NEW METHODS OF TRANSPORTING EGGS AND FISH

By Walter S. Kincaid

General Superintendent of State Fish Hatcheries, Denver, Colo.

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

National Oceanic and Atmospheric Administration

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NEW METHODS OF TRANSPORTING EGGS AND FISH.

By WALTER S. KINCAID,
General Superintendent of State Fish Hatcheries, Denver, Colo.

HANDLING GREEN EGGS OF TROUT.

This method consists of packing the eggs in a case containing 4 trays, each about 8 by 20 inches, each tray containing 10 cells about 4 inches square, or 40 cells in each crate, the bottom of each tray covered with brass screen cloth to allow water to drain off and also to prevent rust. Each cell carries 4,000 green trout eggs, and there are thus 160,000 in the entire crate. In packing the eggs in the cells, make a nest of moss in each cell; place cloth down firmly in cell, leaving top of cell open; pour just 4,000 eggs in cell, fold cloth carefully over them, and then fill cell to top with moss. Before placing trays in case make cushion of about one-half an inch of moss in bottom of case. After placing trays in case set perforated ice tray on top of eggs, fill ice tray with chopped ice, and the eggs are ready for transportation either by pack horse, wagon, or rail.

This crate when packed ready for shipping weighs 81 pounds.

The advantage claimed for this method is the economy in weight and space in handling green trout eggs successfully either on pack horses, by wagon, or by rail.

HANDLING EYED TROUT EGGS.

This method consists in removing the cell trays and using the flat tray before described.

What is claimed for this method is again the economy in weight and space. The case being canvas-lined and with heavy felt cloth attached to the zinc inner lining, and having an air space between that and the egg trays, insures the eggs against heat or cold while in transit when properly iced and cared for.

This case when packed ready for transportation weighs about 80 pounds.

APPLIANCE FOR AERATING WATER IN TRANSPORTATION.

This device consists in attachments to the bottom of the can, one on each side about one-half inch thick, causing the can to rock continually from side to side with the slightest motion of the car, the water in the can assisting in the motion after once started, thus aerating itself without the necessity of an assistant while the train is in motion.

We claim that this device is very effective, simple, and inexpensive.

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FISHWAYS

By H. von Bayer, C. E.

Architect and Engineer, United States Bureau of Fisheries

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

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FISHWAYS.

By H. VON BAYER, C. E.,
Architect and Engineer, United States Bureau of Fisheries.

GENERAL PRINCIPLES OF FISHWAY CONSTRUCTION.

With the development in late years of water power for commercial enterprises on an economic basis, with the construction of canals for cheapening the transportation of freight, with the proposition of irrigating the otherwise waste lands of the country—all of which improvements call for the erection of dams across our rivers—the steady decrease of fish life in the waters above said dams or other obstructions has become more and more apparent, and the question has presented itself how to enable the fish to ascend to the headwaters of rivers in order to reach their spawning grounds for the propagation of their kind or to follow their migratory habits in search of food as heretofore. This question is being best met by the construction of suitable fishways.

The underlying principle in the construction of fishways is the retardation of the current velocity of a waterfall so as to enable fish to surmount it. Innumerable devices with that end in view have been invented and proved more or less successful. Certain physical conditions in the location and a proper method of construction are the important factors.

Of the physical conditions, the two principal ones are (1) accessibility of the fishway free from disturbance, its outlet being located in a pool at the bottom of the falls where fish would naturally pass in ascending the river, and (2) an abundant discharge of water through the outlet so as to attract the fish. It is to be noted that fish as a rule do not ascend rivers at low-water stage, but between mean and high water, and preferably during sunshine and warm weather.

In style of construction fishways may be classed in four systems:

I. The inclined plane system, in which a series of baffle or deflecting plates are so arranged in an inclined flume as to cause the water to follow in its descent a long sinuous route.

II. The pool and fall or step system, in which the water is brought down to a lower level by a series of short falls with intervening pools.

III. The counter current system, in which the descending volume of water is being checked by meeting a current opposing it at certain intervals.

IV. The lock and gate system, in which a higher or lower level is reached through one or more locks operated by gates.

In all four systems of fishways certain general rules governing the construction must be observed.

1. The slope of a fishway built on the inclined plane system should not be steeper than 1 foot vertical to 10 feet horizontal; the pool and fall system, as well as the counter current system, should not have a slope of more than 1 vertical to 4 horizontal, so as to insure a current velocity of not exceeding 10 feet per second in any portion of the fishway. The lock and gate system deals merely with a vertical lift. The width of a fishway somewhat governs the slope, and the wider the fishway the more gradual the slope should be.

2. The available volume of water and the size of the fish must be considered in the dimensions adopted for the fishway; small fish, like herring, bass, trout, etc., may not require over 6 inches in the clear at the narrowest points or openings in the fishway, while for large fish, like shad, rockfish, salmon, etc., the clearance spaces should not be less than 9 inches in any direction.

3. A fishway for small fish does not need to be more than 2 feet wide by about 1 foot deep, while that for large fish ought to have a least width of 4 feet with a depth correspondingly large.

4. Plenty of light should be admitted in a fishway, both for maintaining therein the natural conditions of the water, and in order that the interior may easily be inspected and any foreign matter removed.

5. A fishway in all its parts should, by the action of the current of water passing through it, be as nearly as possible self-cleaning of all sand, gravel, mud, and rubbish.

6. The water supply of a fishway should be ample and the same, or nearly so, at both ordinary high and low water stages, avoiding thereby any regulating gates or other devices calling for the services of an attendant.

7. The top and sides of a fishway should be above ordinary high water.

8. The fishway should be built very strong and be well protected against the destructive effects of freshets, drift logs, ice, etc.

9. The intake and outlet should be well submerged and the former protected against floating débris, etc., by a suitable grating.

The location of a fishway must be such that ascending fish will not be alarmed and driven off by disturbance from boats, fishermen, etc.

The material of fishways may be wood, stone, concrete, or iron, depending upon the construction of the dam, its size, the topography and nature of the site, the labor and material at hand, and the funds available.

VARIOUS FISHWAY DESIGNS.

I. INCLINED PLANE SYSTEM.

Figures 1 to 11 show a more or less sinuous course for the water current down an inclined plane, to retard the current velocity.

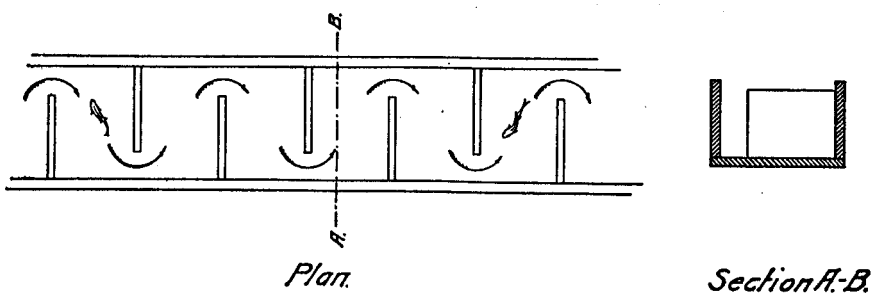

FIG. 1.—Roberts.

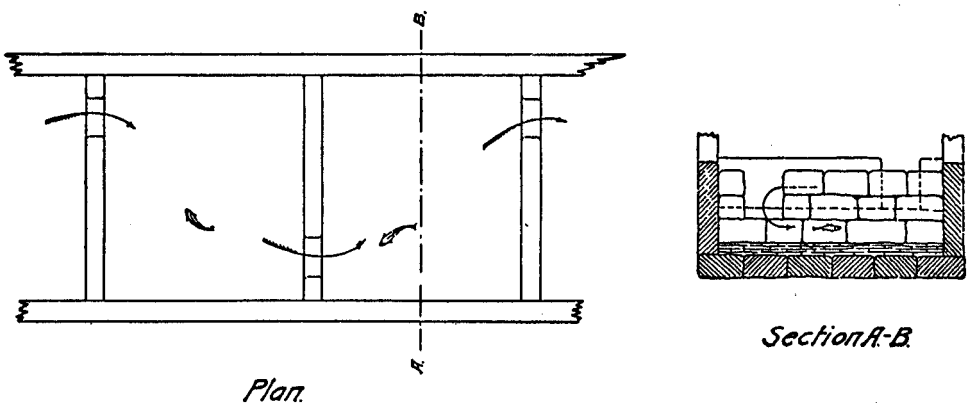

FIG. 2.—Smith.

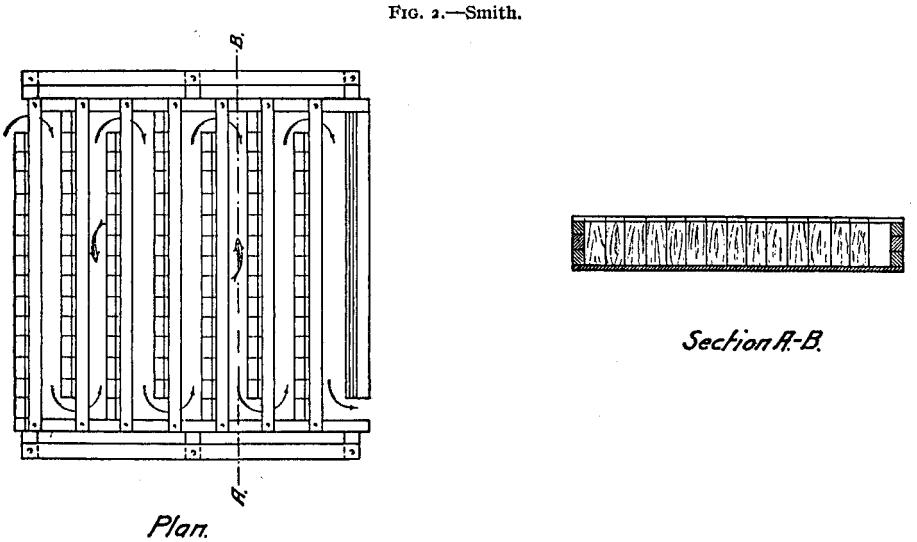

FIG. 3.—Wheeler.

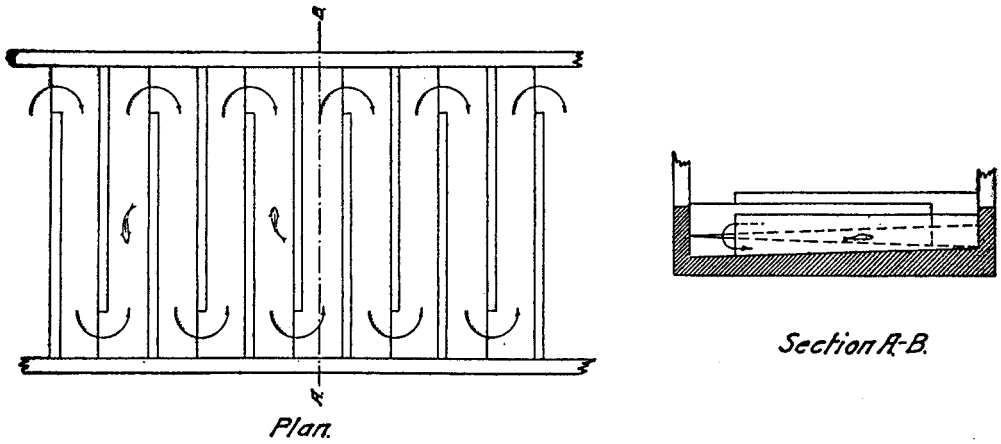

FIG. 4.—Steck.

