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REPORT OF THE DIVISION OF SCIENTIFIC INQUIRY FOR THE FISCAL YEAR 1921.[1]

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[1] Appendix VIII to the Report of the U. S. Commissioner of Fisheries for 1921. B. F. Doc. No. 911.
[2] With the collaboration of the investigators.

INTRODUCTION.

The fisheries industries are immediately confronted with such acute problems of distribution of products that it would seem only natural if attention were temporarily detracted from the underlying and enduring problems of the industry—those relating to maintenance of the resources upon which the industries are based. Nevertheless the discussions among representatives of all phases of the industry when gathered together in such meetings and conferences as have been held during the recent period of stress have always brought to the front the problems that have to do with the perpetuation of fishery resources. Such conditions as the depletion of shad, the decline of the blue-crab fishery, and the deterioration of inshore waters through pollution, command such earnest consideration on these occasions as to prove that fishermen and dealers of broad vision are not misled through immediate difficulties in one department of the industry to minimize the importance of permanent sources of supply.

Upon due thought, of course, it is evident that the problems of supply must not be forgotten even momentarily; for the difficulties of distribution can be only heightened by continued depletion of resources and an inevitably accompanying increase in costs of production relative to the costs in competing industries. Obviously it can not become easier to market fish when they become less easily obtainable relative to other materials of protein food. No economic fact can be plainer than that diminishing abundance of fish must be followed by increasing prices and decreasing consumption.

It is, then, a fundamental and enduring principle that the perpetuation of the fisheries and the maintenance of their relative rank among other food-producing industries are contingent upon the continued productiveness of the fisheries—in a word, upon conservation. Conservation in turn depends upon the exercise of intelligence and restraint in the exploitation of fisheries resources, upon sound action in removing unnecessary causes of depletion, and upon wisdom in adopting plans for bringing about where possible an increase of particular fish or shellfish. The decline of valuable fisheries has been witnessed too often to admit of continued faith in the inexhaustibility of fish or shellfish of any kind. Yet the intelligent determination of what restrictive measures are necessary, what means of exploitation are unreasonable, or what plans of propagation or development are profitable can be made only upon the foundation of full and correct knowledge of the life histories, habits, and conditions of life of the fish that are to be considered.

It seems generally agreed, for example, that the blue crab of the Chesapeake is in actual course of extermination by unwise fishery methods, although there may not yet be agreement as to the particular methods which are unwise. Recently this very important question was referred to a conference of representatives of the two States concerned, together with officers of the Department of Commerce. The practical results of such a conference depend much, of course, upon the sound practical judgment and the broad spirit of those bearing the responsibility for determination of action; but the one indispensable basis of action is an understanding of the life of the crab. The sole hope of practical results from a conference of any group of persons having this problem in view rests upon such

knowledge as we have of the life history of the crab—in short, upon the results of scientific work previously done. Emphasis must be put upon the adverb of time. The significant thing is that the work must in great part, at least, have been already done; for knowledge can not be secured immediately; one can not produce the life history of an aquatic animal upon demand; it is the result of painstaking study through a period of time which can not be fixed in advance, and by the application of methods which can not be definitely plotted beforehand.

It is work of this kind which must be done, and continuously done, so that gradually and steadily we learn more and more about our fishery animals, if we are to be ready at all times to meet the changing problems of regulation and exploitation as they arise.

The scientific knowledge which is the basis of the future welfare of the fisheries requires not only time and application, but also skill and special training. Of greatest importance are the services of men who have not only natural qualifications and the preliminary training which institutions of learning can give, but also such special experience, interest, and devotion as can be gained only as the result of prolonged application to fisheries studies. Something may be done with inexperienced and changing agents, but the most successful and economical work will be done with a trained and continuing force.

In the following report will be found not an account of what might have been done, or what ought to have been done—but rather a statement of the progress which has been attained under the difficult conditions by which the scientific work of the Bureau has been circumscribed. It may be added that the Bureau again closes the year with a less effective force than it had at the beginning. Two members of the already depleted staff have resigned to accept better paying positions elsewhere, and two (including one rendering largely volunteer service) have died and not been replaced. Special acknowledgments are due to those whose interest and loyalty have held them in the public service.

In reviewing the subject of investigation it must be understood that while the Bureau has a definite policy of restricting expenditures to investigations of the most direct practical bearing, it is not entirely untrammeled in the selection of subjects of investigation. The qualifications of the personnel available necessarily determine in part the character of problems which can be profitably attacked.

STUDIES OF FISHES.

THE PACIFIC SALMON.

When consideration is given to the magnitude of the industries based upon the salmons and their near relatives, to the unrivaled rank which some of these fishes hold in the realms of sport and recreation, to the comparative ease with which the more important species may be brought to virtual extermination, and to the fact that all important species are the subject of artificial propagation, it is apparent that no group of fishes demands a greater share of attention in the way of scientific study.

For many years investigations have been directed particularly at the Pacific salmon, and the facts of life histories which are easiest to secure have been acquired, but yet we are far from having possession of the full knowledge necessary to direct propagation most efficiently, or to determine correctly the restrictive measures which may be enforced with least interference with the proper utilization of the fishes. The problems before us now are those requiring the closest and most persistent study, and yielding solution only slowly and by small stages.

IMMATURE SALMON IN THE OCEAN.

The investigations of salmon in Pacific Coast States have been conducted by Willis H. Rich, special assistant. The study of salmon taken by troll and purse seine in the open ocean has practically been completed. A preliminary report was prepared and, by authority of this Bureau, was published by the California Fish and Game Commission. The conclusions reached may be briefly summarized.

The fish taken in the ocean off the mouth of the Columbia River contain, in the spring and early summer, approximately 70 per cent of individuals which will not become sexually mature for one or two years, but by the middle of August this condition has changed so that nearly 90 per cent are fish which will soon enter the river for the purpose of spawning. The rate at which this change takes place and the time at which it occurs have not yet been determined, but will be taken up in a later report. A comparatively small percentage of the fish found just within the mouth of the Columbia River are immature. It should be mentioned in this connection that it is only occasionally, when unusual tidal conditions obtain, that any immature fish are taken inside the mouth of the stream.

The fish taken by troll in Monterey Bay in June contain a considerable proportion of immature individuals. The data obtained in 1918 are most reliable and indicate that only about 40 per cent of the fish taken would have spawned during the same year. The data for 1915 indicate that 75 per cent were mature, but selection may well have taken place in making this collection which consisted of egg samples only.

The fish taken near Drakes Bay and Fort Bragg in July and August, 1918, contain approximately 30 per cent of immature fish. It is of interest to note that this is an approach to the conditions found off the mouth of the Columbia River in August and suggests that the composition of all the schools found near the coast changes materially during the summer season.

It is understood that the preliminary report was used to advantage in the recent movement restricting the operations of both trollers and purse seiners off the coasts of Oregon and Washington. Additional data will be embodied in a later report.

Incidental to the work with the fish taken in the ocean considerable data have been collected which will apply to the report dealing with the general life history of the chinook salmon. Progress has been made in the identification of races, and additional evidence from the scales of returned marked fish has confirmed the work done last year on the significance of the various types of nuclear growth.

RESULTS OF MARKING EXPERIMENTS.

Mr. Rich has also submitted a report on "Returns from the experiments on the marking of young chinook salmon on the Columbia River." The experiments were started in 1916–17 and described in Economic Circular No. 45.

The percentage of returns of marked salmon was rather low, but the results obtained are of some significance. Examination of the scales of the marked fish which have returned after a period of three to four years corroborates the theory that the arrangement of the concentric rings (circuli) provides an accurate record of the previous history of the fish. A study of the scales of these marked fish will, moreover, aid very materially in the solution of perplexing problems which have arisen in interpretation of the scales of the chinook salmon.

Facts gathered during the investigation throw some light upon the rate of spawning migration of adult chinooks, indicating that the rate is approximately the same as that previously determined for sockeye salmon passing through Puget Sound and the Fraser River, that is, some 10 to 15 miles per day.

Perhaps the most interesting and important contribution which these experiments have made to our knowledge of the biology of the salmons relates to the hereditary character of the factors determining the time of the year at which the adults enter fresh water and begin their upward migration to the spawning grounds. It is an important practical question whether or not it is necessary to breed from fish of the spring run in order to produce the spring-run fish, which are more desired than the fall-run fish. The evidence of the marking experiments gives some indication that spring-run fish will be derived from spring-run parents and fall-run fish from fall-run parents.

A comprehensive program of experiment has been planned to extend over a period of several years. Two new marking experiments have been started on the Columbia River in cooperation with the Oregon Fish and Game Commission, nearly 100,000 young chinooks having been marked at Little White Salmon station and the State hatchery at Bonneville.

SALMON INVESTIGATION IN YUKON RIVER.[8]

During 1920, from May until September, Prof. Charles H. Gilbert, temporary investigator, and Henry O'Malley, field assistant in charge of Pacific coast work, conducted an investigation in Yukon River with reference to the runs of salmon, the commercial packs in and near the mouths of the rivers, and the requirements of the natives and others dependent on the runs of salmon in the Yukon River system. Data were secured for a comparison of conditions prevailing in 1919 and 1920. The primary object was to determine whether or not commercial fishing for export should be allowed in the Yukon River and its tributaries.

While all five of the Pacific coast species of salmon make their appearance at the mouth of the Yukon, only three species have sub-

[8] Cooperative investigation by Divisions of Fish Culture, Alaska Fisheries, and Scientific Inquiry. Only the biological data are summarized here. The full report is published on pp. 128–154 *in* Alaska Fishery and Fur-Seal Industries in 1920, by Ward T. Bower, Appendix VI, Report of the U. S. Commissioner of Fisheries for 1921, B. F. Doc. No. 909.

stantial runs in the Yukon River (king, chum, and coho), and of these king and chum are of the greatest importance by far. The few reds or sockeyes taken near the mouth of the river are perhaps strays, for no breeding has yet been reported from any part of the Yukon Basin. Humpbacks appear at the mouth of the river more numerously than the red salmon, but never in sufficient numbers to constitute a run even of small dimensions. As they were far advanced toward spawning in July, it was evidently impossible that they could ascend the river far with their spawning period so close at hand. The coho runs more or less numerously than the king or chum salmon and in addition is the latest to appear, often not presenting itself in any numbers in the middle and upper reaches of the river until the ice is forming in the fall.

The king salmon begins running in the last week of May or the early days of June. The run culminates quickly and then almost as quickly declines. The rate of migration was found to be remarkably high, the average rate of travel from Tanana to Dawson being slightly less than 45 miles per day, and from Pilot station to Dawson, involving practically the entire length of the river below Dawson, the average rate was 57 miles per day. No record of any other river approaches this in completeness, nor in the high rate of travel indicated. This unexampled speed with which salmon ascend the Yukon is doubtless associated with the great distances to be traversed before reaching their upper spawning areas, taken in connection with the shortness of the summer season.

The most important natural enemies of the king salmon are the white whales, or belugas, and the lamprey eels, the former being undoubtedly exceedingly destructive, while the latter, though causing scars on the fish in much greater abundance than in any other river, as observed by investigators, do not appear to effect serious injury to the fish.

The chum salmon, which is the principal food product of the Yukon River, made its appearance but a few days later than the advent of the king salmon, the rate of migration being approximately the same as that of the king.

