer *Fish Hawk* was also at work in Buzzards Bay and Vineyard Sound during a part of the summer.

[1] Observations on the Gemmule and Egg Development of Marine Sponges, by Henry V. Wilson. Journal of Morphology, IX, No. 3, pp. 277–406, plates 14–25, 1894.

Mr. Vinal N. Edwards, the permanent collector at this station, whose work has been referred to in previous reports, was actively employed during the entire year in making collections of fishes and in recording the daily catch of the fishermen at all points in this vicinity. In the spring of 1893 special attention was paid to the spawning habits of the menhaden and mackerel, both of which species breed to some extent in this neighborhood. During several weeks of the summer of 1892 the writer was at Woods Hole, carrying on, in conjunction with Mr. Edwards, a thorough investigation of the shores and inlets of Buzzards Bay and Vineyard Sound with respect to the habits and life-history of the younger stages of the common food-fishes which resort to that region. Extensive collections and observations were made, the more interesting relating to the menhaden, the young of which occur in myriads in most of the brackish waters thereabouts, especially in the Acushnet River at New Bedford and in the Wareham River at the head of Buzzards Bay. At different times during the year visits were made by Mr. Edwards to more distant localities, such as Narragansett Bay and Cape Cod Bay, in search of further information respecting the breeding and other habits of the menhaden.

INVESTIGATION OF INTERIOR WATERS.

COLUMBIA RIVER.

During the early part of the fall of 1892 inquiries were conducted along a part of the Columbia River and several of its tributaries, with the object of determining: (1) The character and extent of the obstructions to the ascent of salmon in the Clarke Fork; (2) the advisability of establishing a hatching station for salmon in the eastern part of the State of Washington. The first of these inquiries originated in a joint resolution introduced in the United States Senate on February 19, 1891, and again on February 9, 1892, calling for an appropriation "to be expended under the direction of the Secretary of War in the removal of such obstructions in the Clarke Fork of the Columbia River as prevent the ascent of salmon and other fish up said river and its tributaries to the Flathead Lake and other waters in that vicinity." More definite information respecting these obstructions and the utility of their removal being desired before final action was taken in the matter, the United States Fish Commissioner was directed, by an item in the sundry civil appropriation bill, approved August 5, 1892, to make the necessary examinations; and the same bill also authorized the investigations relative to the hatchery site in Washington.

These inquiries were placed in charge of Dr. C. E. Gorham, engineer of the Fish Commission, who was assisted in the natural-history work by Mr. Barton A. Bean, of the United States National Museum, and Mr. A. J. Woolman, an ichthyologist of South Bend, Ind. This party reached the upper waters of Clarke Fork, in Montana, the middle of September, and continued in the field about a month. It was found impossible,

however, to cover the ground during that period as thoroughly as was deemed advisable, and arrangements have been made to continue the work during the summer of 1893. The principal features of interest brought out by Mr. Gorham's party in respect to the Clarke Fork may be noted as follows:

The upper part of the river was first examined between Flathead Lake and Lake Pend d'Oreille, but within that part of its course no obstructions were discovered which could, to any extent, impede the passage of salmon in case they had free access to Lake Pend d'Oreille. The lower Flathead River drains the lake of the same name and, after flowing first southerly and then westerly a distance of about 70 miles, unites with the Missoula River to form the Clarke Fork. Just below the lake Flathead River is occupied for several miles by a succession of rapids, with still water here and there, its width averaging about 300 feet, and its depth probably from 6 to 10 feet. Even less active species than the salmon would have no difficulty in passing this point.

The next place of interest in going downstream is Thompson Falls, situated in the Clarke Fork some sixty-odd miles above Lake Pend d'Oreille. At this point the stream is very much contracted, and rushes through a rocky gorge a distance of several hundred feet. There is also here a fall of about 6 or 8 feet, over which a large volume of water pours, sufficient, it is supposed, to permit of the movements of salmon without difficulty. Immediately below the falls are large eddies and the river there appears as an ideal home for both salmon and trout. The water is clear and pure, and on September 19 had a temperature of 61° to 62° F. The course of the river from Thompson Falls to Lake Pend d'Oreille is clear of all obstructions, and the same is also true with respect to this lake itself, which has a length of about 20 miles between the mouth of the Clarke Fork and the beginning of the Pend d'Oreille River, being, in fact, practically only a general widening out of the river.