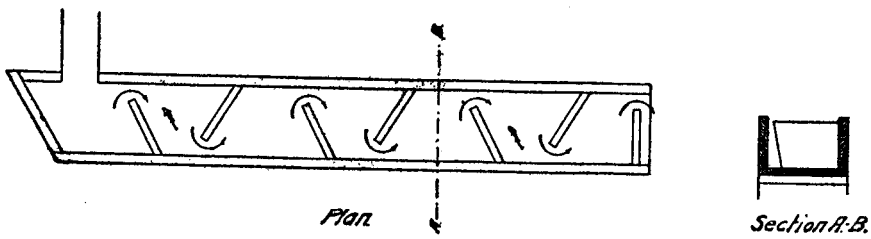

FIG. 5.—Foster.

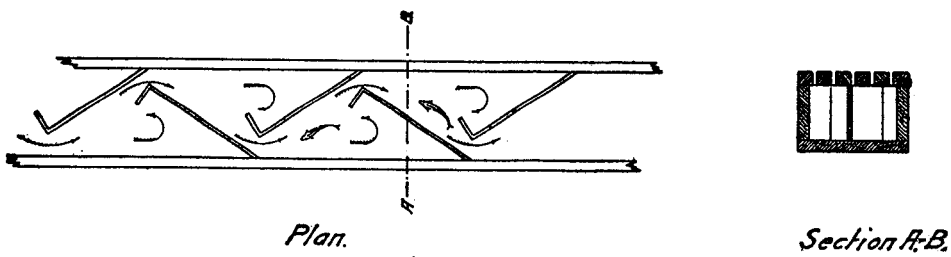

FIG. 6.—Rogers.

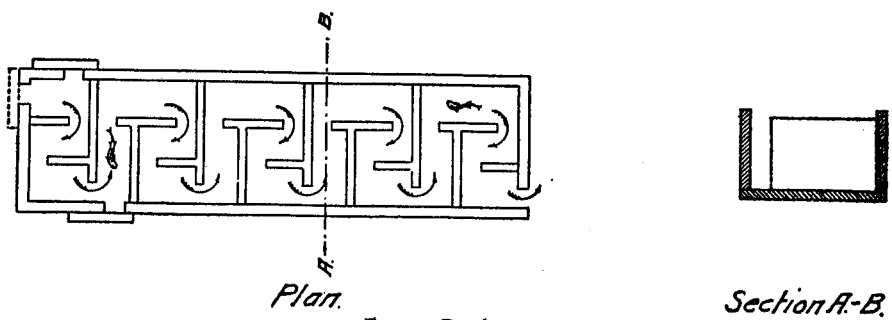

FIG. 7.—Brackett.

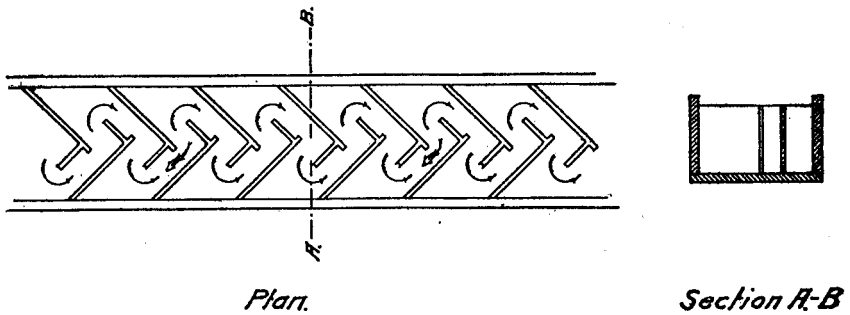

FIG. 8.—Swazey.

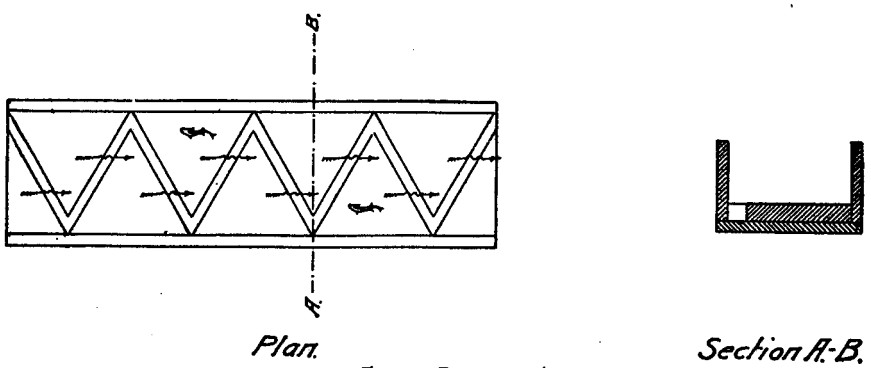

FIG. 9.—Brewer.

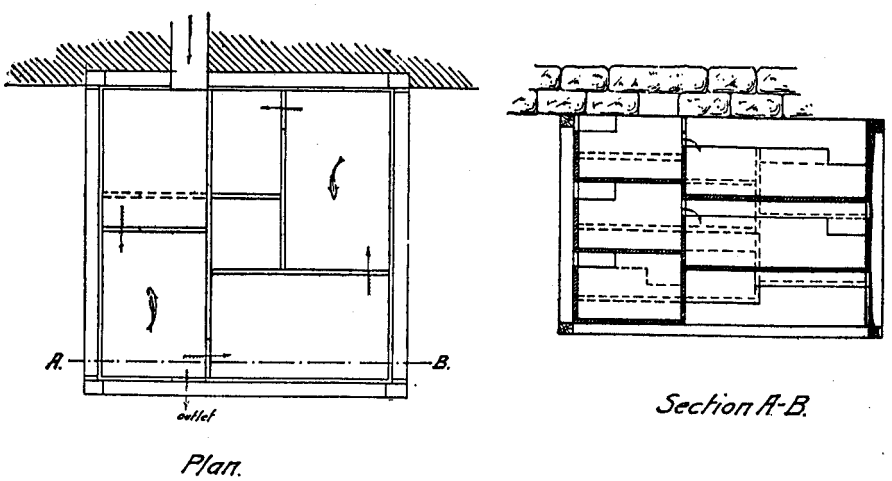

FIG. 10.—Shaw.

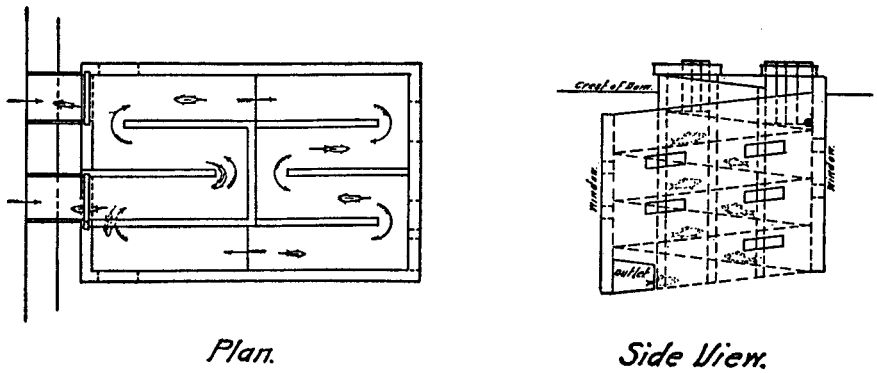

FIG. 11.—Atkins.

Under system 1 may be reckoned also the fishways for young eels, which consist merely of an inclined pipe from 4 to 6 inches in diameter, or a narrow flume, which is filled with loose gravel and pebbles, with fascines of brush and saplings, or with a mixture of both, through which the young eels can readily pass.

II. THE POOL AND FALL, OR STEP SYSTEM.

Figures 12 to 14 show the current carried down an incline broken by steps into a number of pools of relatively still water.

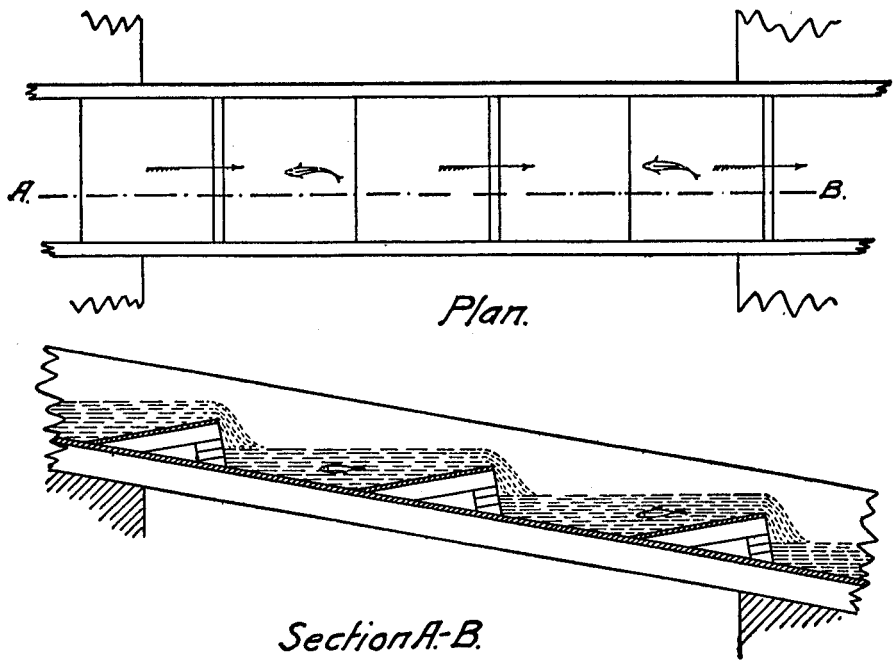

FIG. 12.—Richardson

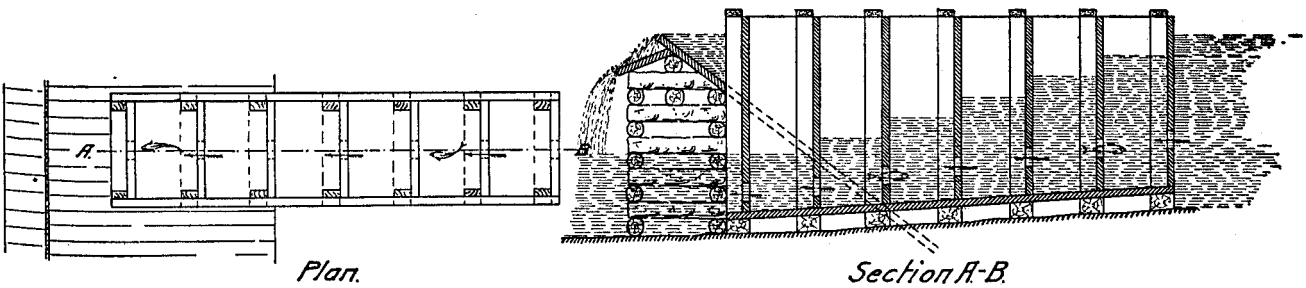

FIG. 13.—Hockin.