Two phases in the development of the chum salmon are distinguished by the natives under the names of "dog salmon" and "silver salmon," the dog salmon comprising the individuals furthest advanced toward spawning. In general the "dog salmon" along any stretch of the river consist of those individuals which will turn into some adjacent tributary to spawn, while the "silvers" are on their way to the upper reaches of the river, show relatively little of the sexual changes they will exhibit on their spawning beds, and are still richly provided with the oil which serves as fuel and the principal source of nourishment during the long journey still before them.

"Dogs" and "silvers" were in general keeping apart from each other and following distinct migration routes, the "dogs" predominating on the right and the "silvers" on the left side of the stream. Heavier runs of kings and cohos were found in company with the "silvers" along the left limit of the river. It appears, therefore, that there is a prevailing use of the left shore by those fish which are found in the upper reaches of the river. This may have

connection with the fact that the majority of the tributaries of the lower river enter on the right bank.

Fishermen recognize the succession of phases in the run—the chums which accompany the king salmon being of relatively small size and poor quality, after which there is a run of bright fish of good quality, but inferior size ("silvers"), and finally the last run of "silvers" of a bright rich form and of distinctly larger size. This last run of "silvers" is ordinarily of short duration and furnishes the most highly prized fish of the season. A further more detailed study of the characteristics of the chums at different times and in different localities and the distribution of the various strains to their respective spawning areas would offer results of importance from the biological and equally from the strictly practical points of view.

The investigators record their opinion that the king salmon of the Yukon is the richest in oil of any known king salmon, and express the same view with even greater emphasis regarding the Yukon chums. In this connection it is remarked that in other river basins the chums do not travel far from the sea, but enter late in the season to seek spawning beds not far inland, while the best of the Yukon chums travel 1,000 to 2,000 miles up a river known for its consistently rapid current.

Consideration was given to the passage through which the salmon enter the river, and the investigators considered it not beyond the bounds of probability that nine-tenths of the salmon run enter by the Kwikluak Pass and its subsidiary channel, the Kwiguk.

CHEMICAL STUDIES OF SALMON.

Without expense to the Bureau, Prof. C. W. Greene, of the University of Missouri, has continued his chemical studies of material collected several years ago to determine the changes in salmon ovaries and tissues during the period of migration from sea to breeding grounds. The results of such studies can at first be given only technical expression, but they are none the less likely to yield in the end data of direct economic value.

The chemistry of the king salmon ovaries during their development in the migration period followed in the year 1908 on a series of samples collected on the Columbia River and its tributaries has been tabulated and prepared for publication.

These studies show the following major points: First, the growth of the ovary takes place primarily during the migration while the salmon is fasting. The average increase in weight is from about 135 to 150 grams at the end of the feeding period to 2,000 to 2,500 grams at maturity. In short, about 90 per cent or more of the development takes place during the prolonged fast of the migration.

Chemical analyses of developing ovaries show that between the 500-gram stage and the mature-egg stage there is a remarkable uniformity of chemical composition. The proteins are high, averaging from 29.38 to 31.16 per cent. This is undoubtedly all stored protein. The neutral fats decrease with the development and migration, from an average of 14.15 per cent at the mouth of the river to 10.83 per cent at the spawning. Phospholipins average 4.78 at the mouth of

the river and 2.85 at the spawning, showing a decrease with development. The phospholipins are much lower than in the yolk of bird eggs, the hen's egg averaging 11 per cent. The water-soluble organic extractives and the ash are both remarkably uniform, the extractives averaging 1.87 to 1.65, the ash 0.66 to 0.81 per cent. The organic extractives and ash are both low in comparison with other salmon tissues, but compare favorably with their percentages in the yolk of other eggs.

The salient points in this study are found in the showing of high protein storage in the salmon-egg yolk, the relatively low percentage of neutral fats and of phospholipins, and the decrease of neutral fats and phospholipins during development. Since in other eggs these fatty contituents are higher and tend to increase with development, it is probable that in the salmon the decrease is due to the extreme drain on the fatty deposits for the production of dynamic energy during the migration.

Determination of carbohydrate content of certain tissues of the king salmon during the spawning migration was undertaken as an accessory test. The gross samples were preserved in alcohol, and in the final analysis all glycogen was converted to glucose and the determination made in that form. The results show a very low glucose content of all organs and tissues. Glucose was present in all the tissues of the feeding salmon, Monterey Bay and Bolinus Bay specimens, but was absent or in reduced amount in the migrating and spawning salmon, with the exception of one tissue, the ovaries. In the ovaries, the percentage of glucose was practically constant throughout the migration.

LIFE HISTORIES OF MARINE FISHES.

During July and August, 1920, studies of the life histories of fishes of the middle Atlantic coast were carried on by W. W. Welsh, scientific assistant, aided by C. M. Breder, at a temporary station on Young's Pier, Atlantic City, N. J. Through the courtesy of Capt. J. L. Young, owner of the pier, a serviceable two-room building, formerly used as a wireless telegraph office, was adapted for use as a laboratory. A small hatchery, equipped with tidal box and Chester jars, was set up and supplied with filtered salt water from the pier aquarium. A great variety of material was obtained from the two pound nets operated under the pier. Eggs of several species, obtained from fish taken in these nets, were hatched in Chester jars, and the fry carried on as long as possible for study. Series of scale samples for the determination of age and growth were also taken.

Among the species studied were northern and southern king whiting (*Menticirrhus saxatilis* and *M. americanus*), squeteague (*Cynoscion regalis*), spot (*Leiostomus xanthurus*), croaker (*Micropogon undulatus*), silver perch (*Bairdiella chrysura*), menhaden (*Brevoortia tyrannus*), and puffer (*Spheroides maculatus*).

Although the facilities generously furnished by Capt. Young could hardly have been improved upon, the work was greatly handicapped by the abnormally cold water which prevailed throughout the summer. Water temperatures ranged from 53 to 65° F. and averaged about 57° F. This low temperature is believed to be the cause of the

scarcity or entire absence of a number of species which it was hoped could be obtained and studied.

The same investigators completed during the year a valuable report on the life histories of fishes of the family Sciænidæ of the Atlantic and Gulf coasts. The family includes some of the most important food fishes, the annual catch on these coasts approximating $3,000,000 in value. No less than 37½ per cent of the fish landed at the municipal fish wharf, Washington, D. C., in 1919 were of this family; the principal species were the squeteague, or weakfish, often erroneously called sea trout, the highly esteemed king whiting, the red drum, or channel bass, the croaker, spot, and silver perch.

How can we act intelligently with reference to the exploitation of such resources or determine wisely how to preserve them for all time if we do not know the life histories of the fishes, when and where they breed, their migrations in summer and in winter, the rate of growth, and the food they require? The present report not only brings together the fragmentary data hitherto available but adds materially to existing knowledge by embodying the results of years of researches, particularly those of the senior author, whose death unfortunately preceded the final completion of the paper.

The report also serves the valuable purpose of making evident the gaps in existing knowledge, revealing the need of additional observations, and showing plainly the directions which further studies should follow. As similar work is done for other families of fishes we shall come nearer to realizing the practical value of applying science to the study of fishes.

Mr. Welsh also completed descriptions of seven new species of marine fishes (Malacopterygii) taken during the explorations of the United States Coast and Geodetic Survey steamer *Bache*, conducted in 1914 under the direction of the United States Bureau of Fisheries. The fish were taken at various stations in the vicinities, respectively, of Cape Hatteras, the Bermudas, and Bahama Islands. After Mr. Welsh's death the descriptions were prepared for publication by C. M. Breder. The report has been accepted for publication by the United States National Museum.

Both assistants have been lost to the Bureau during the year, the one by untimely death, the other by resignation.

FRESH-WATER FISHES.

WHITEFISHES OF THE GREAT LAKES.

There is scarcely a sadder feature of the history of American fisheries than the progressive depletion of the important resources of the Great Lakes, notably in respect to the whitefishes. We may have overestimated the possibilities of exploitation, we may have been shortsighted in the fishery policies we pursued, or we may not have propagated them with proper energy or efficiency. But the simple fact is that no one has had enough knowledge of the distribution, habits, and requirements of whitefishes to give proper advice. The best intentions can not save a situation when founded upon ignorance. If the whitefish fisheries of the Great Lakes are to be preserved to the future or perhaps restored in part to their earlier rank, we must study the fishes and ascertain the condition of their existence.

Therefore, for several years the Bureau has had a skilled assistant devote exclusive attention to the whitefishes and related species. This investigation, pursued by Walter Koelz, scientific assistant, is not all that is required, but it will surely provide a fund of information for more intelligent guidance in future.

The investigation of the systematic relationships and habits of the coregonines was conducted in the year 1920 on Lake Michigan. Forms allied to those which the investigations of the previous year disclosed in Lake Huron, and in addition two undescribed species, of which at least one is now known to occur also in Huron, were obtained. Diagnoses of the species have been prepared from over 2,000 preserved specimens. Data have been collected bearing on the distribution in the lake and on the spawning habits of the various forms. To avoid dissemination of premature conclusions a report will not be published until work is done upon other lakes.

These studies have been supplemented by microscopic examination of the scales and systematic investigation of the food, conducted, respectively, by John Van Oosten and Carl L. Hubbs, temporary investigators, under the direction of Prof. Jacob Reighard.

Mr. Van Oosten first determined that the scale characters of the lake herring (*Coregonus artedi*) are so well defined as to permit the determination from them of the age of individuals and the rate of growth of the species. The variations in the scales of individuals were found to be within specific limits. But scales from different parts of the body of an individual are so unlike that for comparison of individuals or species it is necessary to use scales from the same body region.

The scales of 10 specimens of each of the 10 Lake Huron forms recognized by Koelz were next compared, and it was found that 8 of them (including the two races) are discriminable. Further study will probably enable discrimination of the two other forms. It appeared that in one of these forms (*Coregonus artedi*) there are probably two geographic races which differ in rate of growth, but the matter needs further study.

Through the courtesy of Dr. C. H. Townsend, director of the New York Aquarium, it was possible to secure specimens of whitefish (*Coregonus clupeaformis*) hatched and reared at the aquarium and therefore of known age (7 years). The 10 specimens studied show that there is one annulus for each year of age. This, so far as known, is the first demonstration of this fact and enables the determination of the age of coregonine fish from scale characters to be undertaken with confidence. Two individuals of the 7-year-old whitefish were segregated at the New York Aquarium and kept living, while scales were removed at intervals of a month. A study of these scales shows that the annuli are formed in winter, fixes the time of formation, and indicates temperature change as one of the factors. It is believed that a continuation of these studies will add materially to our knowledge of age and rate of growth of coregonine fishes, aid in their systematic grouping, and lead to the discovery of local races in some of the forms.