Below the lake the river is known as the Pend d'Oreille River. From Sand Point it flows almost directly west to the Washington line; thence northwesterly and northerly until within British America, where it makes a sharp turn to the WSW., and empties into the Columbia River within sight of the pole marking the international boundary line. The length of the river within the territory of the United States is slightly over 100 miles, and in British Columbia about 22 miles.

Between Lake Pend d'Oreille and the Idaho-Washington boundary line it presents only a single, rapid descent called Albany Falls, which are located about 1½ miles above the town of Newport, Idaho. An island divides the river here, and the Great Northern Railroad crosses it at the same place, making use of the island as the base of one of the bridge piers. The falls are therefore double, being situated on each side of the island. They have a rapid but not vertical descent of between 8 and 10 feet. They are much broken, and at the time they were visited had a good volume of water passing over them; but at

periods of low water their descent would become somewhat more abrupt. Trout pass freely up the falls, and they would therefore present no obstacle to salmon.

The river is navigable above these falls to Lake Pend d'Oreille, and below them as far as Box Canyon, a distance of about 60 miles, being generally wide and comparatively quiet, though with a strong current. At Box Canyon the river is confined between vertical walls from 30 to 150 feet high and not more than 70 feet apart in places. Being reduced to such a narrow gorge, the stream becomes very deep and, although comparatively smooth, is very swift and dangerous for boats, but offers no obstacles to the passage of fish. Rowboats pass through the canyon, and a small steamer was taken through at one time. This part of the river could be greatly improved for navigation by the removal of a few obstructions at slight expense.

About 7 or 8 miles below the canyon and about 35 miles above the mouth of the Pend d'Oreille River are the Metaline Falls, the most serious of all the obstructions in the entire river. Their total descent is somewhere between 25 and 30 feet, more or less broken, and forming rather a series of rapids. On one side are perpendicular bluffs, 30 to 80 feet high, and on the other four large rock masses have fallen into the stream from the mountain which rises abruptly on that side. The possible effect of this obstruction upon the movements of salmon was not determined satisfactorily, although Dr. Gorham inclined to the opinion that it would be insurmountable in its present state, and he suggested that the conditions could be much improved by blasting out the head of the falls and by breaking up the large rock masses which cause the second or lower rush of waters.

Below the Metaline Falls the river is wide and deep. About 10 miles below, and 2½ miles in a direct line south of the Canadian boundary line, is Big Eddy Canyon, between 2 and 3 miles long, which has been reported to contain several falls. It is very difficult of inspection, and at only a few points, where the walls were somewhat broken, was it possible to get close enough to see inside. The walls are from 80 to 300 feet high, and at one place contract the river to a width of only about 20 feet. The current attains great velocity, but so far as could be determined there are no actual falls in the canyon, and this was also said to be the case by Mr. John Everett, a prospector, who has lived thirty-three years in this region.

From here on to the mouth of the Pend d'Oreille there are several rapids or slight falls, but none of great importance. These are all in British Columbia territory, partly above and partly below the Salmon River, which enters the Pend d'Oreille a short distance above the international boundary line. Just above the mouth of the Salmon, all contained within a distance of a few hundred feet, are five rapids or low falls, with a total descent of about 30 feet. The upper one, located at a point where the river is confined in a narrow gorge, scarcely 50 feet wide, has a height of about 5 feet. The second has about the same

height; the third is about 6 feet high, and the fourth 4 feet high, while the lower one, quite near the mouth of Salmon River, has a total descent of about 10 feet. In Dr. Gorham's opinion none of these rapids, unless it might be the lower one, would serve to obstruct the ascent of salmon even during low water, while at times of high water it is quite certain that all difficulties in that respect would disappear.

Below the mouth of the Salmon River the Pend d'Oreille flows through a narrow gorge and forms a succession of rapids, after which it widens out and continues less turbulent for some distance; but the last 5 miles of its course are confined within another canyon. At its mouth it is from 150 to 200 feet wide, and before emptying into the Columbia it passes over a fall from 4 to 10 feet high, depending upon the stage of water in the Columbia River. Ordinarily salmon would have no trouble in passing over this obstruction.