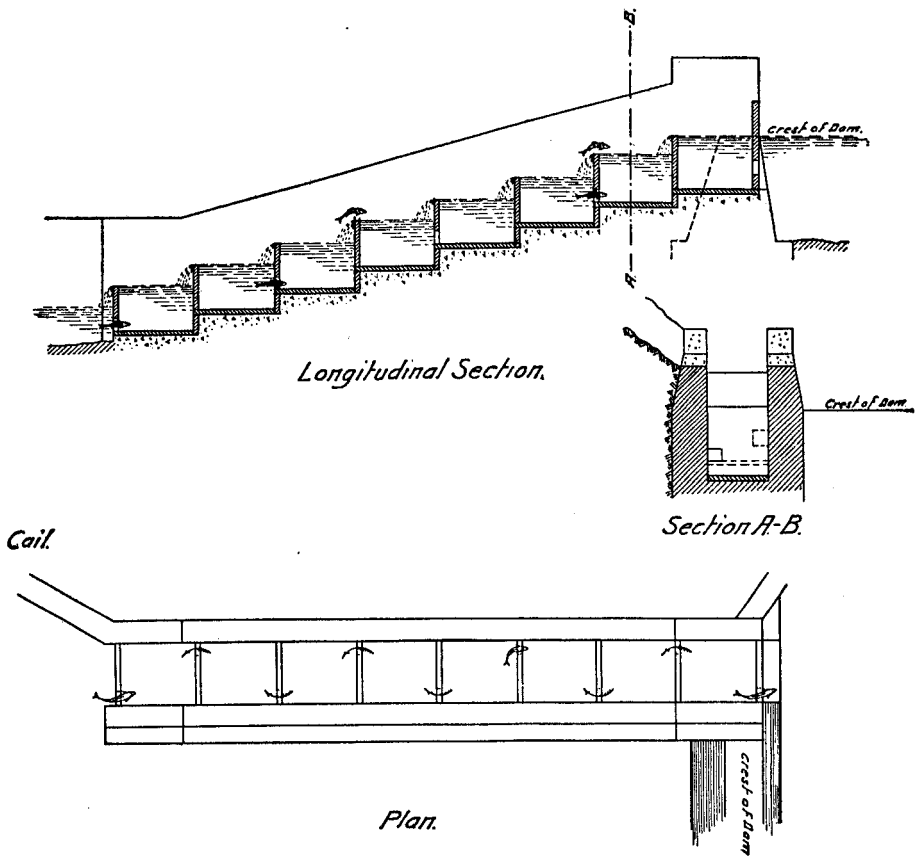

FIG. 14.—Cail.

III. THE COUNTERCURRENT SYSTEM.

Figures 15 to 17 show the action of a twofold current, the parts opposing each other and thereby retarding the velocity of the two combined.

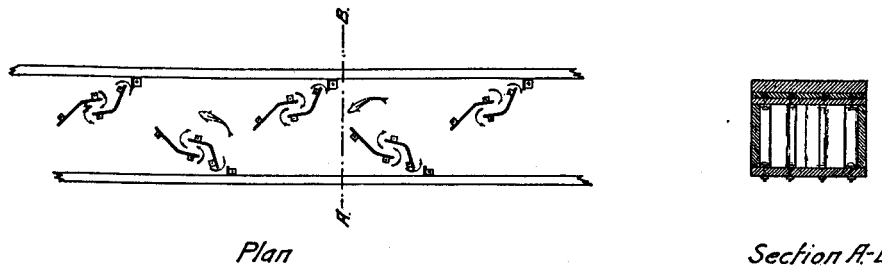

FIG. 15.—McDonald.

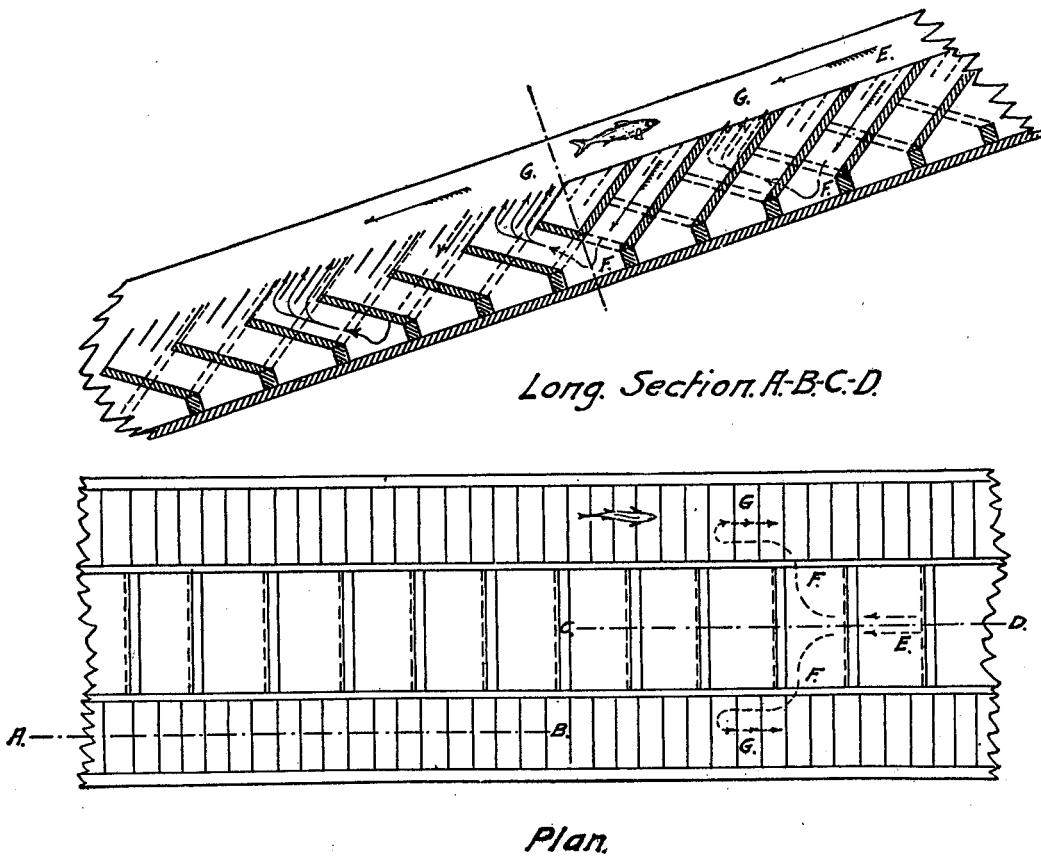

FIG. 16.—McDonald.

In this fishway the water passes through a series of centrally located buckets inclined downstream into another series of buckets located at either side of the fishway, provided on top with deflecting plates, whence it issues in an upstream direction, opposing the down current, as shown by arrows. The fishway may be protected by an iron grating over which the fish ascend.

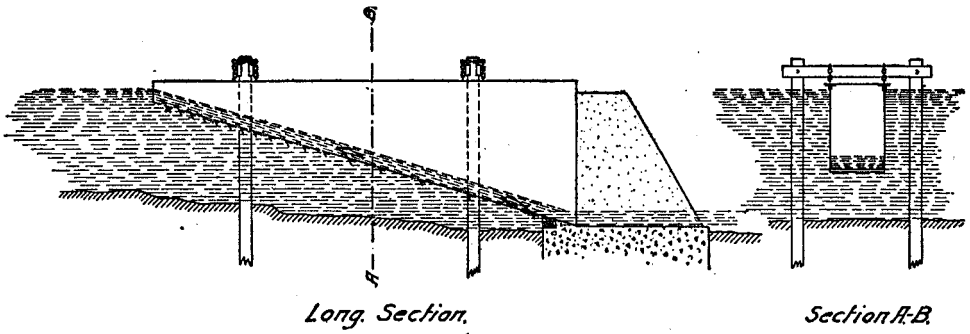

FIG. 17.—Caméré.

This fishway consists of a suitable chute submerged in the water as shown, and is provided with a series of slits in the bottom through which a current of water enters under a static pressure opposing the descending current of water in said chute. The design was later on improved by adding to the slits in the bottom a corresponding number of slits in the sides.

IV. LOCK AND GATE SYSTEM.

Figures 18 and 19 show the admission of a body of water by gates into a lock chamber and out of it to a lower level, whereby fish are being lifted vertically in ascending a stream.

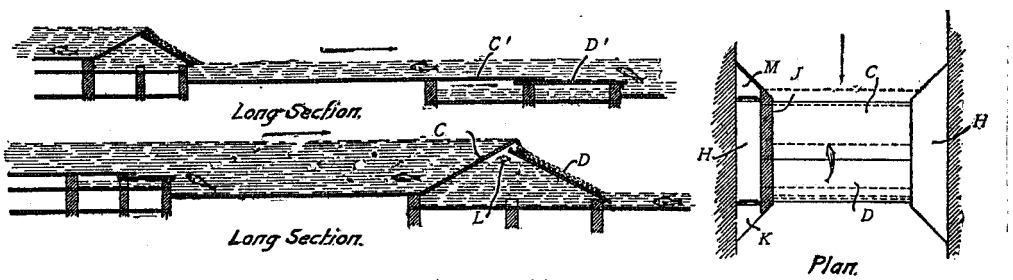

FIG. 18.—Kirk.

Process: If valve M is opened chamber HH will fill with water, and, by means of passageways under abutment J, the water will pass into chamber L and force gates CD to rise. The gates will rise until the water reaches an overflow opening at L. If valve M is closed and K opened, the water under the gates escapes and they will go down to position C' D'. Making the lower set of gates double the height of the upper set and arranging for an automatic alternate rising and lowering of the gates at certain intervals of time, the fish are enabled to pass upstream through these locks thus forming.