The food of the whitefish, lake herring, and allied species of Lake Huron coregonines in the Koelz collection was investigated by a volumetric method by Carl L. Hubbs, of the Museum of Zoology,

University of Michigan. The deep-water forms, as the blackfin (*Leucichthys nigripinnis*), were found to feed almost exclusively upon the crustacean *Mysis relicta*, probably the only available food. The deep-water race of the bloater (*Leucichthys hoyi*) feeds chiefly on Mysis, while a 30-fathom race eats for the most part another lake crustacean, *Pontoporeia hoyi*. The food of the shallow-water forms is much more varied. The pilot or menominee (*Prosopium quadrilaterale*) is strictly a bottom feeder, subsisting on mollusks, insect larvæ, crayfishes, etc. The whitefish (*Coregonus clupeaformis*) is also a bottom feeder, but its food is, on the average, not so coarse as that of the pilot, consisting largely of insect larvæ, as those of the mayflies Hexagenia and Ephemera. The lake herring feeds in part upon the same animals, in part upon the minute Crustacea of the plankton. In reference to their available food supply the deep-water forms are absolutely competitive (more so perhaps than any other group of fishes), while the shallow-water forms are only in part competitive. It is probable, however, in view of the former greater abundance of these fishes, that sufficient food exists in the lakes to support a larger population of all the species of whitefishes.

FISHES OF WISCONSIN LAKES.

The food and distribution of the fishes in certain Wisconsin lakes have been studied by Dr. A. S. Pearse.[4] The results indicate that in summer fishes are generally more abundant as conditions approach those in swamps and are fewest when the environment is most like that in rivers. When food is present in quantity and when other conditions are favorable, there are more fishes per unit area in certain inland lakes than in the Mississippi River or in Lake Michigan. Lakes produce considerable food supplies within themselves, while rivers are more dependent on swamps, ponds, and other tributaries. The factors of importance in limiting the distribution of fishes are discussed (shores, turbidity, depth, bottom, height of water, currents, etc.). An abundant supply of food and vegetation permits many fishes to *exist* in a lake, but other favorable conditions must be present in order that they may grow to large size.

A statistical study of the infection of fishes by parasites has been made, the Mississippi and St. Lawrence drainage systems being compared, and various types of lakes studied. The results are now being tabulated and will soon be ready for publication. A short paper on the habits of the mud puppy, in which its relations to fishes are discussed, has been published.[5]

In order to secure information on the rate of growth of cold-blooded animals in natural conditions, attempts are being made to recover the fishes and turtles tagged and released in Lake Mendota during the summer of 1919. Some specimens have already been secured.

Studies on the metabolism of fishes are being continued. In this connection quantitative analyses are being made to show the water, ash, nitrogen, and ether extractives of fishes at various stages of growth.

[4] Pearse, A. S.: The Distribution and Food of the Fishes of Three Wisconsin Lakes in Summer. University of Wisconsin Studies in Science, No. 3, June, 1921, 60 p. Madison.

[5] Pearse, A. S.: Habits of the Mud-Puppy Necturus, an Enemy of Food Fishes. Bureau of Fisheries, Economic Circular No. 49, issued May 16, 1921, 8 p. Washington.

THE PADDLEFISH.

The study of the natural history and artificial propagation of the paddlefish in Bayou Pierre at Westdale, La., was continued by Dr. A. D. Howard, scientific assistant, with the cooperation of the Louisiana Conservation Commission. During March good catches of egg-bearing females and sufficiently ripe males were obtained, but no females were ripe enough to allow of fertilization of eggs. Late in the month heavy rains flooded the Red River and Bayou Pierre and prevented the capture of fish in sufficient numbers to continue the investigation.

There are few added data regarding the breeding grounds of the fish and the time and manner of spawning. Some information of minor importance was obtained regarding certain habits of the species. Bottoms suspected of being the breeding grounds of the paddlefish were dredged for the purpose of obtaining eggs, but without success.

POISONOUS ACTION OF GAR ROE.

In a previous year experimental attempts to produce caviar of gar roe were made by Prof. C. W. Greene, temporary investigator. Out of this work it developed that the pigment in the gar roe is not a melanin as in the sturgeon roe, but a form of pigment that changes color under various chemical treatments of the roe. The pigment color is changed to an orange red on boiling the gar eggs, on treatment with alcohol or ether, and on salting. This changes the commercial quality of the product and gives easy methods for detecting the adulteration of sturgeon roe by gar roe.

The important observation, however, was the demonstration of an active physiological principle of a toxic nature present in gar roe. It is apparently this principle that gives the unpleasant acrid taste to gar-roe caviar. When tested biologically by the method of feeding the natural product the following points were made: (1) Gar roe is poisonous to the chicken and to the rat; (2) it paralyzes the neuromuscular mechanism of the chicken crop; (3) it produces in the rat an intestinal irritation with active diarrhea.

During the summer of 1920 a series of experiments were made to chemically separate and biologically test the unknown toxic substance. It was shown that (1) extracts in boiling water free from coagulable protein and (2) similar alcoholic extracts contained an active principle toxic to the heart of the frog; (3) globulin fractions made by the method of salting out, centrifuging, and purifying by dialysis were sharply toxic to the heart; (4) the globulin fractions fed to a young rat produced extreme diarrhea and death in about 20 hours, effects comparable to feeding the entire fresh ovary; (5) the effect on the chicken's crop was positively toxic; (6) not only was the crop paralyzed but an acute diarrhea occurred in the chicken through some alimentary canal poisoning; (7) these effects also occurred after feeding the purified globulin.

Attempts to isolate and identify the individual chemicals, of which at least two classes are present, have thus far not been brought to a successful issue. Further experiments are planned.

FISHES OF THE PANAMA REGION.

The Bureau of Fisheries, late in 1910, entered into an agreement with the Smithsonian Institution and the Field Museum of Natural History for a cooperative study of the fishes of the Panama Canal Zone. The work was carried on under the auspices of the Smithsonian Biological Survey of the Panama Canal Zone. The field work was done by Dr. Seth E. Meek, of the Field Museum, and Samuel F. Hildebrand, of the Bureau of Fisheries, during two expeditions made to the Canal Zone, from January to June, 1911, and January to March, 1912, respectively. The study of the collections which were sent to the National Museum was begun during the interval between the two expeditions and continued after the second visit to Panama by the collectors. After two small preliminary papers containing descriptions of new species of fresh-water fishes had been written, and a majority of the forms had been roughly identified and separated, Dr. Meek was obliged to withdraw from the work because of an illness from which he never recovered. The completion of the work was then left to Mr. Hildebrand. As other duties were necessarily assigned to Mr. Hildebrand from time to time, the completion of the study of the collections was greatly delayed. The final report on the fresh-water fishes, however, was completed and published in 1916, but the study of the marine forms was not completed until the spring of 1921. In the last months of the work the author was assisted by W. C. Schroeder.

The total number of species recorded from the coasts of Panama, either taken by Messrs. Meek and Hildebrand, or previous collectors, or both, is 640. The remainder of the species included in the paper were discussed because their known range of distribution is such that they may be expected on the coasts of the Isthmus. The fishes on the Pacific coast run larger than those on the Atlantic and are more numerous both as to species and individuals. Much more collecting, however, has been done on the Pacific side than on the Atlantic, which undoubtedly accounts in part for the large difference in the number of species recorded. The total number of species listed as common to both coasts of Panama is 72, but of these 48 are more or less cosmopolitan in their distribution, that is, they are not confined to American waters. A very large number of species considered distinct are, however, very closely related, differing only slightly but in apparently constant characters.

It was pointed out in the report on the fresh-water species that the fishes of the opposite slopes of Panama are very closely related, some of them remaining identical. This close relationship indicates that the fishes of the two slopes had not long been separated. Since the opening of the Canal they, of course, can again freely intermingle in those streams which are connected with the Canal. The close parallelism of the marine species of the opposite coasts is evidence of a comparatively recent passageway from ocean to ocean, even for salt-water forms. The genera of many families have representatives on both coasts, and if they do not include identical species they at least have very closely related forms on the opposite coasts. A few families, however, deviate from this general rule in having many more representatives on one coast than on the other. The reasons

for this may be found by consideration of the habits of the species of those families which do not conform to the usual rule. The Siluridæ (including the catfishes), for example, are very much more numerous on the Pacific coast than on the Atlantic. The Scaridæ (including the parrot fishes and viejas), on the other hand, are much more numerous on the Atlantic than on the Pacific. It is well known that most catfishes frequent water with soft or muddy bottom. The Pacific coast of Panama has many large mud flats partly or wholly exposed at low tide but flooded during high water. The Scaridæ prefer rocky bottom, and especially coral reefs, which are large and extensive on the Atlantic side. These conditions undoubtedly prevailed, in part at least, before the last passageway between the two oceans was closed, and it is probable that these families had already sought out regions best suited to their particular needs.

The commercial fisheries of Panama are still largely undeveloped. The possibilities for profitable fisheries appear to be especially good on the Pacific coast, but apparently less promising on the Atlantic side of the Isthmus. The people of the Isthmus are less wasteful of fishes than the people of the United States, as nearly all species of fish taken, including sharks and skates, are utilized as food.

PACIFIC HERRING.

During the year the Bureau issued a memorandum dealing with the distribution, migrations, sizes, and spawning times and places of the Pacific herring in southeast Alaska and British Columbia, based upon the observations of D. R. Crawford, scientific assistant.

There are apparently two races of herring (*Clupea pallasii*), one of which resides in the bays and inner waterways along the coast from Puget Sound northward to British Columbia and southeast Alaska. The other, which is composed of larger individuals, passes along the outer coasts where it is taken off Vancouver Island in June, July, and August.

The smaller race of herring is found to be sexually mature in the summer, but no milt or roe is found during the winter. Sexually mature individuals vary in size from 6 to 10 inches. The probable spawning time is late summer or early fall. The larger race of herring reaches sexual maturity in the fall and winter, the individuals varying in size from 9 to 12 inches or longer. The probable spawning time is winter or early spring.

USE OF FISH IN COMBATING MALARIA.

COOPERATION IN ANTIMALARIA CAMPAIGN.

Investigations of fishes in relation to mosquito control were conducted during the mosquito-breeding season of 1920 by Samuel F. Hildebrand, scientific assistant, working in cooperation with the United States Public Health Service. In the spring and early part of the summer Mr. Hildebrand inspected various localities in 12 Southern States where malaria-control work was to be undertaken. Suggestions were offered concerning the employment of fish for the control of the mosquito, and the waters suitable for fish control were pointed out to the officers in charge. The result of these inspections

was that the top minnow, *Gambusia affinis*, was very widely employed as an agent in the control of malaria. A report of observations made by Mr. Hildebrand during this campaign has been published by the Public Health Service.[6]

The latter part of the season was devoted to investigations at Savannah, Ga., where a special effort was made to determine the relative value as eradicators of mosquito larvæ of two other American viviparous species of fishes, *Heterandria formosa* and *Mollienisia latipinna*, both of which are abundant at Savannah. It was demonstrated that *Heterandria formosa* is of real value and is well worth careful consideration wherever it occurs. *Mollienisia latipinna*, on the other hand, appeared to be practically worthless.

The antimalaria campaigns in the various States were brought to a close early in November, in which month the annual meeting of the National Malaria Committee and the conference of sanitary engineers engaged in antimalaria work took place in Louisville, Ky., where the outcome of the past season's campaign was reported and discussed. The subject of mosquito control by the use of top minnows received extended discussion, and the fact was brought out that nearly every sanitary engineer had made use of *Gambusia affinis* as an agent in malaria control with excellent results. The saving of large sums of money was reported, because fish control replaced other methods at much less expense.

Similar advisory work was done by Mr. Hildebrand in the spring of 1921 before establishing headquarters at Augusta, Ga., for further investigations to determine more fully the conditions of effectiveness in the employment of fish for destruction of disease-bearing mosquitoes.