Kettle Falls, the only important obstruction in the Upper Columbia River, located about 9 miles from Colville, Wash., and 40 or more miles south of the mouth of the Pend d'Oreille, were not visited by the party, but from information obtained from others it is evident that they do not constitute a serious impediment to the ascent of salmon, which formerly were said to have passed over them in greater or less numbers, although they do not at present.

No positive information was obtained respecting the occurrence of the true salmon (*Oncorhynchus chouicha*) in the Pend d'Oreille River, and it is said that none go farther upstream than the falls at the mouth of Salmon River. The evidence secured points to the fact that the salmon (so called) of both those rivers is the steelhead (*Salmo gairdneri*), and specimens of this species were observed. There was not, however, sufficient opportunity to study this question satisfactorily, and a prolonged series of observations may be necessary to determine the range and relative abundance of these two species in the upper waters of the Columbia River. Until conclusive evidence is obtained that the true salmon is prevented from ascending to the upper part of this river system because of the presence of natural barriers and not from other causes, it should not be considered advisable or judicious to expend money in the removal of any supposed obstructions to their passage. There are many conditions which require careful study and consideration before any definite steps are taken in that direction, and it is intended next year to begin upon a careful and detailed investigation of the subject throughout the entire course of the Columbia River and its tributaries.

Inquiries relative to a site for the establishment of a salmon-hatching station in eastern Washington were confined chiefly to Little Spokane River and Colville River. No success was met with, however, as no locality was found convenient of access and at the same time affording the means for securing an abundance of breeding fish. This subject will also be covered by the proposed general survey above referred to.

MINNESOTA, NORTH AND SOUTH DAKOTA.

During July and August, 1892, investigations were carried on in the contiguous parts of these three States by Mr. A. J. Woolman, of South Bend, Ind., assisted during a portion of the time by Prof. U. O. Cox, of the State Normal School, Mankato, Minn. The waters examined were Lake Traverse, Big Stone Lake, and the Minnesota River as far down as Montevideo, Minn.; the Red River of the North as far as the international line, including many of its tributaries; Devils Lake and the James River in North Dakota, the latter being a tributary of the Missouri River. The work was executed in a thorough manner, and was comprehensive in its scope, being directed toward determining the physical characteristics of the different bodies of water visited, as well as their fishes and other aquatic inhabitants, both animals and plants. No extensive ichthyological studies had previously been made in this region, and the report of Mr. Woolman upon the results obtained contains many observations of scientific and practical interest.

After discussing the geological history of the region examined, which points to the former existence of a very extensive lake, reaching northward to and including Lake Winnipeg, and drained by a broad waterway leading southward through the trough now occupied by Lake Traverse, Big Stone Lake, and the Minnesota River, Mr. Woolman proceeds to describe and account for the present conditions and relations of the principal water areas which he visited. Red River of the North is not the outlet of Lake Traverse, as is often represented on maps, nor has it been in modern times. Lake Traverse and Big Stone Lake, both lying in the valley of "River Warren" of geologists, are only about 5 miles apart, being separated by sediment piled a few feet above the surface of the former lake. The similarity of the species of fishes living in the two lake basins indicates that at one time they were connected, and yet the number of comparatively unimportant or minor differences, quite noticeable and constant, and reaching in some cases almost varietal significance, shows the landlocked condition of the fauna of Lake Traverse and points to the fact that these two lakes could not have been united in recent years.

Lake Traverse, lying between Minnesota and the northeastern corner of South Dakota, is about 14 miles long by 1 to 1½ miles wide, and has a maximum depth of about 30 feet, the average being possibly half that or less. The temperature of the water was high, having been 77° F. when the lake was visited in July. It must change rapidly with the seasons, and in winter the lake freezes to the bottom over much of its extent. There are only two small inlets, and the volume of water in the lake is gradually diminishing. The lake supports a rich and varied growth of plant life, and teems with crustaceans, mollusks, and insects. Nothwithstanding this fact, however, it contains few kinds of fishes, none of which can be regarded as abundant. About the only species utilized as food is the pickerel (*Lucius lucius*), although a few catfish (*Ameiurus nebulosus*) and strawberry bass (*Pomoxis*) are taken

for this purpose. No small fishes were observed in the lake proper, and the total number of species obtained from the lake and its tributaries was only 7.