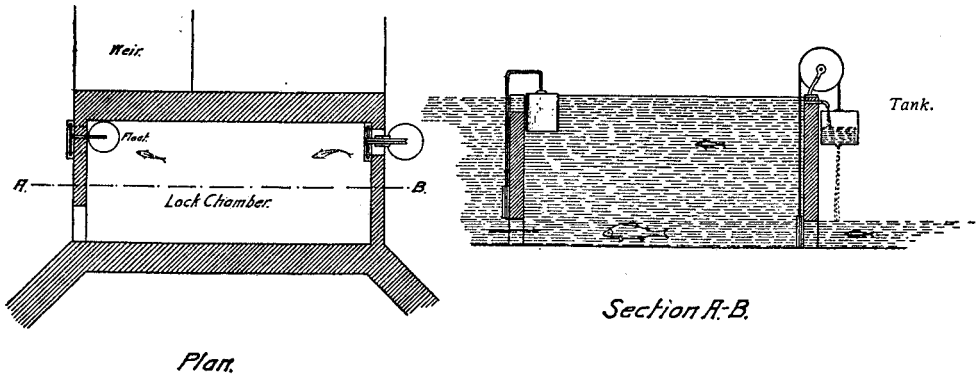

FIG. 19.—Recken.

Here the water chamber is shown full, and a water tank at the right is filling. When latter is full it will descend of its own weight and raise the gate, to which it is attached by means of a cable over a grooved wheel, allowing lock chamber to empty to lower level. When lock chamber is empty a float and gate in the upper partition, rigidly connected together, will be down; water tank being cut off from supply will also become empty, the water dripping gradually out of the bottom opening as shown. Supply through a notch in upper partition will begin to fill lock chamber and lift float and gate, thus repeating the process described.

THE IMPROVED CAIL FISHWAY.

The "Improved Cail fishway" (fig. 20) is a combination of the inclined plane system with the pool and fall or step system. It consists of a series of compartments arranged in steps and separated by a number of cross partitions, which are provided with suitable orifices at the bottom, alternating successively from side to side, so as to allow the fish, according to their individual habits, to ascend the fishway by either leaping over the small waterfalls over the cross partitions or by darting through the orifices, at the same time enabling them to rest in the compartments in comparatively still water.

The present improved Cail fishway embodies certain improvements made by B. M. Hoecht, of Germany, who built at Hameln, on the lower Weser, a large fishway on the Cail principle, constructing it of masonry and concrete, with a fall of about 1 foot in 8 feet. The design was brought to another form by the present author, and is now the pattern recommended by the United States Bureau of Fisheries. Its construction embraces all requirements for a fishway, as enumerated above, viz:

1. The slope of the fishway as per figure 20 is in a proportion of 1 vertical to 4 horizontal, the fall from compartment to compartment is 1 foot 6 inches, and the greatest velocity of the current through the orifices is less than 6 feet per second.

NOTE.—$V=m\sqrt{2gH}=0.57 \times 8 \times 1.23=5.6$ feet per second. V is the velocity in feet per second; g, acceleration per second of a falling body, 32.16 feet; H, head of water column proper, 1.5 feet; m, coefficient for contraction obtained by actual experiment, 0.57.

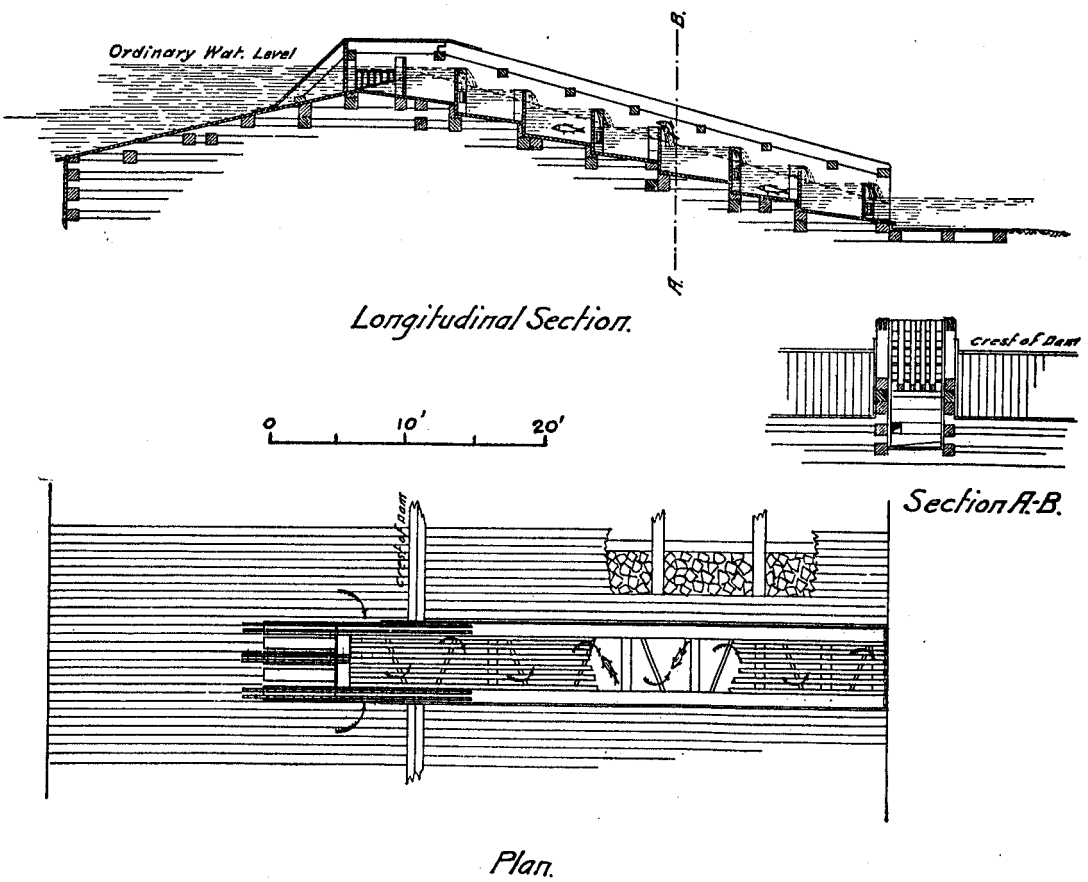

FIG. 20.—Improved Cail fishway.

2. The fishway proper is 4 feet wide inside, with orifices in the cross partitions varying from 12 inches by 12 inches at the outlet to 18 inches by 18 inches in the uppermost cross partition near the inlet, allowing fish of the size of shad, rockfish, salmon, etc., as well as smaller fish, to pass through.

3. The mean depth of water in the compartments is 3 feet.

4. Plenty of light is admitted through the open spaces between the protecting timbers on top, thus allowing ready inspection and easy removal of any débris lodging in the fishway.

5. The cross partitions are set at a slight angle to the axis of the fishway, and the floor of the fishway is slightly slanting, to bring the orifices in the lower ends of the cross partitions and cause a current in the angles formed between the cross partitions and the floor, thus automatically removing any accumulation of sand, gravel, mud, and rubbish.

6. The crest of the uppermost cross partition is at an elevation equal to that of ordinary high water, so as to keep the water supply in the fishway nearly the same at ordinary and high-water stage, avoiding thereby the need of any regulating gates.

7. The top and sides of the fishway are kept well above ordinary high water, to prevent the flooding of the fishway and possible injury.

8. Heavy timbers strongly bolted together are used in the construction of the sides and top of the fishway when built of wood, with strong fender pieces above the intake secured to the dam with heavy iron straps, to protect it against drift ice and logs during freshets.

9. Both the intake and the outlet are well submerged below mean water level, and the intake is protected against floating débris, etc., by a substantial iron grating.

The necessary volume of water for supplying a fishway of the dimensions as described here should not be less than 8 cubic feet per second.

The construction of the fishway is alike adapted to wood, masonry, or concrete, and it may follow either a straight line or have angles and returns, as the local conditions may require. The construction is applicable to the various forms of existing dams and natural waterfalls. The cost of construction of a fishway built of timber as per illustration under ordinary conditions will be about $1,000.

Fishways of this design have proved quite efficient and have been built in late years at various dams in the Susquehanna River and its tributaries; others, built of concrete, were constructed at a number of the large electric-light and power dams in several of the states. (See fig. 21, p. 1056–1057.)

REGULATIONS FOR THE CONSTRUCTION OF DAMS AND FISHWAYS.

The United States Government does not exercise any jurisdiction over waters not navigable, the construction of dams and fishways in these waters being regulated through the state laws. Most of the state legislatures have enacted such laws and fixed certain penalties for violation of the same. For navigable waters, an act of Congress approved June 21, 1906, to regulate the construction of dams provides as follows:

SECTION 1. That when, hereafter, authority is granted by Congress to any persons to construct and maintain a dam for water power or other purposes across any of the navigable waters of the United States, such dam shall not be built or commenced until the plans and specifications for its construction, together with such drawings of the proposed construction and such map of the proposed location as may be required for a full understanding of the subject, have been submitted to the Secretary of War and Chief of Engineers for their approval. * * * *Provided*, That in approving said plans and location such conditions and stipulations may be imposed as the Chief of Engineers and the Secretary of War may deem necessary to protect the present and future interests of the United States, which may include the condition that such persons shall construct, maintain, and operate, without expense to the United States, in connection with said dam and appurtenant works, a lock or locks, booms, sluices, or any other structures. * * *

SEC. 3. That the person, company, or corporation building, maintaining, or operating any dam and appurtenant works, under the provisions of this act, shall be liable for any damage that may be inflicted thereby upon private property, either by overflow or otherwise. The persons owning or operating any such dam shall maintain, at their own expense, such lights and other signals thereon and such fishways as the Secretary of Commerce and Labor shall prescribe.

SEC. 4. That all rights acquired under this act shall cease and be determined if the person, company, or corporation acquiring such rights shall at any time fail to comply with any of the provisions and requirements of the act, or with any of the stipulations and conditions that may be prescribed as aforesaid by the Chief of Engineers and the Secretary of War.

SEC. 5. That any persons who shall fail or refuse to comply with the lawful order of the Secretary of War and Chief of Engineers, made in accordance with the provisions of this act, shall be deemed guilty of a violation of this act, and any persons who shall be guilty of a violation of this act shall be deemed guilty of a misdemeanor and on conviction thereof shall be punished by a fine not exceeding five thousand dollars. * * *

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[a] Since this writing a most interesting article, "La genèse d'une échelle à poissons nouvelle," by G. Denil, has appeared in the Bulletin Populaire de la Pisciculture, no. 9, 1909, p. 155–183, Paris, 1909.