CONDITIONS GOVERNING ABUNDANCE OF MOSQUITO-DESTROYING FISH.

R. L. Barney and Barry Anson have continued the organization and summarizing of data collected at Mound, La., where investigations of the use of fish for control of mosquito breeding were previously conducted in cooperation with the Bureau of Entomology.

Reports[7] printed outside the Bureau's publications demonstrate the varying seasonal frequency of Gambusia, the mosquito-eating fish; the seasonal variation in the proportions of the sexes and its bearing on the abundance of the species in nature; the effect of environment on the abundance of the species; and the relation of plants of varying habits of growth to oxygen supply and to the capacity of small ponds to support the top-minnow Gambusia. Further observations have been made on the seasonal abundance of Gambusia, especially in relation to the fecundity of the species. Appropriate consideration has been given certain points concerning the anatomy of the female reproductive organs of this fish.

[6] Hildebrand, Samuel F.: Top Minnows in Relation to Malaria Control, With Notes on Their Habits and Distribution. Treasury Department, Public Health Bulletin No. 114, May, 1921, 34 p. Washington.

[7] Barney, R. L., and Anson, B. J.: Relation of Certain Aquatic Plants to Oxygen Supply and to Capacity of Small Ponds to Support the Top-minnow (*Gambusia affinis*). Transactions, American Fisheries Society, 1920, pp. 268–278.

———. Abundance of the Mosquito Destroying Top-minnow *Gambusia affinis*, Especially in Relation to Male Frequency. Ecology, Vol. II, No. 1, January, 1921, pp. 53–69.

The study of the natural history and ecology of the pigmy sunfish, *Elassoma zonatum*, has been concluded and given publication.[8] It appears that this fish, under certain conditions, may have some value in eradicating immature mosquitoes.

MOSQUITO CONTROL IN NORTHERN WATERS.

While in northern States mosquitoes have a less acute relation to public health than in regions where malaria is prevalent, they nevertheless constitute there a distinct menace to health and efficiency, besides being effective in causing a material reduction of property values, especially in regions which are normally resorted to for purposes of recreation and recuperation of vigor. During the year Prof. J. P. Moore, temporary investigator, has completed a report upon his observations of the use of fish and other aquatic animals for the control of mosquito breeding in northeastern States. His conclusions and suggestions may be summarized.

Although no fish to which mosquitoes are more than an incidental item of the diet has been found in the fresh waters of the northeastern States, nevertheless several species of small fishes and the young of some large ones native to these waters eat mosquito larvæ, pupæ, and eggs more or less habitually. The most important of these mosquito repressors are the common sunfish, the mud minnow, and the common killifish.

Fishes are found to be far more detrimental to culicine than to anophelene mosquitoes. While in the aggregate they destroy vast numbers of eggs, larvæ, and pupæ, and (along with other enemies) probably prevent mosquitoes from becoming everywhere an intolerable nuisance, the destruction is never complete. Some breeding of mosquitoes continues in nearly all bodies of fresh water even when well stocked with mosquito-eating fishes. This imperfect suppression arises through conditions limiting the efficacy of the fishes, most important of which are (1) the barriers that almost all natural bodies of water afford and which prevent the fishes from finding the young mosquitoes, and (2) the abundance of other food for the fishes. Most native mosquito-eating fishes will not thrive in water contaminated by excess of decaying vegetation or otherwise.

The most prevalent of the barriers is the shallow water and marginal vegetation. In ponds formed by dams provided with head gates a simple, effective, and economical method of controlling and reducing marginal vegetation is by lowering and raising the water level periodically, thus alternately drying and drowning the plants. In ponds and lakes of fixed level mechanical means of clearing the margins must be employed.

The most practical method of keeping the per capita food supply low is by overstocking with a variety of small fishes. Reduction of the vegetation also diminishes the supply of fish food.

The common sunfish (*Eupomotis gibbosus*) is the most useful species for ponds and lakes generally. With it may be associated the long-eared sunfish (*Lepomis auritus*), roach (*Abramis chrysoleucus*), some of the smaller minnows, black bass, etc. If there is much

[8] Barney, R. L., and Anson, B. J.: Life History and Ecology of the Pigmy Sunfish (*Elassoma zonatum*). Ecology, Vol. I, No. 4, October, 1920, pp. 241–256.

aquatic vegetation the blue-spotted sunfish will prove a valuable addition, and if very shallow or swampy areas occur, the mud minnow. The common killifish is very effective in fresh and brackish tidal marshes, and the translucent killifish is useful in upland creeks and dams. Rapid multiplication of small fishes should be encouraged by providing suitable nesting sites and protection for the fry.

Gambusia, the favored top minnow of southern waters, has not survived the northern winters but multiplies so rapidly that it may be used effectively against both Culex and Anopheles in small ponds and water gardens by planting a small number each spring. Small goldfishes are useful in fountain basins and small ponds with clean sides, and, for use in rain barrels and tanks, are preferable to Gambusia.

FISH-CULTURAL EXPERIMENT WORK.

EXPERIMENTS IN PROPAGATING AND REARING FISH IN PONDS.

The Fairport station has continued its valuable experimental work in reference to the propagation and rearing of fishes in ponds. Certain observations were made on the value of fertilizing ponds with chemicals and manure, but data obtained to date are inconclusive. Further study will be directed toward this problem.

The small pond, which for several years has been handled as a farm pond with minimum care and expense, has yielded valuable information. Originally it was stocked with bluegill sunfish. Occasionally, when necessary, the pond has been wintered out. There has been no manipulation of the pond in any respect other than the control of the number of bluegills of various ages in it. During the past year the actual production of fish meat in the ponds has been 333 pounds per acre. Of this, however, fishes of edible size represented about 33 per cent of the total fish-meat production. In this connection it may be well to note that the average annual production of beef per acre on untilled meadowland is said to be 125 pounds; that for hogs is 225 pounds.

Buffalofish, *Ictiobus cyprinella*, artificially reared in the station ponds, reached maturity and produced young for the first time at the age of 4 years. They averaged 13.6 inches in length and approximately 2 pounds in weight. The small-mouth buffalofish, *Ictiobus bubalus*, which in previous years had failed to spawn in the experimental ponds unless an artificial rise in the level of the pond was produced, spawned this year in a pond in which the rise did not occur. While the production of fry of this species does not appear to be as numerous as for those fish held in the pond with artificial rise, the occurrence indicates that the rise is not entirely necessary, though it may be advantageous.

The channel catfish, *Ictalurus punctatus*, for which this station showed the feasibility of pond culture, has continued to spawn in the experimental ponds. Certain 4-year-old offspring of wild stock came to sexual maturity during the year and produced the first brood of truly domestic fish. The adaptability of this species to pond culture is suggested by the fact that the catfish has spawned in certain of the smallest ponds on the reservation, one of which has a water-surface area, when completely full, of only 3,485 square feet (less than one-twelfth of an acre).

WATER BEETLES IN RELATION TO POND CULTURE.

The home fishpond is a subject of continued interest among farmers and others who value the additional table food made available or the means of recreation provided. There must be a great deal in a pond besides fish; otherwise the fish would starve. There must be small animals which serve as food to fish and still smaller animals and plants which serve as food for them. Some things in a pond are desirable, others objectionable in varying degree. The fishpond is, indeed, not a simple thing, but a very elaborate complex, the scientific unraveling of which is necessary before the best plans of pond management can be known. The unraveling of the complex can be accomplished eventually only by tracing particular threads, that is, by centering attention at one time upon a particular group or species of the inhabitants of the water. An instance of such special studies carried through to a point where helpful practical conclusions are derived is afforded by the investigation of water beetles conducted at the Fairport station.

Dr. C. B. Wilson has made a comprehensive study of the rôle beetles play in pondfish culture. He has found that larvæ and adults of the three beetle genera, Hydrophilus, Dytiscus, and Cybister, destroy small fish under normal conditions. The larvæ of Dineutes are known to have killed and eaten fish fry under certain abnormal conditions. The larvæ of three other genera (Acilius, Graphoderes, and Hydrocharis) are suspected of being capable of committing similar depredation.

On the other hand, both beetle larvæ and adults are eaten freely by the young of nearly all our common food and game fishes after the latter attain a length of 25 to 40 millimeters. This is just as true of the seven genera mentioned above as of the others that are harmless.

Practically speaking, only the young fish of the year are menaced by beetles. Fish a year or more old are large enough to feed on the beetles and are almost never attacked by the latter. Consequently beetles are really harmful only in breeding ponds, and even in those places, as everywhere else, they contribute materially to the available food supply for the fish.

Adult beetles migrate and travel so constantly that every fishpond is sure to be stocked with them as soon as it is completed, and yet the beetles of two ponds side by side are likely to differ radically in numbers and variety. If they occasion trouble in one pond, the temporary removal of the fish to another pond will usually prove an effectual remedy. Beetles may also be kept in check by abruptly raising and lowering the water in the pond at intervals of a week or 10 days during their breeding season in July and August.

STUDIES OF SALMONIDÆ IN RELATION TO FISH CULTURE.

In a previous report reference in detail was made to the investigations by Dr. W. C. Kendall of rainbow and steelhead trout and of some hitherto unrecognized anatomical characters of trout which seemed to have a direct bearing upon fish-cultural practices. It is worthy of note that the results of the latter investigation were deemed of such value by independent persons that the report upon them was

awarded a prize by the American Fisheries Society as the most important contribution in the application of biological science to the advancement of fish culture. A series of practical experiments based upon these results was conducted during the winter at one of the fish-cultural stations of the Bureau. Just before the close of the year they were transferred to another station where more adequate facilities were available, and it is planned to continue them during the coming fiscal year that definite results may be obtained.

MINNOWS IN RELATION TO FISH CULTURE.

The smaller members of the minnow family are important to fish culture since they represent a primary source of food for more than 20 of the larger food and game fishes. The success of the introduction of game fish into streams or ponds necessarily depends to no small extent upon the suitability of the stream or pond for the support of minnows. Hence the budget of knowledge requisite for efficient fish culture includes information regarding the food and other requirements of minnows. Therefore, while the study of minnows by C. M. Breder and D. R. Crawford, scientific assistants, was conducted almost entirely outside of office hours and represents a by-product as it were, the results gained are of practical value.

They studied six common species in the vicinity of the District of Columbia; chub minnow, *Semotilus bullaris;* red-bellied dace, *Leuciscus vandorsalis; Notropis procne;* shiner or red fin, *Notropis cornutus;* black-nosed dace, *Rhinichthys atronasus;* cutlip, *Exoglossum maxillingua.* All were found to be predominantly carnivorous, insects forming the bulk of the food taken, although two species, *Notropis procne* and *Exoglossum maxillingua*, consumed much vegetable matter. Various worms, filamentous algæ, and diatoms entered into the food in considerable quantities. These minnows are, therefore, in direct competition with the young of important game fish and may even prey upon the fry of them. It is suggested, therefore, that if minnows are introduced into ponds as food for game fish, discretion should be exercised regarding the use of larger and more rapidly growing minnows, such as the chub minnow and red fin, which may outstrip young trout in growth and under some circumstances become a menace rather than a benefit.