Big Stone Lake is 35 to 38 miles long and 1½ to 2 miles wide, with a maximum depth of 35 feet. The average depth is greater than in Lake Traverse, the water is clearer and purer, and it contains but little vegetation. Invertebrates are also less plentiful, although occurring in sufficient quantities to constitute an ample food supply, and there are many small fishes, such as minnows and darters. In the variety and abundance of its fishes this lake presents a marked contrast with Lake Traverse, 25 species having been secured. Food varieties are common, the most important being the pickerel, wall-eyed pike, black bass, rock bass, and crappies. From the Minnesota River and its tributaries, between Big Stone Lake and Montevideo, a total of 35 species of fishes was obtained, and from the James River, in North Dakota, 20 species.

The Red River of the North presents many features of special interest. It is the only large stream within the boundaries of the United States which finds an outlet toward the far north, suggesting marked differences in its faunal characteristics as compared with other water areas even within the adjacent region, conditions which were not found to exist, however, emphasizing the former connection of this river with the Minnesota and Mississippi. The course of the Red River of the North is northward down a long, gentle slope from a low watershed, which separates its basin from that of the Mississippi on the south, east, and west. Many of its tributaries take an opposite course, in keeping with the streams of the Mississippi system, trending southward until within the immediate valley or flood plain of the main river, when they bend abruptly. The narrow valley now occupied by this river is the product of erosion, and is cut down from 50 to 75 feet below the surrounding level country. Examinations were made at intervals along the main river and also on twelve of its tributaries, the most important of which were the Otter Tail River, Red Lake River, Sheyenne River, as far up as Valley City, N. Dak., and Pembina River, as far up as Minot, N. Dak. Thirty-eight species of fishes were obtained in this basin.

IOWA, NEBRASKA, SOUTH DAKOTA, AND WYOMING.

The sundry civil appropriation bill approved August 5, 1892, provided for investigations in these several States for the purpose of determining their requirements from a fish-cultural standpoint and of ascertaining the most suitable locations for the establishment of such hatching stations as the circumstances may warrant. It was found impossible to begin upon this inquiry until early in October, and operations for the season were suspended during the first part of November on account of inclement weather, which prevented the carrying on of many of the more essential observations, especially those relating to temperature and other physical conditions of the water. The investigations were resumed in the middle of June, 1893, and were completed

in the middle of August following. The work was in charge of Prof. Barton W. Evermann, assisted in the fall of 1892 by Mr. Lewis M. McCormick, of the United States National Museum, and in 1893 by Prof. U. O. Cox, of the State Normal School, Mankato, Minn.; Mr. Cloud. Rutter, of Long Pine, Nebr., and Prof. R. G. Gillum. of the State Normal School, Terre Haute, Ind.

An account of the results of this inquiry must be deferred until the next annual report, to which it properly belongs, only a brief mention being made in this connection of the work accomplished during the fiscal year 1892-93. During October, 1892, many of the streams and springs among the Black Hills and in their vicinity were examined, some of the places visited being Belle Fourche, Spearfish, Rapid City, and Hot Springs, S. Dak., and Newcastle, Wyo. As the cold weather came on the party started eastward through Nebraska, making observations at Ravenna, Lincoln, Crete, and South Bend, in that State, and subsequently at Ames, Cedar Rapids, and Spirit Lake, in Iowa. During June, 1893, the investigations were confined to the southern part of South Dakota and northeastern Nebraska, streams being visited in the vicinity of Mitchell, Chamberlain, Scotland, and Springfield in the former State, and of Niobrara, Verdigris, and Creighton in the latter.

As is customary in inquiries of this kind, very complete and detailed observations were made, relating not only to the character and richness of the aquatic fauna, but also to the fitness or requirements of the waters with respect to stocking, their physical and other conditions, and to the relative advantages afforded by different localities for the carrying on of fish-cultural operations, the latter involving the consideration of several important factors, such as the water supply, transportation facilities, and to a certain extent the proximity of natural breeding-grounds, etc. Large collections of fishes and of other aquatic animals were made, a study of which will add greatly to our knowledge of the natural history of the regions examined.

WISCONSIN.