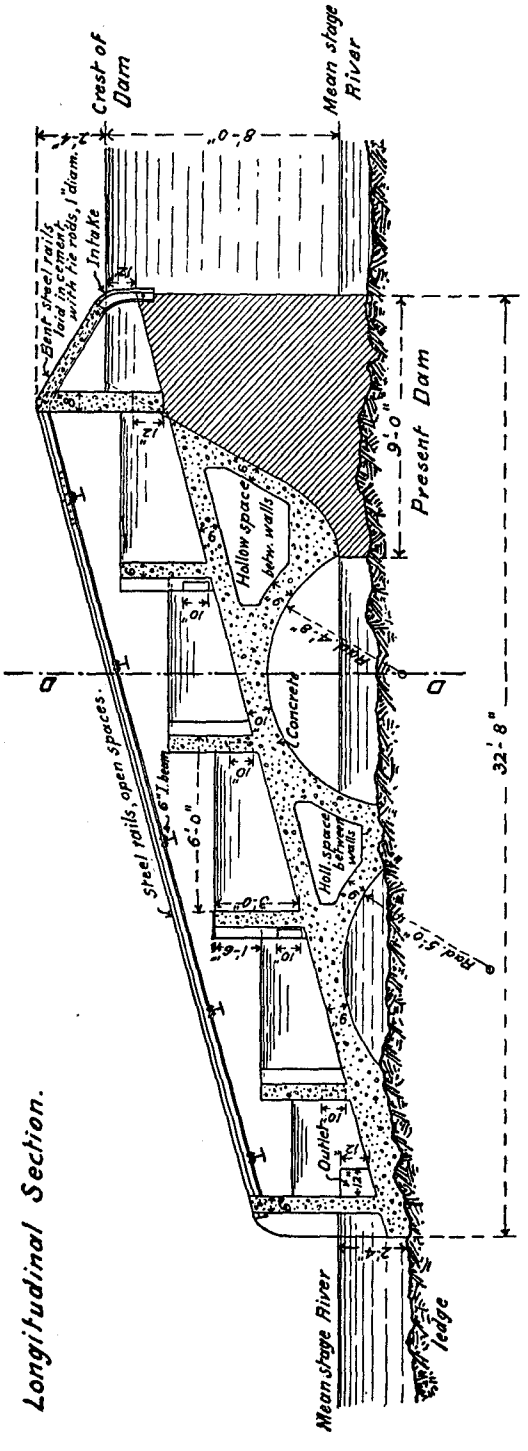

FIG. 21.—Adaptation of the improved Cail fishway, constructed of concrete. Designed by H. von Bayer for the Shenandoah River, in Virginia.

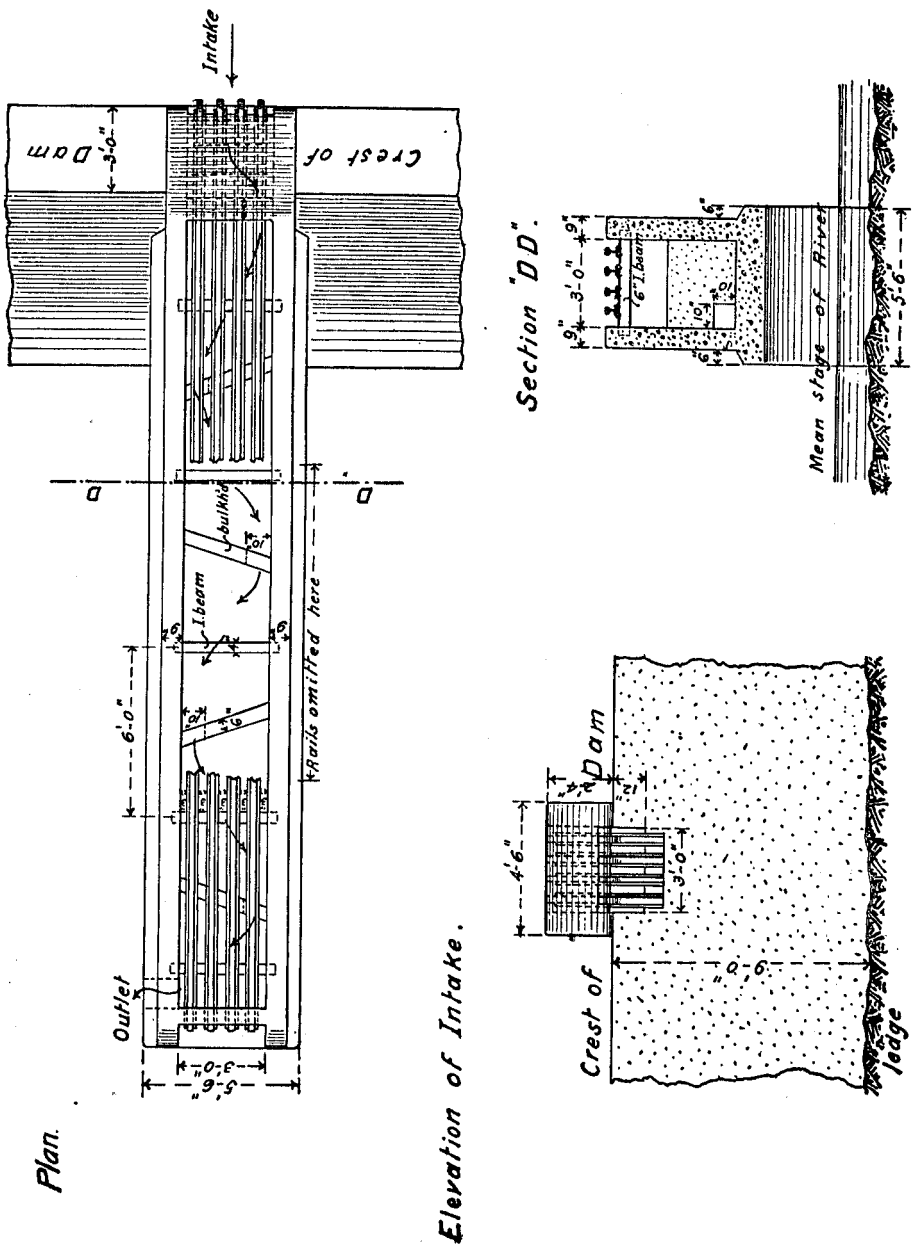

FIG. 21.—Continued.

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A PLEA FOR OBSERVATION OF THE HABITS OF FISHES AND AGAINST UNDUE GENERALIZATION

By Theodore Gill, Ph. D., LL. D.

Honorary Associate in Zoology, Smithsonian Institution

Address before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

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A PLEA FOR OBSERVATION OF THE HABITS OF FISHES AND AGAINST UNDUE GENERALIZATION.

By THEODORE GILL, Ph. D., LL. D.,
Honorary Associate in Zoology, Smithsonian Institution.

I have been requested to address the International Fishery Congress, but on account of the extensive programme provided for it brevity will be recognized as a virtue if not demanded as a requisite. I shall therefore confine my remarks to a plea for the presentation of much wanted information respecting the habits of fishes in general, but especially those which are the objects of pisciculture. Indeed such knowledge is a necessary prerequisite for successful pisciculture and should be made public in the interests of industry as well as of science. Nevertheless, essentials of some of our most esteemed fishes are scarcely known beyond a very small circle of pisciculturists. The crappie of America (*Pomoxis sparoides*) is a notable case. It is one of our best fresh-water fishes, but the accessible accounts of its habits are extremely meager and no account has been published of its sexual intercourse, the preparation of a nest, or the care of the eggs and young by the parent fish.

Too much care can not be given to the detailed observation of the economy of any fish, for differences between related species may exist which might be least foreseen. For instance, two silurids occur in Europe which are so near each other that they have been long nominally confounded; they are the common wels of central and eastern Europe and the glanis of Greece. Notwithstanding their great morphological similarity, they differ remarkably in their habits, for the wels takes no care of its eggs, while the male of the glanis exercises paternal supervision for a prolonged period. Why the statement that the two have been nominally confounded has been made will be explained later. One more example of contrast may be cited. One of the best known and most generally published accounts of parental care among fishes is that one, three quarters of a century ago (1828), attributed to the hassars (*Callichthys* or *Hoplosternum*) by Dr. John Hancock. Yet the species of a related genus (*Corydoras*) have quite different habits in general as well as in courtship and oviposition; no care is exercised over the eggs by either parent.

Fishes that do exercise parental care differ as to the manner in which it is shown and the length of time it is maintained. Most, if not all, of our centrarchids, for instance, protect their eggs, but there is a difference between species or genera otherwise. It was first declared some years ago (in 1903), by Prof. Jacob Reighard, that the black bass continues the care begun with the nest and new-laid eggs till the young fishes have acquired a considerable size, while sunfishes of the genera *Eupomotis* and *Lepomis* discontinue care after the eggs have been hatched.

Undue generalization has been exercised also in statements respecting the relative sizes of the sexes of fishes. A celebrated ichthyologist, in an "Introduction to the Study of Fishes," positively declared that "it appears that in all teleosteous fishes the female is larger than the male," and yet there are many exceptions to this statement. Indeed, in most fishes whose males are differentiated by marked secondary characters, so far as known the male is larger than the female. Even in some of our common cyprinids such is the case; the species of *Semotilus*, often miscalled "chub" or "horned dace," are examples. The males of those species are stone-rollers, thereby preparing a nest for the eggs. An undue generalization might be extended from the examples for it might be assumed that there was coordination between the size and the care-taking function. In contrast, however, the lumpsucker (*Cyclopterus*) confronts us; in this case the male is much smaller than the female. In fact, we are in much need of definite information as to relative sizes of fishes generally.

A common African fish, the bolti (*Tilapia nilotica*) of Egypt, has males larger than the females, and presumably many others of the same large family do likewise. In this case the males prepare a nesting place but the females act as nurses by taking their eggs into their mouths for incubation.

There is a tendency among almost all men to too great generalization and to an assumption that, because certain forms manifest special modes of behavior or action, others do so also. Thus, because the fishes that had been noticed by early observers did not take care of their eggs but left them after deposition and fertilization to unaided nature, it was assumed that all fishes were alike neglectful. Later, it was found that some forms did take charge of their eggs and then it was assumed that it was the females, simply because among mammals and birds the females do so. Our catfishes and sunfishes, for example, were discovered to care for their eggs, but the old observers invariably credited such care to the females. Meanwhile it was ascertained that it was really the males, only or chiefly, that assumed such charge, and as such was found to be the case also among the sticklebacks and various other fishes, the generalization was conceived that in the case of all fishes that care for their eggs it was the male that was the guardian.

This generalization was applied to the cichlids of Africa and Palestine and, in various accounts of the habits of the bolti and similar fishes, reputable writers, such as Günther and Lortet, especially credited the males with exclusive parental care. Subsequent dissections of the same species and other species observed by these naturalists revealed the fact that in all the cases in question the females took charge, taking their eggs in their mouths and caring for them and the newly hatched young until they had attained a considerable size. In fact, so far as the cichlids are concerned, numerous African species have now been examined, and for all of those so examined the females have been ascertained to be the egg-carriers. Let it not be assumed, however, that all the other cichlids take such care of the young and that all American species do so, as well as the African. Indeed, even now it is known that certain South American species provide for their eggs in nests made by heaping pebbles over their eggs or otherwise preparing the bottom, rather than by oral incubation. But more than this is not known and we are ignorant of the parts played by the respective sexes.