In all cases the suitability of the introduction depends both upon the species of minnow and upon the species of fish which is to be fostered, as well as upon other conditions prevailing in the water and upon the degree to which the various factors are under the control of the fish culturist. Minnows seem to thrive best in streams or ponds where the banks bear overhanging vegetation that supports an abundance of insect life. Where this condition prevails there is probably less likelihood that the minnows will prey upon the eggs or young of other fishes.

A NEW FORM OF POND OUTLET.

Practical success in fish culture depends in no little measure upon economy in construction and operation of the pond and upon the convenience with which it can be drained for removal of brood stock or young, elimination of enemies, cleaning the bottom, or removing obnoxious plants. The concrete-box outlets commonly used are not

only expensive, but they are also frequently a subsequent source of annoyance, expense, and loss of fish, when damaged as the result of freezing and thawing. It is worthy of special comment, therefore, that H. L. Canfield, superintendent of fish culture at the Fisheries biological station, Fairport, Iowa, has devised a type of pond outlet which has been found, after long trial, to be both relatively inexpensive of installation and convenient and enduring in operation. The Canfield L outlet, here described and illustrated, provides both for all ordinary overflow and for draining the pond as easily and quickly as with the concrete outlet.

The outlet consists of two pieces of threaded pipe of required length screwed hand-tight into an elbow. When connected for service one pipe is joined to the drainage line, and the other, the elbow acting as a hinge, becomes a movable standpipe, the raising and lowering of which controls the depth of the water in the pond. A pipe stop about 2 feet high is arranged back of the elbow to stay the standpipe from passing the center.

Two or three cement blocks about 2 by 2 by 2 feet are set about the drainage line to anchor it and to give protection to the embankment against animals and water seepage leading into it along the line. These blocks serve also as couplings for the joining of the pipe to the drainage line and for other connections in the line as desired. When a kettle is used one block joins a side of it, anchoring the pipe connection with the drainage line and serving as a base for a walk support. A second block is placed about the drainage line approximately beneath the top and inside edge of the embankment. This is usually a drainage line connection block. If the drainage line passes entirely through the embankment a third block should be placed around it several feet into the embankment from the outside.

The outlet screen consists of a half coupling (whole coupling if desired) with a quarter-inch groove around it 2 inches below its top, to which is attached, by means of galvanized wire, a covered cylindrical screen of desired mesh, 1 foot high. This is screwed to the outlet pipe. A cylindrical or square screen of large proportion may be installed about the standpipe if maximum screen area is needed, although for general use this will not be required.

A cement kettle 12 by 6 by 1 feet set parallel to the embankment, and within this kettle a small kettle about 15 inches wide, 3 inches deep, and about 7 feet long (long enough and wide enough to admit the standpipe with screen, when down level) are used at Fairport with the L outlet. The drainpipe enters the side of the main kettle about 6 inches from the elbow and 1 foot from the end. The bottom of the inner kettle is made level with the base of the outlet pipe when it is down level in position to drain, and provision is made for the removal of the elbow by cupping out the cement beneath it and filling the space with clay, to prevent the trapping of fish when the pond is drained. The main kettle has a slight rise from the inner kettle to the sides to provide drainage.

A walk of 2-inch plank supported by 2 by 4 inch stringers is made to extend from the embankment to within a foot of the outlet screen, the stringers resting about 6 inches above the top of the outlet pipe when erect. This walk rests on two pipe supports which extend from the cement blocks in the drainage line.

The standpipe is chained to the sides of the outer walk support by a piece of galvanized pump chain the length of the distance the pipe travels. This chain passes through a loop eye in the post and is provided with a ring larger than the eye, so that the end of the chain can not be drawn through. By means of this chain the standpipe may be raised and lowered and the level of the water in the ponds adjusted and held as desired. An ordinary lock, or an iron bolt may be used to secure the chain in the loop.

Malleable iron pipe is excellent material for the outlet, but ordinary black steel pipe is cheaper and gives good service. One piece of pipe of required length for the standpipe, threaded both ends, an elbow, and about 2 to 2½ feet of pipe threaded one end, to serve as connecting pipe with the drainage line, are all the materials required for the outlet. It is recommended, however, that metal pipe be provided from the elbow well into the embankment for the better protection of the drainage line. Eight-inch pipe is recommended for ponds of 1 acre in area and proportionately smaller pipe for smaller ponds.

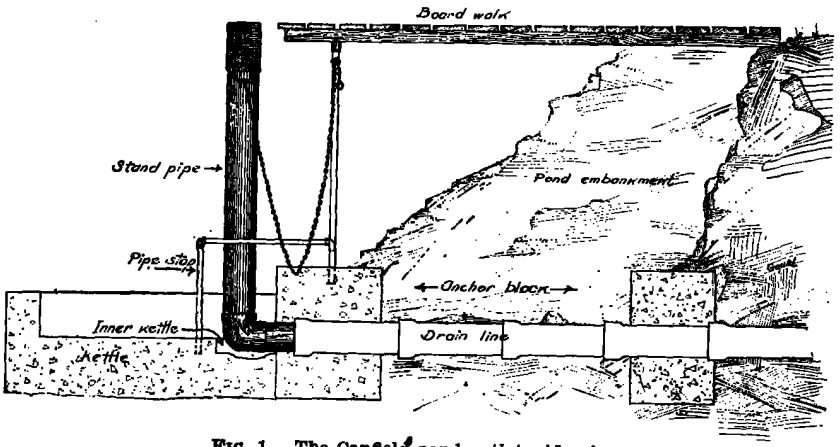

FIG. 1.—The Canfield pond outlet, side view.

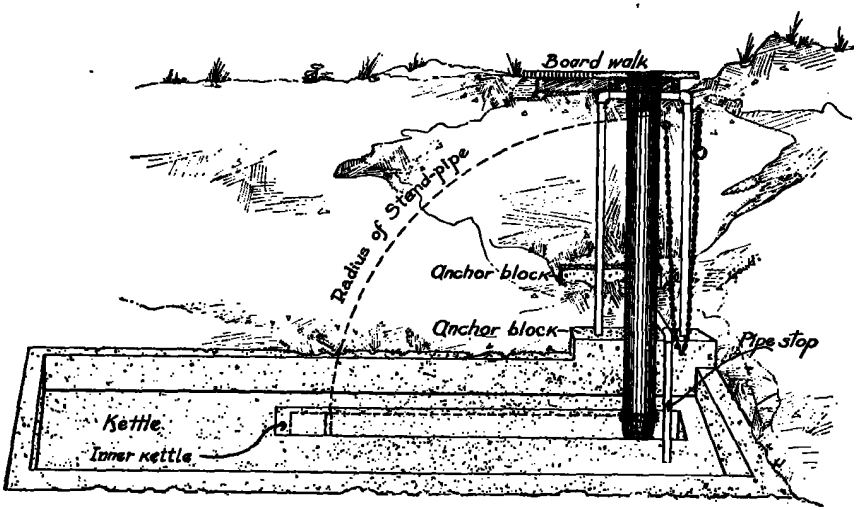

FIG. 2.—The Canfield pond outlet, end view.

It is well to paint the pipes with waterproof paint, and a mixture of graphite and oil is recommended for use in the elbow and coupling threads. Pipe threads should penetrate elbow 1 inch, hand screwed. When the drainage line is to be of terra cotta its joints should be sealed with cement throughout the line rather than laid partly open, as is sometimes done.

The elbow and two pieces of threaded pipe comprising the outlet proper and modifications as to size and detail of the L outlet and appurtenances may be made to suit requirements and material available. If it is necessary to reduce expense, the kettles may be reduced or omitted entirely, but the installation of a kettle, even though of small size, is recommended because of its usefulness when drawing the pond and sorting the fish. The cement blocks, the chief use of which is to protect the outlet drainage line against water working an opening about it, and which also prevents animals such as crayfish and muskrats following it through the embankment, must not be omitted because without the blocks to protect and stay the drainage line leakage is certain to occur. The depth of these blocks should not be reduced, but in unfavorable soil may be increased to advantage.

All surfaces over which embankments are to be laid should be plowed before the fill is commenced, so that the earth will bind satisfactorily, and all foreign matter such as brush, rock, etc., should be excluded from the fill dirt.

The outlet is placed at the drain point and stayed as described, after which the fill is laid over it, the outlet being ready for service as soon as the fill is started. Pipe 4 to 6 inches in diameter is sufficiently large for ponds of less than 1 acre in area. It is always better to have the outlet pipe too large rather than too small.

Many of the spillways and outlets in general use give more or less trouble through leakage, and those of cement construction often freeze and crack, or settle and crack, causing serious trouble and considerable expense. Many of the outlets in use are built into the embankment, thereby weakening and subjecting the embankment to the danger of washouts. Loss of fishes often arises from screens below the water surface becoming damaged, and many outlets, when the pond is being drawn, have too much suction for the good of the little fish. These and other troubles have been eliminated in the L outlet, some favorable features of which are enumerated below:

The action of the outlet is quick and easy.

Leakage and freezing difficulties have been overcome.

The outlet operating from the surface provides minimum suction, which works to the benefit of small fish.

The screen is visible, therefore safe, and easily cleaned.

The outlet does not weaken the pond embankment.

The outlet may be assembled, installed, and maintained at low cost, and is so simple of construction that any "handy man" can build and install it.

ERADICATION OF SOME OBJECTIONABLE PLANTS.

The rank growth of cat-tails in ponds and lakes, particularly at fish-cultural stations, has often become a serious nuisance, causing a substantial reduction in the effective area of the pond. Hitherto there has been no inexpensive or practicable method of combating them, since removal by cutting alone is quite ineffectual. Superintendent Canfield has devised and demonstrated the efficacy of a method of elimination of these plants, based upon the necessity of areation through contact of the plant or its landward roots with the air.

The water level in the pond is lowered below the limit of growth of the cat-tails, which should then be mowed as low as practicable. With spade or plow a ditch is made below the normal water line and between the cat-tails and the shore. The ditch must be sufficiently deep to sever the roots that connect the plants in the pond with the shore or with any plants that are allowed to remain above the ditch. In this way the air supply from the land roots is completely cut off. The pond should then be immediately flooded and the water

level continuously maintained above the stubble for a week or 10 days, when the cat-tails will have been killed out. It is essential to flood the stubble immediately after mowing in order to get ahead of the rapid growth of the cat-tails. If in consequence of stored oxygen in the severed roots a few weakling shoots should appear above the water surface, they should be pulled out; when this is done a few times the plants will not reappear.

STUDIES OF FISH DISEASE.

The position of fish pathologist in the Bureau was vacant during the last half of the fiscal year, the last incumbent having left the service at the end of December after a year's service. Some studies of diseases and parasites were also conducted by other investigators principally in temporary employ.

MORTALITY IN PIKE-PERCH EGGS.

The great losses in the hatching of pike-perch eggs have made this phase of fish culture a ground of repeated inquiry, although as yet no investigation has been carried to a conclusion revealing the exact causes of the high death rate. Further observations during the past fiscal year were made by Dr. Franz Schrader, who inquired into the practices of handling fish and eggs and investigated the actual changes taking place within the abnormally developing eggs. His observations point to the conclusion that the original cause of abnormal development and mortality of eggs is to be sought in physiological injuries sustained by the parent fish while held in captivity before spawn can be taken. The penning of fishes prior to spawning is a practice of long standing in the artificial propagation of pike perch and other species of fish. Some species withstand the confinement very well, while others manifest such ill-effects as hardening of ovaries, wateriness of milt, and low percentage of hatched fry—in short, degeneration of eggs and sperms. The general inference of the investigator finds some confirmation in the investigations reported in the next paragraph and also in the experiences of several superintendents who have observed that the mortality of pike-perch eggs is proportional to the length of time the fish have been retained in pens, and conversely, that the percentage of hatch is greater in the case of eggs from fish stripped as taken from the nets than in the case of eggs taken from fish that have been held in pens.