During the season of 1892 the physical and biological features of lakes Geneva, Delavan, and Winnebago, in Wisconsin, were investigated by Prof. S. A. Forbes, assisted by several of his students in the State University of Illinois. The main part of the work on lakes Geneva and Delavan was accomplished during May, but visits were also paid to the same lakes in July, August, and September following. Lake Winnebago was studied during the middle part of June. The contour of the bottom of these lakes was determined by means of soundings; temperature observations were made at the surface and at different depths, and sketch maps were prepared to illustrate their physical characteristics. The biological work consisted in dredging, the constant use of the surface tow net, and in collecting along the

shores, the inquiries being extended into the creeks, ponds, sloughs, and other waters adjacent to the lakes.

ARKANSAS.

Beginning in the summer of 1891, Prof. S. E. Meek, of the Arkansas Industrial University, has carried on, from time to time, in the interests of the United States Fish Commission, important observations relating to the fishes of Arkansas. In his report upon these inquiries[1], Professor Meek has described the principal characteristics of the several rivers and of the more conspicuous springs for which some parts of the State are noted, and has given complete annotated lists of the fishes which are now known to occur in four of the principal river basins, the White River having a total of 84 species, the Little Red River 58 species, the Arkansas River 61 species, and the Illinois River 31 species.

The following remarks are extracted from Professor Meek's report:

From an ichthyological standpoint Arkansas is well favored. The State is bordered on the east by the Mississippi, and has four large navigable rivers flowing through it. Two of these rivers, with most of their tributaries, rise in the Ozark Mountains within the boundaries of the State. These streams are fed by many large and beautiful springs, whose waters are cool enough for the mountain trout, their suitability being well demonstrated by the success which has attended trout-culture at the several hatcheries already mentioned. In fact, it has been proven not only that trout will thrive in the Ozark Mountain region, but that their growth there is much more rapid than in some other places farther north, where their artificial cultivation is being carried on. The important question for the consideration of the practical fish-culturist is, how many pounds of fish he can secure from a certain number of eggs within a given period and with the least expenditure of artificial food. The records of the Neosho hatchery clearly indicate that fish-culture can be conducted successfully in this direction. While the mountain streams bid fair to contain an abundance of trout in the near future, the larger and more sluggish waters are well suited to the coarser food-fishes native to the State, the most important among them being the black bass, wall-eyed pike, eastern pickerel (*Lucius reticulatus*), buffalo-fishes, etc. All of the important rivers mentioned supply many fishes to the markets every year, and they may continue to do so if assistance shall be given toward restoring, so far as possible, the balance of life in favor of those species which man has done so much to destroy.

There is no doubt that Arkansas possesses piscatorial features of a high grade, which warrant more attention in the future than they have received in the past. The angler may find amusement along the picturesque streams of the Ozark Mountains, while the fish-culturist will come to recognize in this region one of his richest fields in North America. Arkansas is as yet only thinly settled, and a thorough exploration of the streams of the State before their fauna have been much changed by cultivation would be of great economic and scientific interest. The increase and protection of her food-fishes, both the native and introduced species, can not be successfully accomplished without a more complete knowledge of the physical and natural-history features of the streams, and it is to be hoped that the means for making such a survey will not long be delayed.

[1] Report of investigations respecting the fishes of Arkansas, conducted during 1891, 1892, and 1893, with a synopsis of previous explorations in the same State. By Seth Eugene Meek. Bull. U. S. Fish Comm. for 1894, pp. 67–94.

CALIFORNIA.

From 1891 to the close of the fiscal year just past the fresh-water fishes of California have been made the subject of investigation for the Fish Commission by Prof. Charles H. Gilbert, of Leland Stanford Junior University, during such times as his college duties would permit. A report upon these researches has been deferred until further observations can be made, but the field work so far accomplished may be summarized as follows:

During the fiscal year 1891–92, the inquiries related to the streams which, draining the eastern slope of the Santa Cruz Mountains and the western slope of the Mount Hamilton Range, enter the southern arm of San Francisco Bay, and those which drain the western slope of the Santa Cruz Mountains and enter the sea between San Francisco and Santa Cruz. These two sets of streams were found to have very different faunæ, the former containing, in addition to the fishes of general distribution in California, many of the peculiar forms of the Sacramento Basin, such as *Hysterocarpus traski*, *Archoplites interruptus*, *Orthodon microlepidotus*, *Lavinia exilicauda*, and *Pogonichthys macrolepidotus*, which are wholly excluded from the streams draining the western slope of the Santa Cruz Mountains. The latter have only species of general distribution, like the sucker (*Catostomus occidentalis*), trout (*Salmo gairdneri*), sticklebacks (*Gasterosteus microcephalus*), sculpins (*Cottus asper*), and occasionally a minnow.