The tendency to undue generalization has been exhibited in a striking and even amusing manner in the case of two European fishes already referred to, the wels of Germany and the glanis of Greece. The wels had long ago been declared by many observers to exercise no parental care after deposition and fertilization of their eggs. It happened, however, that Aristotle, over twenty-two centuries ago, gave elaborate details of the glanis and the care taken of the eggs by the male parent. Instead of those accounts, which bore the impress of observation and truth on their face, serving as a check to identification, it was assumed by some of the greatest of modern ichthyologists, such as Cuvier, Valenciennes, and F. A. Smitt, that the wels and the glanis were of the same species; the Frenchmen declared that Aristotle's account "borders a little on the marvelous" and the Swede reechoed with the remark that "it is now regarded as dubious." Yet over half a century ago (1856) Agassiz declared that Aristotle was right and that the Aristotelian fish differed, not only specifically but generically, from the wels. Later, comparative descriptions and illustrations of the Grecian species were published; nevertheless the two continued to be confounded in Europe under the same name. But recently a new attitude has been assumed otherwise. At last it has not only been acknowledged that the facts recorded by Aristotle were credible, but assumed that what was true of the glanis must be true of the wels; in a reference to the species made by a distinguished French ichthyologist this year the wels ("l'enorme Silure d' Europe") is credited with paternal instinct and attention. Thus has generalization been carried to an extreme and assumption piled on assumption. One further assumption apparently was that because the glanis was not in a European

museum it could not be a distinct species, and another that the American authors were incompetent to determine the species.

It might be thought that related species would agree at least in the character of their eggs and oviposition, but exceptions to this also occur. A notable case is manifest among the clupeids. There are several species of the northern seas so closely related that they are associated by most ichthyologists except in America in the same genus—*Clupea*. Nevertheless there are remarkable differences between species in their eggs, as well as in the manner of depositing them. The typical herrings (*Clupea harengus* and *Clupea pallasi*) have opaque eggs destitute of oil globules, deposited in the sea in water of moderate depth and adhering in masses to foreign bodies at the bottom; the pilchards (*Clupanodon pilchardus*, etc.) have translucent eggs, buoyant by oil globules, and cast near the surface of the sea often quite far from land and there hatched; the shads (*Alosa* species) leave the sea and ascend rivers to deposit their eggs near or on the bottom in fresh water; the alewives and hickory shads (*Pomolobus*) are also anadromous and agree in most respects with the shads.

Another requisite, too often overlooked for the successful historian of a fish's habits, is that the species in question should be correctly identified or the means for identification furnished. Many instances might be given of interesting details of habits of animals worthless to science because the species are not recognizable. Only one such need be mentioned and that because it has recently come up for notice. Many years ago (in 1874) a French amateur naturalist, Carbonnier, published some remarkable details of the breeding habits of fish received from New York which he called "la Fondule (*Fundula cyprinodonta*, Cuv.)." I have been frequently appealed to for information as to the proper name of that fish. No such fish was described by Cuvier and apparently the Frenchman had been informed by some one, in an offhand manner, that it was a *Fundulus*—a cyprinodont—and had been satisfied with the suggestion and even misinterpreted the statement. In fact, the fish was not a cyprinodont at all, although having a considerable superficial resemblance to one, but an umbrid, the common *Umbra pygmæa* of New York. To this day, so far as published records show, Carbonnier is the only man who has succeeded in breeding this fish, but his record was long unusable because it was not known what fish he really had.

Another fault we must take care to guard against is the counterbalancement of a difficulty against a certainty. Many examples of this are to be met with in the history of the common eel. Several are still persistent.

The breeding resorts of the eel of northern Europe have been discovered within the last two years, thanks to the International Council for the exploration of the North Sea and the excellent work of Johannes Schmidt; they are in the ocean at "depths of at least about 1,000 meters (corresponding to a pressure

of ca. 100 atmospheres)." In other words, eels can not mature their gonads nor breed in fresh water, yet there are many persons to the present day who maintain that they must do so, because they can not perceive how eels could be found in ponds and waters isolated from rivers communicating with the ocean. There are many ways in which they might be diffused, but that need not concern the biologists; that they must have originated in the ocean is certain.

No eels which have once spawned have been found in fresh waters, but because large eels have been seen at some place pursuing an upward course, strenuous claims have been made that some do ascend rivers after spawning; here again we have a difficulty (but an extremely slight one) balanced against a counterfact.

We have still much to learn about our most common and longest-known species. The *Apogon imberbis* or *rex-mullorum* is a Mediterranean fish which had never been regarded as of much interest. Several years ago (1903), however, a French naturalist (L. Vaillant) found its own eggs in the mouth of the male of a related Caribbean fish (*Cheilodipterus affinis*) and quite recently the United States Deputy Commissioner of Fisheries (Hugh M. Smith) found also in the waters of the Philippine Archipelago a number of species exercising oral incubation. This present month (September 1, 1908) Dr. L. Plate records the discovery of a small species of the same group (*Apogonichthys strombi*) as a commensal of the large whelk known as *Strombus gigas*.

With these facts discovered respecting congeneric species, renewed observations should be made. It would be another example of the undue generalization which has been deprecated to assume that the Mediterranean fish agreed with its relatives in oral incubation—very much more that it was a commensal. It should be reexamined till something definite can be learned of its habits during the breeding season. Fishermen may often have found individuals with eggs in the mouth and assumed that they had been taken in as food, so that the fact of none of these fish having been recorded with such eggs is a matter of minor consequence. We would have reason for surprise if it should be found that the Mediterranean *Apogon* does not exercise oral incubation, and also if other species have commensal habits like the *Apogonichthys strombi*, but positive assumption is illegitimate in both cases.

The relationship of fishes to other animals is a subject which will repay future investigation, and search may be rewarded by many cases scarcely less expected than the parasitic habit of the *Apogon*. Certain tropical pomacentrids of the genera *Amphiprion* and *Premnas* use actinizoans for shelter; the butterfish of the American coast (*Poronotus triacanthus*) harbors during its early youth under the disk of a medusa, and so does also the scad (*Trachurus trachurus*) of Europe. Still more remarkable are the fierasfers which seek

shelter and home by obtruding into the posterior end of the abdominal cavity of holothurians.

Another subject that will furnish interesting cases is courtship among fishes. Many American fresh-water fishes furnish examples. The males become more or less brilliant and assume bright liveries for and during the spawning season and variously show themselves to the females; the best known species are the sunfishes (*Lepomis* and *Eupomotis*) of different kinds, but representatives of most or all families have their special modes of action. A still more elaborate courtship was observed a decade ago (1898) by Ernest Holt among sea fishes of the genus *Callionymus*.

One fact, too often forgotten, is that there is considerable individuality among fishes and that there may be exceptions to most general propositions. Species, for instance, may prefer certain food, but if they can not get such they will act very much like human beings—take what they can get. Yet our periodicals, monthly as well as weekly, are often charged with bitter controversies because one man makes an assertion respecting habits which is denied by another who asserts that the animal in question always has certain other habits. Both may be right in their observations but wrong in contending each that the other is wrong.

Such are a few of the many interesting phenomena manifested by fishes and such a few of the special exceptions to general propositions. No men are professionally in such excellent positions for observation of the habits of fishes as are pisciculturists, and, if they would, they could add greatly to our knowledge of their ways and means; that they should do so the scientific ichthyologist and the practical fisherman must alike hope.

I conclude with a recapitulation of some of the characteristics by which fishes are distinguished among themselves and which may direct attention to points overlooked or forgotten. Any biography of a fish that is wanting in attention to any of the characteristics indicated is to such extent incomplete.

SCHEDULE FOR OBSERVATION.

Specific characters:
- Adults.
- Sexual differences.
- Relative size.
- Length.
- Weight.

General behavior:
- Character of water preferred.
- Character of ground preferred.

General behavior—Continued.
- Manner of resting.
- Manner of swimming.
- Use of fins.
- Respiration.
- Association (in schools, etc.).

Feeding:
- Kind of food preferred.
- Manner of taking.

Feeding—Continued.
- Time of taking.
- Abstinence during spawning season.
- Abstinence during cold periods.

Distribution:
- General.
- Seasonal (summer, winter, etc.).
- Migration.
- Arrival.
- Departure.
- Route of travel.
- Relative appearance of sexes.
- Schooling.

Reproduction:
- Age at maturity.
- Preliminary changes.
- Special male seasonal characters.
- Special female seasonal characters.
- Season of reproduction.
- Temperature of water.
- Preparation.
- Manner of sexual excitation.
- Nest-making.
- Parts assumed by sexes.
- Selection of place.
- Depth of water preferred.
- Manner of spawning.

Reproduction—Continued.
- Frequency of spawning.
- Behavior of males and females meantimes.
- Disposition of eggs.
- Number of eggs.
- Period of incubation.
- Retardation or acceleration of incubation by temperature.
- Care of eggs.
- Care of fry.
- Period of care.
- Food of young.

Growth:
- Development.
- Successive changes.
- Size and characters, first year, second year, third year, fourth year.

Parasites.

Diseases.

Economical value:
- Value as food and otherwise.
- Manner of capture.
- Statistics.

Legends:
- Beliefs or sayings connected with species.

DISCUSSION.

Prof. E. E. PRINCE (Canada). I feel again as if I ought to apologize for rising to speak, at the same time I am impelled out of a sense of gratitude to Doctor Gill, which all the younger workers in ichthyology and the students of fish and fisheries generally feel for one who is the Nestor of the science of fish and fisheries. It is a privilege which I think we shall long remember to have heard Doctor Gill on this occasion; and I think that on the principle of keeping the good wine to the last it was appropriate that Doctor Gill should come in even at the end of the programme. I may claim to be one of the younger workers, and I have always felt that Doctor Gill was one who gave credit to the young workers for anything they contributed to science.

I do not wish to trespass very long on the time of the congress, but I feel especially interested in Doctor Gill's reference to the development of the eel, because since I came to this congress I have received quite a long letter from Doctor Schmidt, of Copenhagen, asking about the movement of young eels in our Canadian waters, and I hope to be able to report, as indeed I have previously, certain observations of my own as to the migration of young eels up some of our Canadian rivers. Countless multitudes ascend in the summer, especially in August, and they surmount obstacles such as high falls.

The statement that one can never prophesy the characteristics of a fish as to its eggs and its young I know to be very true, and we should remember the warning which I think Sir Ray Lancaster, long ago, gave embryologists, that embryology was so full of surprises and wonders that we must never prophesy until we know. I remember, years ago, my own experience in regard to *Clupea sprattus*, for I felt as if all the herring family should deposit their eggs in a certain way, viz, on the sea bottom, because *Clupea harengus* did so; and I remember with great surprise finding that *Clupea sprattus*, the small sprat in European waters, deposited not only a pelagic or floating egg, but an egg of extreme delicacy. The egg of *Clupea sprattus* is the most delicate and most buoyant. This is surprising when one remembers the nonbuoyant eggs of the herring. Then, the fact that the smelt also deposits, like the Salmonidæ generally, not only a heavy egg, but an egg which is attached by a kind of pedestal to stones in brackish water, not a loose free egg, shows that we must investigate by actual observation and by actual study the character of the eggs and spawning peculiarities of every species.