ABNORMAL CONDITIONS OF FISH OVARIES.

Dr. Schrader also conducted inquiries into ovarial conditions in fishes with the purpose of throwing light upon various difficulties arising in hatcheries, including the loss of spawning fishes, ovarian diseases, and failure of fertilized eggs to hatch, troubles which possibly have some relation to abnormal conditions of confinement, handling, or stripping. Observations were made upon developing immature eggs of the scup, the retention of eggs beyond the normal period of spawning, the reabsorption of retained eggs, and the hardening of ovaries. Abnormally retained eggs show signs of degeneration in course of one or two weeks. Reabsorption takes

place through invading cells, but is not always successfully accomplished; it apparently makes a demand upon the body of the fish, which, if excessive, may lead to death.

DISEASE OF RESCUED FISH.

Dr. H. S. Davis, temporary investigator at the Fairport biological station, has found that a high mortality may occur among rescued fishes immediately after the handling incident to rescue operations. This heavy death rate is especially characteristic of the crappies, buffalofish, and bluegills, when taken in warm weather, the first-named species being the weakest. While the mortality may be founded in part upon "shock" sustained during the seining and handling operations, it is due more directly to bacterial infection following slight injuries and gaining headway from the weakened condition of the fish. Immersion for one minute in a solution of copper sulphate in 1 to 1,000 dilution reduces the loss among rescued fishes to a minimum.

In certain experiments 75 to 100 per cent of the crappies rescued from inland sloughs and untreated were lost through death. Under similar conditions, except for a one-minute treatment with 1/1,000 copper-sulphate solution after the fish were allowed to remain a short time in fresh clean water, this experimental loss was reduced to 30 or 40 per cent. The necessity and practicability of the treatment depend upon the conditions attending work in particular fields and at particular times. It is believed that frequent tests should be made in connection with rescue operations and the prophylactic measures taken wherever a substantial mortality rate is to be expected. Dipping in a simple disinfectant can not be very expensive and will be worth while if it will increase appreciably the percentage of survivors.

Dr. Davis's experiments not only point out the possibilities of loss and the means of prevention, but they also emphasize the necessity for great care in handling rescued fish. Rough methods, including the throwing of fishes into receptacles and the abrasion of the fishes' bodies by seines, hands, or débris are the main causes of a high death rate.

PARASITIC FLATWORMS OF FRESH-WATER FISHES.

The parasitic flatworms which infest the body surface and gills of fishes (ectoparasites) may be more of a nuisance to fish culture in ponds, tanks, or aquaria than those which live within the body of the fish. The endoparasites generally can not complete the life cycle without passing different stages in two or more hosts, which are likely to be animals of widely different groups. Therefore, as regards these parasites, fish can not directly infect fish. With external parasites it is otherwise; there being no alternation of hosts, infection may proceed from fish to fish and thus multiply in such abundance as to cause extreme weakness or death of the fish. Such a parasite is *Gyrodactylus fairporti*, a new species described by Dr. H. J. Van Cleave from bullhead and carp of certain ponds at the Fairport (Iowa) station. These flatworms are very small, usually

less than half a millimeter in length, and so translucent that one may easily overlook them.

Some bullheads removed from a quarry pond near the Mississippi River died within 24 hours after being placed in an aquarium of running water. The early death of these usually most hardy fish could be explained only on the supposition that their vitality had been greatly diminished by the small and abundant trematodes (Gyrodactylus) scattered over the entire surface of the body. Possibly many fish in the river are unfavorably affected by these worms.

Dr. Van Cleave found a species of another genus of parasitic flatworms upon the gills of sunfish, black bass, and channel catfish, but it is believed that worms of this genus (Ancyrocephalus) do not cause dangerous infestations.

Very little study has been devoted to the ectoparasitic flatworms on this continent, and previously but four species have been reported from fresh-water fishes. Much attention has been given them in connection with fish culture in Europe. Treatments which European writers have recommended are: (1) A one-fourth of 1 per cent solution of salicylic acid, in which the fish remains half an hour (Hübner); and (2) a solution of 1 part of potassium permanganate to 100,000 parts of water. The treatments may require modification for our species of fish and of parasites.

Dr. Van Cleave has also described a new genus of trematodes based upon specimens taken from the white bass, *Roccus chrysops*, collected in Iowa, Illinois, and Minnesota. The parasites were found only in the digestive tract and at present are ascribed no economic significance. The parasites are not found in *Morone interrupta*, although that species is a close relative of the white bass. He finds, indeed, that the trematode parasites of the yellow bass are entirely distinct from those of the white bass, although the two related species display marked similarity in range, local preference, feeding habits, and food.

TREATMENT OF ICHTHYOPHTHIRIUS DISEASE.

One of the most troublesome external parasitic affections of fresh-water fishes in aquaria and ponds is due to a microscopic protozoan (Ichthyophthirius), which becomes embedded in the skin and sets up a violent irritation. H. L. Canfield, superintendent of fish culture at the Fairport station, who has conducted experiments in the treatment of channel catfish heavily infected with the protozoan parasite, reports that commercial carbonate of soda in the form of sal soda (washing soda) is effective in alleviating the trouble.

Using a receptacle other than metal to hold the solution, 150 g. of sal soda are placed in 4,000 c. c. of water, in which solution the affected fish are dipped. The diseased fish are held in troughs of lively running water, which aids in the treatment and facilitates handling. Before each treatment the fish are forced to the lower half of the trough, where they are separated from the upper half by means of a cross screen. The diseased fish are caught in a hand net, immersed in the solution until they show signs of discomfort (darting about), and then placed in the fresh water at the upper end of the trough. This process is continued until a material reduction in parasites is noticed

(usually about six days), after which the treatment is given once a day for about 10 days, which is usually sufficient to rid the fish of the parasites.

The effect of the sal-soda solution is to cause the parasites to shrink and wrinkle as they die. It is apparent that the solution kills the free swimmers, the young just attached to the fish, and all but the larger and more thoroughly embedded parasites. These last leave the fish in the natural process of development, and their offspring are killed with others after they attack the fish and before they attain their maturity. Thus in time the parasites are entirely exterminated.

The channel catfish were fed, as usual, ground liver three times a day while the treatment was in progress, and the usual care was given the fish and troughs as to cleanliness.

OCEANOGRAPHIC AND LIMNOLOGICAL STUDIES.

INVESTIGATIONS IN THE ATLANTIC.

Because of deficiency in funds and personnel the *Albatross* has not been at sea during the year.

Some brief cruises to complete the field work of the hydrographic and biological survey of the Gulf of Maine were made by the small Fisheries steamer *Halcyon* under the direction of Dr. H. B. Bigelow. The preparation of the report upon all the data gathered at different times during a period of years is now in progress, although its completion has been delayed by the death of William W. Welsh, who was giving special attention to the portion of the report dealing with the occurrence, distribution, and life histories of the fishes.

By joint action of the Governments of the United States, Canada, and Newfoundland there has been formed during the year an International Committee on Marine Fishery Investigations, with the object of bringing about a better correlation of the activities of the several Governments in fishery investigations in which two or more of the countries are directly interested. Knowledge of the cod and the conditions of its perpetual conservation, for example, possesses the same interest to Canada and Newfoundland as to the United States. No formal cooperative effort is contemplated, but it is believed that progress will be attained more rapidly and economically by regular interchange of data and counsel than by entirely detached endeavor on the part of each nation. The members of the committee are as follows: For Canada, Mr. William A. Found, Assistant Deputy Minister of Fisheries; Dr. A. G. Huntsman, member of the Biological Board of Canada, and Mr. Loring C. Christie, legal adviser, Department of External Affairs, Ottawa; for Newfoundland, Mr. D. James Davies, chemist to the Newfoundland Government; for the United States, Dr. H. F. Moore, Deputy Commissioner of Fisheries, Dr. R. E. Coker, assistant in charge, scientific inquiry, Bureau of Fisheries, and Dr. H. B. Bigelow, consulting oceanographer, Bureau of Fisheries.

The first meeting of the committee was held in Montreal, June 23, 1920, when, after full discussion, agreement was reached as to correlation and interchange of statistical data with regard to particular fishes, uniformity in methods of plankton study, and concentration of attention upon certain species.

SURVEY OF CHESAPEAKE BAY.

The biological and hydrographic survey of Chesapeake Bay has been continued by Dr. R. P. Cowles, temporary investigator, during the past year, and a large series of data on salinity, temperature, current velocity, and current direction has been accumulated, together with qualitative and quantitative collections of plankton, bottom samples, and many specimens of the larger animals and plants. The observations made and samples collected have not been confined merely to the surface nor to the bottom but have been obtained at definite depths, equal intervals apart, from the surface to the bottom. Probably the most valuable characteristic of the work is the fact that the observations have been made about every sixth week during the year at fixed stations arranged in lines across the bay, these lines being so placed as to adequately cover the bay from the region of Baltimore to the Capes. The Fisheries steamer *Fish Hawk* has been employed in the work on the bay.

During the year preliminary work has been undertaken to determine the hydrogen ion concentration of the sea water by colorimetry. This method has now been perfected, and the tests made on the so-called 24-hour stations, where observations are taken every 1½ hours at definite intervals from the surface to the bottom for a period of 24 hours, have shown some very interesting conditions.

The coming year will be devoted to working over the data and material, with possibly an occasional cruise on the bay to collect information that may be lacking. The general purpose of the investigation is to gather and record the data that are necessary for the interpretation of the seasonal and irregular movements of fishes, for the solution of practical problems that arise from time to time regarding fish and shellfish, and for the conservation and development of the important fisheries of the bay.

This general survey is being supplemented by a special investigation of fishes of the Chesapeake Bay, conducted by S. F. Hildebrand and W. C. Schroeder. While many fishes, especially the younger examples of several species, have been collected in connection with the general survey, the supplemental field work on fishes was undertaken only in the last months of the fiscal year.

SURVEY OF SELECTED AREAS IN MISSISSIPPI RIVER.

In an investigation to determine the distribution of fresh-water mussels, Dr. A. D. Howard made a somewhat detailed study of the entire bottom in a portion of the Mississippi River, the area selected being 3 miles in length and situated in Andalusia Chute, one of the channels of the river in the vicinity of Fairport, Iowa. The river in this section is comparatively straight and of rather uniform character as to gradient and depth, passing over soil of clay, sand, and sedimentary rock (mostly limestone).

The life on the bottom was found to have a rather definite distribution with reference to physiographic features of the river. In general it was restricted to a zone 200 feet wide along each shore. Where islands occurred a narrower zone was found along the shores of the islands. The distribution had apparently no particular relation to depth of water, for the middle area of the stream (about 500

feet wide) was not deeper than the 200-foot strips alongshore. The zones near shore are by no means equally productive throughout, the more densely populated portions manifesting definite relations to the position of the channel and to other features of the stream, especially those that affect the stability of the bottom. Productive areas usually occur in parts of the shore strips that are bathed by the current, or where the channel approaches the shore. Character of bottom soil is a significant feature, but this is often controlled by current, topography, and other conditions.