Within the past year further examinations were made in the same region, and, in addition, the Pajaro River was studied from its mouth, in Monterey Bay, to the source of its principal tributary, the San Benito River. Los Gatos Creek, Fresno County, was also visited, but was found to be without fishes. This will probably prove true of all other streams entering the San Joaquin Valley from the west, as they are likely to be without running water during part of the hot, dry summer.

MISCELLANEOUS INQUIRIES.

MACKEREL INVESTIGATIONS.

The act of Congress passed in 1886, which virtually prohibited the spring mackerel vessel fishery prior to June 1 of each year during a term of five years, ceased to be operative after 1892. In order to determine, so far as possible, if any immediate benefits had resulted from this series of close seasons, and also to obtain information for the use of the Joint Fishery Commission between Great Britain and the United States, the schooner *Grampus*, Capt. A. C. Adams in command, was detailed to follow the progress of that fishery throughout its entire course in the spring of 1893. Sailing from Woods Holo at an early date, Captain Adams was directed to conduct a detailed series of physical observations on the way south until the body of mackerel had been

discovered, after which he was to keep track of the movements, habits, and abundance of the latter, and to study the conditions of their environment as far north as Nova Scotia. The presence of a large fleet of purse-seiners on the grounds afforded excellent opportunities for learning of the distribution of the fish at all times, and through their means it was expected that specimens for examination would be obtainable. The *Grampus* also made use of the fishing apparatus she had on board, and an hourly record of physical determinations was maintained day and night, besides which the surface tow nets were frequently employed to discover the presence of mackerel food. The natural-history observations were conducted by Mr. W. C. Kendall. Mr. B. L. Hardin was stationed at Fulton Market, New York City, to inspect all arrivals of mackerel there from the purse-seine fleet, as well as from the shore apparatus tributary to that market.

The *Grampus* sailed from Woods Hole on April 10 and reported at Lewes, Del., April 21, having experienced heavy weather up to that date. Very few fish had been observed, and the fishing fleet had accomplished comparatively nothing. The latter also sought shelter at the same place. Poor success, both in the catch of fish and in the opportunities to make observations upon them continued thence to the close of the season, and by the middle of May nearly all the purse-seiners had left the southern grounds for the coast of Nova Scotia. The small catch made this season was partly due to stormy weather, but, even when all the conditions seemed favorable, mackerel were either scarce or difficult to capture. More light will probably be thrown upon this question when the elaborate series of notes obtained have been worked up, but the fishermen have failed thus far to recognize any beneficial results from the restrictions placed upon their spring fishery during the previous five years.

On May 23, the southern fishery having ended several days before that time, the *Grampus* left Woods Hole, where she had put in for supplies, and proceeded to Nova Scotia, to continue the inquiries on the same plan as at the south. The entire fleet had assembled there, but no fish were taken on this coast, except in trap nets on the shore, until after June 1. By June 5 some of the fleet had done fairly well, the others poorly. After their first appearance on this coast the mackerel moved rapidly eastward, the purse-seiners and the *Grampus* following them as far as Cape North on Cape Breton Island, the former as a whole making a good catch to the eastward of Halifax, as compared with former seasons. There were 75 seiners on the Nova Scotia shore, and their average fare was about 160 barrels each. The *Grampus* returned to Woods Hole the latter part of June, bringing a large quantity of specimens bearing upon the breeding habits, food, size, etc., of the mackerel, together with very complete records of the daily observations.

Mr. B. L. Hardin remained at New York from April 12 to June 3, and examined every fare of mackerel landed from the southern fishery,

as well as the smaller catches made in the pound nets along the shores. Notes were kept upon the abundance, sizes, and spawning conditions of the fish, and interviews were held with the masters of the different schooners relative to the more important incidents connected with their several cruises.

INVESTIGATIONS IN CHESAPEAKE BAY AND ADJACENT WATERS.