Again, the fact that the male in some species and the female in others perform certain functions during the life of their young brood has a most interesting but a somewhat perplexing side. I remember only last summer, just a year ago, finding on the Pacific coast a fish which is well known, I am sure, to Doctor Gill, *Porichthys porissimus*, a very unprepossessing fish in appearance, but a fish which has the peculiar habit of sitting beside its eggs through development; and not only sitting by them and watching them, but singing to them, and as you walk along the beach you hear the peculiar cooing sound, or kind of croaking sound, which the parent fish makes when sitting by her brood and watching them. What the meaning is we can not surmise; but we find the fish singing to its young when they are actually attached firmly to the underside of the rock where the female deposited the eggs. Whether it is the male

or the female that sings I am not able to decide, but I did observe that the young when hatched out remained attached to their place of birth—a very remarkable phenomenon. Instead of hatching and liberating themselves in the water, the young emerge and remain still attached to the stones where the eggs have been attached through their development; and not only are the young thus attached for a considerable time, but they are "oriented;" their heads seem to be all turned the same way. These young, like a little army, all point their heads the same way and point their wiggling tails the other way, a very curious and quaint spectacle.

I say we are doubly indebted to Doctor Gill for bringing his very important observations in a condensed form before us at this time, and I think the congress is with me heartily in saying this.

Dr. HUGH M. SMITH (Washington, D. C.). I do not intend to attempt to express my obligations to Doctor Gill for all the encouragement he has given to me and to numerous others with whom I am acquainted, because it would take all the remainder of the session to do that. I simply rise to confirm the statement that Doctor Gill made in regard to oral incubation in certain little fishes, of which I have recently caught a great many in the Philippines. Only a few months ago, while engaged in collecting on a coral reef in the southern part of the Philippine Archipelago, we exploded half a stick of dynamite, and as a result of that one discharge we actually collected 800 specimens, representing nine species of the genus *Apogon*, or *Amia*, as it is now called; and, as far as I was able to see at the time, in each of these species the male fishes had their mouths crammed with eggs. [Applause.]

Dr. TARLETON H. BEAN (New York). Just a word with reference to the remarks of Professor Prince concerning the toadfish of the west coast. Professor Prince doubtless is aware, and, I dare say, it has been brought out in this conference, that the reason for the attachment of the young toadfish, *Opsanus*, or *Porichthys*, as the case may be, is the presence of a ventral disk which is similar to the ventral disk of the lump-fishes, but which disappears, in *Opsanus* at least, after the fish has reached the length of about three-quarters of an inch. I have often collected the little fellows, and have been extremely interested in observing how it was that they remained attached, not only to their place of shelter, but to the place at which they derive their first supply of food. [Applause.]

The ACTING CHAIRMAN (Doctor Gill). Are there any further remarks? If there are no further remarks, I beg to thank the president and the gentlemen for their kindly expressions.

But a few words with reference to the subject at issue. I was very glad to hear Professor Prince make his remarks about the toadfish of Pacific waters, for it tallies very well with the habits of the species of our eastern coast (*Opsanus*). The species, however different externally, are rather closely related; that is, they belong to the same subfamily but to very different genera; and Professor Prince is the first one who has given the details respecting the species of the west coast (*Porichthys*). The habits of our eastern species have been long known. They were described more than a quarter of a century ago by Doctor Ryder, who gave illustrations of the adhesion of the eggs to blocks of wood, and also maintained that the young were attached in the same way during the early condition of life.

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HABITS AND LIFE HISTORY OF THE TOADFISH (OPSANUS TAU)

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HABITS AND LIFE HISTORY OF THE TOADFISH (OPSANUS TAU).

By E. W GUDGER, Ph. D.,
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MATERIALS AND METHODS OF STUDY.

The material on which this paper is based was collected and the notes were made while the author was a temporary assistant in the United States Fisheries Laboratory at Beaufort, N. C., during the summers of 1906, 1907, and 1908. The collections were made in all parts of the harbor, but the best collecting ground was a shoal lying directly in front of and not farther distant from the south front of the laboratory than 100 yards.

The "nests," consisting of tin cans, empty *Pinna* shells, pieces of board, etc., were brought in in buckets of water and placed in aquariums or in shallow pans under jets of running salt water, or in a large tank 3¾ by 7¾ feet, filled with fresh salt water to a depth of 6 inches. In some of these aquariums there were placed nests with guarding fish; in others nests without any fish; while in the tank there were always numbers of fish, both adults and half grown.

The nests thus placed were perfectly accessible and could be inspected at any hour of the twenty-four. Daily they were taken out, put in shallow pans of water, and minutely examined under a glass. Selected eggs and larvæ were put in killing fluids, careful notes were taken, and at intervals the eggs and nests were photographed.[a]

GENERAL DESCRIPTION OF ADULT TOADFISH.

For a description of this singular fish the writer can not do better than quote Doctor Gill (1907) and Miss Clapp (1899), since their descriptions leave little or nothing to be added. Doctor Gill says:

> They [the toadfishes] have an oblong form, a broad flattish head, restricted lateral gill openings, two dorsal fins, the anterior very small and with only two or three spines, the second very long, the anal moderately long, the pectorals broad, and the ventrals jugular and imperfect (1, 2- or 3-rayed).

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[a] I am under obligations to Mr. Henry D. Aller, Director of the Beaufort Laboratory, for furthering this research in every way possible, and to Dr. H. E. Enders, of Purdue University, for taking the photographs from which some of the figures are made. The other figures are made from photographs taken by myself.

According to Miss Clapp:

There is something singularly grotesque in the appearance of the toadfish; and, as its name would imply, there is a superficial resemblance to the familiar batrachian. The sluggish disposition, the mottled brown and gray of the wrinkled, scaleless skin, the depressed head and toadish eyes do not suggest the typical teleost. The young fish are tadpole-like in their form and motions. * * * It will be seen that there are quite conspicuous projections of the skin on the head. Besides the paired flaps found in connection with the sense organs, there are other single, often longer projections to be found, which become laciniated in the older fish. These are especially prominent about the mouth, fringing the margin of the lower mandible and opercular regions, while over each eye rises a broad conspicuous flap, giving an owl-like facial expression. * * * The function of these skinny tentacles seems evidently to be for protection, as they strikingly resemble both in color and form the seaweed (*Fucus*) that abounds near their favorite haunts.

Toadfish are somewhat variable in color, but may, generally speaking, be grouped in three classes—those which are a muddy green, those with brown on the upper parts, and those which approximate yellow. I am inclined to think that the former are found largely in deeper water, the latter two classes in shallows. There is, it must be understood, no definite line of demarcation, since all degrees of gradation from class one to two and to three exist. Perhaps the greatest variation, however, is not so much in the ground color as in the markings and blotches which render one fish distinguishable from another. These markings, generally of darker color, are found on the head and fins, particularly the dorsal and caudal. One very large fish of particular marking comes to mind. This was a brown male with an enormous head, the whole right side of which was of a velvety black color, the bright eye with its St. Andrew's cross being near the center. This fish always recalled a bulldog with a black patch covering the right side of the head. It may be added that the toadfish has to a considerable degree the power of changing its color to correspond with the bottom on which it happens to find itself.

HISTORICAL ACCOUNT.

When one considers the abundance in which this fish is found along the Atlantic coast, the large size of the eggs, and the ease with which, owing to the nesting habits of the parents, the eggs can be obtained, one wonders that the embryology and habits of the toadfish have never been worked out. But, excepting two short papers by Ryder, there has been no attempt to study the life history of *Opsanus tau*. There are, however, several papers, long or short, dealing with the habits and with the development of particular organs, which will be referred to later. Since those particular points in the articles cited which touch upon this research are referred to at length in the body of this paper, the references in most cases taking the form of quotations, it will not be necessary here to do more than list the papers and give a general synopsis of their contents.

This fish was first described and named (*Gadus tau*) by Linnæus from a specimen collected by Doctor Garden, of South Carolina. The earliest figures of the toadfish that I have been able to find are in plate LXVII of Bloch's Atlas to his "Oeconomische Naturgeschichte der Fische Deutschlands," published about 1782. These figures, one a dorsal, the other a lateral view, are very good, the latter especially.[a]

The first American describer was Doctor Mitchill (1815), of New York, who allied it with the angler (*Lophius*) because of its large head adorned with skinny tentacles, and its cavernous mouth. His description is an excellent one.

Rafinesque in 1818 describes, under the name of *Opsanus cerapalus*, a toadfish from the south shore of Long Island. This, he notes, is found spawning along the shores during the summer but is not seen in winter. So far as the present writer knows, the first American ichthyologist to figure this fish was Le Sueur. His drawing, published in 1819, represents the fish in the attitude of swimming. This admirably drawn and thoroughly characteristic figure has been reproduced in Doctor Gill's (1907) paper, referred to later.

Le Sueur, following the lead of Mitchill, allies the toadfish, which he calls *Batrachoides vernullas*, to *Lophius*. In another paper the same author (1824), in describing what he thought were two new species of the toadfish, thus justifies the name *Batrachoides* which he first applied to this fish:

> The name *Batrachoides* * * * is a very appropriate one, inasmuch as the form of the body of these fishes has considerable analogy with the larval or imperfect and exclusively aquatic state of the frog; this similarity exists in the large depressed head and wide mouth, the attenuated body edged with an almost continuous fin above and beneath, and, in fact, a general conformity which at once reminds us of the numerous family of Batrachians that are inhabitants of almost every country. This general resemblance is evident to the common observer and they are known by the name of toadfish to the inhabitants of Salem, Rhode Island, and Egg Harbor, and probably also Carolina.[b]

His first specimens were very small, consisting of two individuals of 5½ inches each and one of 2½ inches in length. This latter was taken from a living oyster, in which Le Sueur thinks it had taken refuge in alarm at the noise and motion of the oyster tongs.

In 1842, De Kay, following Cuvier and Valenciennes, gives the name *Batrachus tau* to the toadfish, but still retains it in the family *Lophius*. He

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[a] In Marcgrave's (1648) Historiæ Rerum Naturalium Brasiliæ, on page 178, there is figured and described a fish "called Niqui by the Brasilians, and Pietermann by the natives." Both the figure and the description lead me to believe that the fish Marcgrave had was a toadfish. Jordan and Evermann (1898) make no reference to this fish in their description of North American forms. Since, however, in a footnote to page 2315, they refer to certain structures in "the Brazilian genus *Marcgravia cryptocentra*," one may be allowed to conjecture that this is the fish referred to above.

[b] Hargreaves (1904), writing of the pacuma, *Batrachus surinamensis*, of Guiana, says. "The head of the pacuma is exactly like that of a huge toad and has much the same color and markings as the common crapaud."

also describes another fish (1 inch long and undoubtedly the young of the above) as *B. celatus*. This latter he notes is frequently found in oysters, while in 1824 a shower of them fell in the streets of New York. De Kay gives two figures of the toadfish, but they are not to be compared to Le Sueur's splendid drawing. The present writer twice went over the plates of this paper without recognizing either figure as that of the fish in question. One figure has the caudal fin pointed, the other rounded.