Keokuk Lake, formed in the Mississippi River above the dam at Keokuk, has been examined some years after its formation to determine some of the effects of the changed conditions. A report of the observations is in process of preparation.

STUDIES OF INLAND LAKES.

The Bureau has continued to cooperate with the Geological and Natural History Survey of Wisconsin in biological and chemical investigations directed at the fundamental problems of the capacity of inclosed waters for support of fish life. As has hitherto been stated, the Bureau bears only a relatively small proportion of the expense of the investigation. Substantial progress has been made, as is indicated by the following outline submitted by President Edward A. Birge and Chancey Juday representing the State Survey:

1. The bulletin dealing with the quantity and chemical composition of the plankton of the lakes situated in the vicinity of Madison is now ready for the press. During this investigation 481 observations have been made on the net plankton and 182 on the nannoplankton of these lakes, making a total of 663 catches. These catches were combined into 374 samples for the chemical analyses. About 2,500 separate chemical and ash determinations have been made on these samples and 52 samples of special material obtained during the progress of this work.

The quantity of dry organic matter in the total plankton of Lake Mendota (net plankton plus nannoplankton) varied from a minimum of 230 pounds per acre in February to a maximum of 521 pounds per acre in December in the area situated within the 20-meter contour line. When the surface of the entire lake and the volume are taken into account the range is from 126 pounds per acre in February to 256 pounds in December. The live weight of the organic matter is 10 times as much as the dry weight.

Of the dry organic matter an average of 44.5 per cent consisted of crude protein, 7.5 per cent ether extract, and 5.3 per cent crude fiber, leaving 42.7 per cent to be designated as nitrogen free extract (chiefly carbohydrates). The pentosans were the only carbohydrates studied, and they constituted an average of 4.6 per cent of the organic matter.

Lakes Monona and Waubesa yielded larger quantities of total plankton. The amount in the former varied from a minimum of 276 pounds per acre in July to a maximum of 1,063 pounds of dry organic matter in October in the area bounded by the 20-meter contour. For the entire lake the range was from 111 pounds to 426 pounds per acre of surface. The maximum crop of plankton in Lake Waubesa yielded 862 pounds of dry organic matter per acre in the area bounded by the 10-meter contour, or 415 pounds per acre for the entire lake; the average for 16 samples is 216 pounds of dry organic matter per acre.

The dry organic matter in the total plankton of Lake Monona contained 57.5 per cent of crude protein, 4.8 per cent of ether extract, 4.7 per cent of pentosans, and 4.4 per cent of crude fiber. The total plankton of Lake Waubesa yielded an average of 48.6 per cent of crude protein, 4.6 per cent of ether extract, 5.8 per cent of pentosans, and 4.4 per cent of crude fiber.

2. Mr. Wilson's numerical results for the bacteria of Lake Mendota show that the average number from surface to bottom in 23.5 meters of water was 3,000 per c. c. of water in July and August, 1919; in the following autumn and

winter the number fell to 1,500 per c. c. In the spring and early summer of 1920 the number rose steadily to a maximum average of about 30,000 per c. c. from the latter part of June to the end of August. During the autumn and early winter the number gradually declined to an average of 2,000 bacteria per c. c. of water.

Many of the bacteria represent chromogenic forms, and various colors are found in the plate cultures. There seem to be some denitrifying individuals present, but conclusive evidence of the presence of lime-precipitating forms has not been obtained yet. The average size of these bacteria has been obtained so that it will be possible to estimate their live weight and dry weight as well as the organic matter in them.

3. Several reports are now in press in the Transactions of the Wisconsin Academy which deal with investigations in which the Bureau of Fisheries has cooperated. The following may be listed here: "A survey of the larger aquatic plants of Lake Mendota," by R. H. Denniston; "A quantitative study of the larger aquatic plants of Lake Mendota," by H. W. Rickett; "A quantitative study of the bottom fauna in the deeper water of Lake Mendota," by C. Juday.

Some chemical analyses of the larger aquatic plants from Lake Mendota have also been made, but this has been done independently by the Wisconsin Survey.

4. Various analyses have shown that the quantity of organic nitrogen in the lake water itself amounts to five or six times as much as that in the total plankton. and Dr. Schuette has been trying to work out a method for the determination of this dissolved organic nitrogen which will give results that are more satisfactory than the present methods of nitrogen determination. The quantities are so small that the methods now used by chemists do not always give consistent results. So far no other method has been found which will give better results than the standard methods.

AGAR-AGAR AND OTHER GELATINS FROM SEAWEED.

It is obviously unfortunate that the United States should be dependent upon other countries for its supply of a vital necessity. Agar-agar is the commercial name applied to a gelatinous product which has been imported from Japan, China, and other places, the importations in 1919 amounting to nearly half a million dollars. The importance of the material is not, however, measured by its strictly commercial value. While it is used in making food and confections, agar-agar is primarily important because it is a necessary medium for bacteriological work, and is therefore essential to medical laboratories and hospitals. It is a requisite for certain industries, for the maintenance of health, and for national security.

Marine algæ or seaweed have long been used in this country for the preparation of gelatins for particular purposes, but only the recent investigations, conducted for the Bureau by Dr. Irving A. Field,[9] have revealed the fact that we have possible sources of supply for the most valuable gelatin of all in certain species of seaweed on the west coast. In the report for the preceding year reference was made to Dr. Field's preparation of a gelatin suitable for use in preserving fish, and to experiments in producing a substitute for agar from Atlantic coast seaweed. These experiments were not successful, but it was later ascertained that at least one species of the west coast yields agar of the best quality. Agar prepared by Dr. Field and tested at the Army Medical School in Washington was pronounced equal or superior to the imported agar. Another species yielded a product apparently of like quality. The investigation should be followed by a field survey for the purpose of definitely locating the

[9] Field, I. A.: Sources, Preparation, and Properties of Some Algal Gelatines. Bureau of Fisheries, Economic Circular No. 51, issued Oct. 10. 1921, 7 p. Washington.

sources of supply. It was a serious misfortune that Dr. Field died shortly after completing and reporting upon his laboratory investigations.

THE OYSTER.

INVESTIGATIONS OF OYSTER CULTURE.

The investigation of oyster problems of Great South Bay and Long Island Sound was continued according to the general plan of the year before. The work was begun by Dr. E. P. Churchill, assisted by J. S. Gutsell, but Dr. Churchill left the service in August and thereafter Mr. Gutsell continued it alone. Quantitative collections and studies were made with the aid of the pumping equipment and selective screens developed by the Bureau investigators.

At Great South Bay the plan comprised chiefly an intensive study of the distribution, life, and setting of the oyster larvæ. At fixed stations located over a considerable area of the best oyster grounds in the bay quantitative collections were made as in 1919. In that year it had been found that certain of these stations were almost uniformly superior to others in their yield of larvæ, and that the set at these stations was correspondingly more abundant. The work in 1920 was planned to check up and enlarge on this evidence, to see if the general distribution of larvæ was much the same year after year. Addition to our knowledge in other aspects was, of course, to be included.

Unfortunately the season was a poor one. Oyster larvæ until after mid-July occurred scatteringly, at best in small numbers. The conditions indicated a very light set indeed. The one station which showed decided superiority was not located over oyster beds and offered no opportunity of determining a set. A return visit with inadequate apparatus late in August showed young oyster larvæ in apparently fair abundance and indicated an unusually late spawning and a possible late set.

In accordance with the scarcity of larvæ, a very light set was found in the fall; and corresponding apparently to the late spawning, a set was found in the spring which had not attained sufficient size in the fall to be noticeable. In general these sets were so light as to be commercial only to the extent of having sufficient value to repay shifting.

Thus support was given the hypothesis that a relation can be found between the observable abundance of larvæ and the amount of set, and that consequently a scarcity of larvæ indicates that the great expense of "shelling" should be avoided.

In Long Island Sound, where the oysters spawn later than in Great South Bay, the work was curtailed by the reduced personnel and was limited chiefly to the region between Milford and Bridgeport. Collecting was poor indeed except for a time in August, when moderate numbers of larvæ were obtained, particularly about Bridgeport. Something of a set was later reported there. Thus in the Sound, as in Great South Bay, there was little opportunity that season to obtain other than negative evidence as to the relation of the occurrence of oyster larvæ and the abundance and location of set.

The study, made in cooperation with the Bureau of Chemistry, of the trade-waste problem in its relation to oyster culture was continued. Before he left the Bureau Dr. Churchill performed experiments with various dilutions of standard solutions of chemicals known to occur in or to be discharged into water near oyster beds. He found the larvæ very sensitive, certain chemicals being fatal even in great dilutions. In Bridgeport Harbor late in the season samples were collected for the determination of the distribution of injurious wastes, particularly the heavy metals. As a result of the study of this harbor and of the efforts of the two bureaus, the company, which discharged much the greatest amounts of copper, was persuaded to install an electrolytic recovery process, which has given great promise both as a money saver and as a means of improving harbor conditions.

In June, 1921, the spawning of oysters in Great South Bay has been found to begin in earnest almost a month earlier than in previous years of our experience and to occur at decidedly lower temperatures. The work is being so carried on as to check up the data obtained in 1919, and already the larvæ have been found to be much more widely distributed in good numbers. In addition, as opportunity permits, data are being gathered to test out the hypothesis advanced by Dr. T. C. Nelson that oyster larvæ of the larger sizes keep from being washed to sea by sinking with the ebb tide and rising with the flood.

The study of the development and distribution of the larvæ is of interest to local oystermen and has, it is believed, influenced them in determining the times, places, and extent of planting shells for set. The immediate purpose of the Bureau, it must be understood, is to determine the possibilities of the method of larvæ survey in obtaining best results and effecting economies in planting and in the prevention of costly wastes from planting in seasons when a set is not obtainable. Once a satisfactory demonstration is obtained, the method can be applied in other localities as well as at the places where the experiments have been conducted.

EFFECT OF POLLUTIONS UPON PROPAGATION OF OYSTERS.

Pollutions may affect oyster eggs and larvæ, either directly, by the toxic effect of certain chemicals upon the young oysters, or indirectly, through the exhaustion of the oxygen supply and partial or complete suffocation of the larvæ. The latter aspect of the problem was given attention by Dr. P. H. Mitchell, director of the Woods Hole (Mass.) Fisheries laboratory.

In experiments on the effect of oxygen deprivation on oyster larvæ Dr. Mitchell found that while the embryos are sensitive to diminished oxygen supply a number of factors affect the lower limit of the oxygen content of water compatible with life of the larvæ. The factors noted were: (*a*) The previous history of the eggs from which the larvæ were hatched, for example, ripeness at the time of artificial fertilization and previous exposure to pollution; (*b*) the age of the larvæ; (*c*) the carbon-dioxide content of the water; (*d*) the hydrogen ion concentration of the water; and (*e*) the temperature.

Development of a satisfactory technique for handling such unusually sensitive and perishable material as oyster larvæ, in the

manipulations required for this experiment, consumed much time. Consequently the end of the breeding season for oysters came before there was opportunity to work out the relations of all these factors in an entirely quantitative manner.