The fishery investigations begun in June, 1892, in the lower part of Chesapeake Bay and the adjacent waters of the open ocean by the schooner *Grampus* were continued until about July 20, when that vessel proceeded to Woods Hole to take up the physical inquiries along the continental platform, as described above. A few trips were made out to sea during this period, but the examinations were principally confined to the waters of the bay, in which the beam trawl, seines, etc., were employed with good results.

FISHES OF CASCO BAY, MAINE.

During August, 1892, Mr. W. C. Kendall was engaged in collecting and observing the habits of fishes in the more inclosed waters of Casco Bay, Maine, including the lower parts of some of its tributary streams. The special object of his inquiries was to ascertain if the menhaden spawn in that region, and if the young occur in the brackish waters there during the summer months, as is the case south of Cape Cod. No specimens of young menhaden were secured, however, and no evidence was obtained to show that this species has been in the habit of spawning in this bay during recent years at least.

EMBRYOLOGY OF THE STURGEON.

Arrangements were made, in the spring of 1893, for the study, by Dr. Bashford Dean, of Columbia College, New York, of the embryology of the sturgeon (*Acipenser sturio oxyrhynchus* Mitchill), on board the steamer *Fish Hawk*, while stationed in the Delaware River off Gloucester City, N. J., during the shad-hatching season, the object of this inquiry being to supplement the investigations respecting the same species carried on for the Fish Commission several years before by Prof. John A. Ryder. As the necessary material could not be obtained conveniently in the locality named, however, Dr. Dean proceeded to Delaware City, Del., where he made his headquarters, and where he was fortunate in securing an abundance of ripe sturgeon of both sexes. His experiments and observations were carried on with entire success in all particulars. No difficulties were encountered in fertilizing the eggs and in holding them in good condition until they hatched. They were kept in improvised floating boxes, which were moored in several places in the river and canal, those placed in the mid-current affording the best results. Very few eggs were lost in any of the boxes, and

with proper facilities Dr. Dean is confident that he could have produced enough fry to have made his work exceedingly profitable from a practical standpoint. He considers the vicinity of Delaware City especially well adapted to the propagation of the sturgeon, and thinks there would be no trouble in securing a sufficient number of spawning fish at the proper season. He was there from May 14 to 23. Observations were also made respecting the breeding and other habits of the sturgeon, and Dr. Dean has now in course of preparation a comprehensive account of the results of his investigations.

MORTALITY AMONG ALEWIVES, LAKE ONTARIO.

Reference has frequently been made in the Fish Commission publications to the extraordinary mortality which occurs among the alewives in Lake Ontario during every spring and summer, and which also, to some extent, affects other common fishes in the same waters. The cause of this annual epidemic has never been determined; it has a widespread distribution, and the number of dead and dying fishes which are often cast upon the shores in some places is so great as to occasion much inconvenience to residents and summer visitors from the unpleasant odors arising from the decaying bodies. Mr. C. H. Strowger, of Nine-Mile Point, near Webster, N. Y., has paid a great deal of attention to this phenomenon, and the Fish Commission is indebted to him for much information respecting it, as well as for specimens of the diseased fish. In order to reach a more complete understanding of the subject, Dr. R. R. Gurley was dispatched to Lake Ontario in the early part of June, 1893, and remained there about a month, visiting Nine-Mile Point, Wilson, Charlotte, and Cape Vincent. He spent the most of this time at the place first mentioned, where laboratory accommodations were supplied by Mr. Strowger, who also assisted Dr. Gurley personally in his investigations.

From the statements of persons living along the shores of Lake Ontario, the epidemic appears to begin in April, occasionally as early as the latter part of March, reaches its maximum in May, and decreases through June, although in some cases it may be found as late as August. The May and June maximum of the epidemic coincides with the period when the alewives are most abundant inshore. The diseased fish have a patch of saprolegnia, usually from three-fourths of an inch to an inch in diameter, on some parts of the body, but no other parasites were found on any of the dead alewives examined. None of the vital organs were affected by the fungus, the gills in particular always appearing clear, and otherwise also the fish seemed to be in good condition. An inflamed area was almost always noticed on the general surface of the body under the patch of saprolegnia, and very generally a sore or ulcer, the scales in such places being loosened or detached. In some cases the fungus appeared to have effected a lodgment in places where the

surface of the body had been injured; in others the fungus seemed to be primary and the sore or ulceration secondary, but it was impossible to tell whether the fungus was causative or not. Numerous specimens were preserved for future examination.