Results may be summarized as follows:

With regard to the condition of the eggs, it was observed that embryos from eggs of which 50 per cent or more developed quickly to a free swimming stage withstood deprivation of oxygen better than those from eggs of which only a small proportion developed.

With respect to age, it appeared that younger larvæ endured comparative oxygen deprivation slightly longer than older ones, but the experiments were not conclusive.

It was found that embryos show some effect of oxygen lack in water containing 25 per cent of saturation of oxygen at 24° C. and a markedly increased mortality in 10 per cent of saturation. Killing time varied from 12 to 30 hours according to extent of oxygen depletion. At 28 to 30° C. embryos die much more rapidly from oxygen starvation than at 22 to 24° C.

Carbon dioxide seems to have a toxic effect other than that due to hydrogen ion concentration. Embryos died earlier in water containing sufficient oxygen but excessive CO_2 than in water of the same oxygen content and with the same P_H obtained by adding lactic acid.

Investigation of the effect of pollution on satisfactory development of eggs in gonads was also conducted. Results showed that from oysters, kept 7 to 10 days in water polluted so as to markedly lower its oxygen content, only an abnormally small proportion of eggs could be made to develop after artificial fertilization, conducted according to standardized technique, and that the embryos so obtained did not develop as far as controls.

An incidental observation proved of considerable interest. Oysters which had been in cold storage 24 days for the purpose of studying greening were found to have very full gonads. Eggs fertilized with sperm from some of the same lot of oysters developed satisfactorily, and many of the embryos reached the primitive shell stage. Some of them, indeed, were used in oxygen-requirement tests.

Observations on the cause of copper greening confirmed previous conclusions by showing that not only the amount of copper obtainable by the oysters, but also conditions of habitat determine whether or not visible green spots occur. Marked appearance of greenness after one or more weeks in cold storage was observed. It has been twice noted that with gonads filled a smaller proportion of oysters become green during storage than in other conditions. Two-year-old spent oysters, set and reared in Wareham River, did not become green during four weeks in cold storage. This is in contrast to oysters which at some time during their previous history have been in waters known to produce greenness (near Bridgeport and New Haven).

Experiments both in the laboratory and in the field indicated a positive influence of diminished oxygen supply in causing the appearance of green spots. Repeated observations of marked greening of oysters in polluted tanks of sea water were also made, thus confirming the similar results obtained during the previous summer in the Seekonk River.

FRESH-WATER MUSSELS.

PROPAGATION OF MUSSELS.

The Fisheries biological station at Fairport, Iowa, continued its practical propagation of fresh-water mussels in the Mississippi drainage at Lake Pepin and Lake Pokegama, Minn.; at New Boston, Oquawka, and Dallas City, Ill.; at Fairport, Iowa; at Hannibal and Clarksville, Mo.; and in cooperation with rescue crews along the Mississippi in Wisconsin and Minnesota. The total number of glochidia infected upon fish and liberated in public waters during the year was approximately 648,445,000, including 478,705,000 infected upon rescued fish by cooperative agents working in connection with rescue crews of the division of fish culture.

With a view to demonstrating the possibilities of mussel propagation in connection with the rescuing of food fishes, the National Association of Button Manufacturers offered to cooperate with the Bureau by providing men to accompany each rescue crew on the upper river and to inoculate all fishes with the glochidia of the Lake Pepin mucket, the most important of the local mussels. Seven agents of the button manufacturers cooperated with seven crews working under the direction of Supt. Culler, of the Homer (Minn.) station, and during October and November inoculated nearly 6,000,000 fish with glochidia.

The localities in which the work was done and the number of fish subjected to infection in each locality were as follows:

Lynxville, Wis	2,025,200
Genoa, Wis	1,214,900
Ferryville, Wis	907,340
Fountain City, Wis	86,510
North McGregor, Iowa	676,100
Bellevue, Iowa	931,500
Total	5,841,550

Material cooperation of this nature by an association of business men is a source of gratification to the Bureau, not only as evidence of a cordial spirit, but as evidence of faith in the practical value of the service rendered in the propagation of river mussels.

PROTECTION OF MUSSELS.

A prominent feature of the work of the Fairport station for several years has been the part which it has played in bringing about a strong sentiment for the protection of fresh-water mussels and the cooperation it has extended to the several States in giving aid, when solicited, in selecting the areas for closure to mussel fishing. Additional closures of streams or parts of streams has followed the beginning made in the past by Minnesota and Wisconsin. Minnesota in April closed for a period of five years parts of the Minnesota River, and the entire Cannon and Straight Rivers. Iowa, in the same month, closed for a similar period parts of the Iowa, Cedar, and Des Moines Rivers, and the entire Shellrock River.

MUSSEL SURVEY IN UPPER MISSISSIPPI RIVER.

During the months of July and August, 1920, the Bureau of Fisheries made a study and appraisal of the mussel resources in a portion of the upper Mississippi River, beginning at a point about 5 miles above Red Wing, Minn., and extending down through Lake Pepin, a distance of about 80 miles, to Lamoille, Minn. The work was undertaken with reference to recent administrative action on the part of the States of Wisconsin and Minnesota providing for the closure of certain areas for the protection of the fresh-water mussels while permitting the fishery to continue in alternate open areas. The data acquired in this investigation are expected to establish a basis for comparison of conditions before and after a period of protection. The investigation was conducted under the Fairport biological station by Dr. N. M. Grier, with two assistants. Observations were made in five open and five closed areas.

Many data were secured regarding the depletion of formerly productive areas of mussel fishery, the diminution in abundance of mussels in different beds being attributed variously to the indirect effects of the construction of wing dams as aids to navigation, to excessive fishery, and perhaps in some cases to the dumping of rubbish in the river in the vicinity of cities.

The information gained will serve also as an aid to the Bureau in the conduct of mussel propagation for the rehabilitation of depleted and protected areas.

EXPERIMENTS RELATING TO MUSSEL PROPAGATION.

Experiments in retaining in inclosures fish artificially infected with glochidia of the Lake Pepin mucket, *Lampsilis luteola*, have been continued in Lake Pepin by Roy S. Corwin, scientific assistant. It was found in certain experiments that pike perch infected as late as August 19 carried glochidia until the following May, and that mussels during the second year of growth will thrive in an inclosure with a density of 18 mussels to the square foot. Third-year mussels with eight to the square foot flourished and showed an average increase in length of more than 100 per cent in one year.

Artificial infections of the Lake Pepin mucket on pike perch retained in a fine-meshed inclosure in the lake yielded an average of 833 juvenile mussels per fish. Assuming that these fish bore the usual infection of about 3,000 glochidia per fish, the yield of young mussels was 27.4 per cent. This is a much higher percentage than has ever been assumed to result from practical operations in artificial propagation of mussels.

Dr. L. B. Arey continued his study of the encystment of the glochidia of the fresh-water mussel. It has been established that the tactile response of the glochidium alone is adequate to insure attachment. The view that glochidia regularly attached to the host through a chemical activation by blood, derived from gill hemorrhages, appears to be untenable. Cyst formation is not initiated or controlled by any vital influence of the glochidium. It has been induced by the application of tiny metallic clips to a gill filament.

INVESTIGATIONS IN THE KENTUCKY RIVER.

Prior to 1919 the Kentucky River was an unworked and practically unknown mussel stream. In the summer and autumn of 1919 and the summer of 1920 the upper part of the river was investigated by Ernest Danglade, temporary assistant. Preliminary tests were made in the summer of 1919 which indicated that good marketable shells were to be found in the headwaters, and encouragement was offered to various people who had expressed a desire to engage in mussel fishing. As a result, by the middle of July, 1919, two mussel camps were established in the upper courses.

The river was examined from near its source down to Beattyville, Ky., below which place the stream contains many locks and dams and is unsuitable for mussel fishing. In the upper parts of the stream, in the north and middle forks, numerous but small beds were encountered. Fourteen were investigated and are described in some detail in a report on file with the Bureau. Forty species of mussels were obtained, of which 22 have commercial value, the mucket being the most important. Upper Twin Shoals is remarkable for the abundance of young muckets.

THE BIOLOGICAL LABORATORIES.

The Woods Hole (Mass.) laboratory, Dr. P. H. Mitchell, director, was in operation with a limited staff during the summer of 1920. Previous mention has been made of the investigation relating to oysters and the preparation of commercial gelatins from seaweeds. Prof. Edwin Linton continued investigations of the food and parasites of fishes, and Prof. William W. Browne was engaged in completing his report upon the nature and causes of the reddening of salt fish. Because of the unavoidable limitation of the Bureau's activities, it was found impracticable to open the laboratory for the summer of 1921.

Beaufort (N. C.) laboratory has been virtually closed during nearly the entire fiscal year. Since the director, R. L. Barney, was necessarily transferred early in the year to another station, the laboratory has been without scientific direction. Mr. Barney has, however, completed a general report on the natural history and culture of the diamond-back terrapin, embodying the information available from observations and experiments as relating to growth and reproduction of wild and domestic stock, care of young and adults, feeding, housing, and hybridization. Further attention has been given to the study of the bacterial disease which has been the only serious disease affecting winter-fed terrapin. Under the superintendence of Charles Hatsel, terrapin experiments have been continued, the grounds of the station have been kept in good condition, and the buildings in such repair as was possible with the available funds.

At the Fairport (Iowa) biological station the new laboratory building was completed and occupied early in September, and shortly thereafter R. L. Barney was appointed director of the station. In response to an outside demand, the laboratory building was formally dedicated October 7. A large number of prominent persons, including scientists representing the leading universities of the country,

participated both in the exercises of dedication and in the conference on the following day, which gave consideration to the natural resources of interior waters and the possibilities of their utilization and conservation.

The interest manifested in that conference and the demonstration it afforded of the possibility of bringing about better cooperation in the conservation of aquatic resources led to a call by the Secretary of Commerce of a conference of more extended duration to meet at the station June 8 to 10, 1921. On this occasion there were in attendance about 125 persons, including biologists, chemists, sanitarians, fishermen, manufacturers, fish-culturists, game wardens, engineers, and others. During the three days of the conference there was free and informal discussion related to the three major topics suggested in the call for the gathering, viz: The depletion of aquatic resources, causes, and remedial measures; the value of swamp and shore areas and their best utilization; and a constructive program of conservation. Interest was sustained throughout, and the conference adjourned only after recording a request that a similar meeting be called the following year.

The special activities of the Fairport station have been treated under several preceding heads; investigation of the paddlefish, fish-cultural experiment work, studies of fish disease, survey of selected areas in the Mississippi River, and fresh-water mussels. The station frequently also performs services of value to fishing clubs, private hatcheries, and individual owners of lakes and ponds, furnishing advice regarding the stocking and control of ponds and aiding in the solution of such troublesome conditions as may arise. The value of these advisory services is founded upon the scientific research conducted at the station and the experience gained in propagating and rearing fish under conditions of control.

The Key West (Fla.) biological station has been without a director from the beginning of the fiscal year until within a few days of the close of the year, when the services of a competent scientist were secured for a temporary period. During the greater part of the year the station has been in the hands of a caretaker. No further constructions have been undertaken, but the grounds have been suitably fenced for protection, and some plantings of appropriate vegetation have been made.

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