PROPOSED INQUIRIES BY SPECIAL TREASURY AGENT TO ALASKA.

In April, 1893, Mr. John K. Luttrell was appointed a special agent of the Treasury Department, in accordance with the act of Congress providing for the supervision of certain fishery interests in Alaska. Although his services in this respect were not connected with the work of the Fish Commission, Mr. Luttrell kindly offered to make collections of fishes at the different places visited, and to conduct investigations relative to the distribution and habits of the more important species. He was accordingly supplied with a proper outfit for preserving specimens and was given full instructions respecting those matters on which information was especially desired. He left for the north during the latter part of the fiscal year.

COLLECTIONS, PREPARATION OF REPORTS, ETC.

No changes have been made since the last report in the laboratory and other quarters occupied by this division in the Central Station at Washington. Very large collections have been received from the vessels and field parties during the year, but undue crowding of the same has been obviated by an arrangement with the United States National Museum, whereby many of the specimens have been furnished temporary storage-room at the latter place.

The study of certain parts of the collections, especially the fresh-water fishes, by Prof. B. W. Evermann, has progressed rapidly, and some collections have also been placed in the hands of specialists outside of the Fish Commission staff for working up. The mollusks from all sources have been turned over to Mr. William H. Dall, curator in the National Museum, as fast as they were received. Arrangements have also been made with Dr. Alex. Goes, of Kisa, Sweden, to report upon the foraminifera from the dredgings of the steamer *Albatross* on both the Atlantic and Pacific coasts, and likewise with Prof. F. E. Schulze, of Berlin, Germany, with respect to the siliceous sponges from the same source. Prof. William E. Ritter, of the University of California, has offered to study the collections of ascidians made by the steamer *Albatross* in the North Pacific Ocean, and they will soon be sent to him.

There has been transferred to the custody of the National Museum a very large quantity of specimens, representing both the reserve series and duplicates of collections examined during the year. These consist chiefly of fishes and marine invertebrates, but include also representatives of many other groups, conspicuous among which are the skins

and bones of several species of Pinnipedia. Duplicate specimens of marine invertebrates from the collections of the Fish Commission have been supplied by the National Museum to the following institutions: State Normal School, Oshkosh, Wis.; Clark University, Atlanta, Ga.; Columbia College, Van Allstyne, Tex.; Grammar School, Salem, Mass.

Preparations were made during the year for illustrating the objects and methods of work of this division, and the results so far accomplished by it, at the World's Columbian Exposition in Chicago. The exhibits were completed and transmitted in time for installation before the opening day. As this subject will be reported upon in full by Dr. Tarleton H. Bean, the representative of the Fish Commission at Chicago, an account of the material displayed need not be given in this connection.

The following reports from persons not in the employ of the Fish Commission, but based partly upon materials from its collections, were completed and submitted for publication during the year:

A review of the Sparoid Fishes of America and Europe. By David Starr Jordan and Bert Fesler. Report U. S. Fish Comm. for 1889-91, pp. 421-544, plates 28-62.

On the Viviparous Fishes of the Pacific coast of North America. By Carl H. Eigenmann. Bull. U. S. Fish Comm. for 1892, pp. 381-478, plates 93-118.

The Genus Salpa, a Monograph, with fifty-seven plates. By William K. Brooks, with a supplementary paper by Maynard M. Metcalf. Memoirs from the Biological Laboratory of the Johns Hopkins University, II, Baltimore, 1893. Two volumes, quarto, text and plates.

Report on the Actinæ collected by the U. S. Fish Commission steamer *Albatross* during the winter of 1887-1888. By J. Playfair McMurrich. Proc. U. S. Nat. Mus., XVI, pp. 119-216, plates 19-35, 1893.

Report on the Pteropods and Heteropods collected by the U. S. Fish Commission steamer *Albatross* during the voyage from Norfolk, Va., to San Francisco, Cal., 1887-1888. By James I. Peck. Proc. U. S. Nat. Mus., XVI, pp. 451-466, plates 53-55, 1893.

List of Diatomaceæ from a deep-sea dredging in the Atlantic Ocean off Delaware Bay by the U. S. Fish Commission steamer *Albatross*. By Albert Mann. Proc. U. S. Nat. Mus., XVI, pp. 303-312, 1893.