Storer (1855) in his "History of the Fishes of Massachusetts," published about the middle of the last century, gives a very interesting but not wholly accurate account of the nesting habits of the toadfish. As the essential points in his paper will be discussed later, it will not be necessary to go further into it here than to say that he was the pioneer worker on the habits of this fish. He obtained his information chiefly from Dr. William O. Ayres, of East Hartford, Conn. This information must have been conveyed by letter, for in Ayres's paper published thirteen years before (1842) there is a very meager account of the general habits only and no reference whatever to the nesting habits. Ayres's paper will be referred to later.

Yarrow (1877), twenty-two years after Storer, in listing the fishes of Beaufort Harbor, speaks of finding a nest of toad eggs in an old boot leg. In 1881, Alexander Agassiz, in the course of an interesting article, "On the Young Stages of Some Osseous Fishes," describes the coloring of a half-grown larva and figures the heterocercal tail. In a popular article published in Harper's Magazine, C. F. Holder (1883) figures a toadfish in a nest amid seaweeds, and falls into the popular error of making the mother the guardian. With regard to the adhesion of the eggs, however, he merely says that the young are enabled to cling to the rocks by their yolk sacs, remaining until bold enough to swim away. Goode (1884), in dealing with the nesting habits and embryology of the toadfish, quotes Storer (1855) at length and gives the accurate and highly interesting observations of Silas Stearns, of Pensacola, Fla., all of which are quoted in detail further on.

In 1886 John A. Ryder published the first of a series of short but highly interesting papers on the habits and embryology of *Opsanus* (or, as it was then called, *Batrachus*) *tau*. These papers followed in rapid succession. The first appeared in 1886 and seems to have been an abstract of the but slightly longer article which appeared in 1887. This latter paper, which he calls a "Preliminary Notice," contains six figures, the first illustrations of toadfish embryos ever published so far as the writer knows. The third, last, and possibly most valuable of these papers is an oral communication to the Philadelphia Academy, on November 4, 1890, on "The Functions and Histology of the Yolk-Sack of the Young Toadfish." The striking points of these papers are all referred to later in the body of this article.

Miss Cornelia Clapp, in 1891, published an interesting paper entitled "Some Points in the Development of the Toadfish (*Batrachus tau*)." In this she figures segmenting blastoderms, illustrates and describes the closure of the blastopore and its relation to the forming embryo, and discusses the relation of the axis of the embryo to the first cleavage plane. She also briefly refers to the nesting habits.

Five years later Miss Clapp presented as a dissertation for the doctor's degree at the University of Chicago a paper entitled "The Lateral Line System of *Batrachus tau*," which was published in the Journal of Morphology, volume xv, 1899 This contained figures of early larvæ and gave an excellent description of the fish and of its nesting habits. In the same year and in the same journal one of Miss Clapp's students, Miss Wallace, published a short but valuable article on " The Germ Ring in the Egg of the Toadfish," reviewing and extending Miss Clapp's work. A third paper on the embryology of this fish appeared the same year. This is a reprint of a lecture delivered by Miss Clapp at the Marine Biological Laboratory at Woods Hole, during the previous summer, on the relation between the first cleavage plane and the axis of the embryo. Those points in all three of these papers which deal with matters pertinent to this research are taken up at length in the other parts of this paper.

The last article, so far as has come to the writer's knowledge, bearing on the habits and life history of this fish is Doctor Gill's (1907) "Life Histories of Toadfishes (Batrachoidids) compared with those of Weevers (Trachinids) and Stargazers (Uranoscopids)." This, as the liberal quotations from it in various parts of this paper show, has been a veritable mine of information to the present writer.

HABITS AND CHARACTERISTICS.

NESTING HABITS.

Nesting places.—The toadfish in accommodating itself to its environment has developed most interesting habits. The eggs are deposited in nests, which in the writer's observation have been old tin cans, a broken jug, floating boards, rotting logs lying more or less horizontally in the water, stones (ballast thrown overboard) with an exposed under surface, but especially the empty shells of a large fan-shaped lammellibranch (*Pinna seminuda*) which abound in the sandy shoals around the laboratory at Beaufort.

Miss Clapp (1899) says that—

> The fish resort in pairs to large stones, especially near low-water mark, and, scooping out a cavity beneath, remain for days in this retreat.

Again she notes that—

> The toadfish of the Eel Pond near the laboratory [at Woods Hole] seem to prefer the débris of civilization to the excavation beneath the rock—for example, tin cans, old boots, broken jugs, etc.

These points had been briefly stated by her in the earlier paper (1891) elsewhere referred to.

Ryder (1886) found that—

> The adult toadfish burrows a cavity under one side of a submerged bowlder and to the solid roof of this cavity the female attaches her ova in a single layer. The eggs are very adhesive and quite large, measuring about one-fifth of an inch in diameter. Like the male catfish, the male toadfish assumes charge of the adherent brood of eggs and remains by them until they are hatched and subsequently become free.

A year later (1887) he writes:

> They (the eggs) are dirty yellow, almost amber colored, and adherent to the surfaces of submerged objects, especially the undersides of bowlders, under which the parent fish seem to clear away the mud and thus form a retreat in which they may spawn. The ova are attached to the roof of the little retreat prepared by the adults, where the eggs are found spread out over an area about as large as one's hand, in a single layer, hardly in contact with each other, and to the number of about 200.

Yarrow (1877), writing of the Beaufort fish, tells, as already referred to, of a nest which was found in an old boot leg. Storer (1855), the first writer, so far as I can find, to describe the nesting habits, found the fish living in eel grass or under stones, to the latter of which eggs, several hundred in number, were found attached in June, July, and August. At Beaufort a more interesting, and for the collector more dangerous, place of abode is in holes dug by the stone crab (*Menippe mercenaria*) in sand flats covered with eel grass (*Zostera marina*). In short, the fish resort for egg laying to any place which is dark and which secures a protected abode to the hatching eggs and guarding parent.

The toadfish of the Pacific coast, *Porichthys notatus*, which ranges from Alaska to Panama, has the habit, according to Greene (1899), of spawning during spring and summer in shallow water. Here "the eggs are cemented in a single layer to the under surfaces of stones, and, * * * the male remains with the brood until the young become free swimming." Hargreaves (1904) states that the pacuma (*Batrachus surinamensis*) of Guiana has the habit of hiding in holes in the mud flats, but the context does not indicate whether for the purpose of egg laying or for the sake of protection.

The eggs.—How the extrusion and fertilization of the eggs take place and how their fixation to the nest is effected I have not been able to ascertain, although considerable numbers of fish of both sexes were kept for months in the large tank (above referred to) well equipped with tin cans, jars, boards, and especially empty *Pinna* shells. The fish readily inhabited these receptacles, but laid no eggs. On one occasion I found in a shell out in the harbor a pair of fish presumably spawning, since there were a few eggs in very early stages adhering to the nest. Though both fish and nest were carefully brought in and placed in the tank, no more eggs were laid.

The egg is permanently oriented with the ventral pole of the yolk fixed to that part of the egg membrane which is fastened to the object acting as a nest. The part of the eggshell there attached is not, as Miss Clapp (1899–1899a) indicates, always opposite the micropyle, but generally so. So far as my observations go, in the great majority of cases the micropyle is opposite the point of attachment, but it may vary within a zone bounded by a circle about 30° away from the animal pole. The blastoderm, and consequently the embryo, as pointed out by Ryder (1886 and 1887) and Miss Clapp (1891 and 1899a), are at the animal pole opposite the point of attachment, though here we find the same variation as is noted for the position of the micropyle.

Just here it is worth while to correct an error into which nearly all those who have described this fish and its young have fallen. Storer (1855), more than a half century ago, in describing the habits of the toadfish, says:

> We may see the eggs, not larger than very small shot; a little later they are increased in size, and the young fish are plainly visible through their walls; a little later still the young have made their escape (i. e., have burst their eggshells), but are still attached to the stone. The attachment now, however, is accomplished in a different manner. The yolk, not being yet absorbed, occupies a rounded sac protruding by a narrow orifice from the abdomen, and the part of the sac near its outer border, being constricted, leaves external to it a disk, by means of which, acting as a sucker, the young fish adheres so firmly as to occasion difficulty in detaching it.

The error here occurs in the idea that there is any "sucker" at the basal portion of the yolk stalk. The egg is simply glued to its support in a manner to be explained presently. It should, however, be stated that Storer did not get his information at first hand, but expressly credits it to Dr. William O. Ayres, of East Hartford, Conn. This, as previously stated, must have been communicated orally or by letter, since it is not found in Ayres's paper (1842).

Jordan and Evermann (1898), in their great work, "The Fishes of North and Middle America," fall into the same error in describing "the young clinging to the rocks by a ventral sucking disk." And Jordan (1905), in his "Guide to the Study of Fishes" speaks of "the young clinging to stones by a sucking disk on the belly, a structure which is early lost." And, last in point of time, Smith (1907), in his "Fishes of North Carolina," says that "for some time after hatching the young remain attached by means of a special sucking disk."

Ryder (1886) was the first to call attention to this error and to explain that the attachment was due to an adhesion of the eggshell to the nest. Later (1887) he correctly describes and figures the eggs as attached by means of an "adhesive membrane," but does not refer to the origin of this. In 1890 Ryder quotes Jordan and Gilbert as to this voluntary adhesion of the young, expressly corrects their error, and goes on to show definitely how the eggs adhere to the membrane and how the membrane is glued to the nest. Miss Clapp, in the three

papers previously referred to (1891, 1899, and 1899a), also refutes this error. In her first paper (1891) she says:

> The adhesive disk * * * is about 3 millimeters in diameter. It is a transparent thickening on one pole of the egg membrane, at the time of oviposition, and by means of it the egg is glued firmly to the rock.

Later she writes more explicitly (1899):

> The young fish do not attach themselves by a ventral disk which soon disappears, as has been supposed, but at the time of oviposition each egg is securely glued to the rock by means of a secretion on the membrane at the pole of the egg opposite the micropyle. After hatching, the embryo fishes still remain attached to the rock by the adhesion of the yolk sac to the inside of the egg membrane over the disk area until the yolk material has been entirely absorbed, a period of three or four weeks.

Again, she says (Clapp, 1899a):

> The membrane of the egg has a peculiar adhesive disk, about 3 millimeters in diameter, which has a constant position, with the center of the disk at the vegetative pole, directly (?) opposite the micropyle. By means of this disk the egg is firmly glued to the supporting surface. * * * The disk consists of a transparent secretion, which becomes opaque and gluey on contact with water. It is of nearly uniform thickness, and is closely applied to the egg membrane everywhere, except for a narrow margin which projects all around as a thin rim. The disk is saucer shaped and only a little thicker than the egg membrane itself. I have been able to separate it from the membrane in the case of eggs hardened before attachment. As the egg is generally fastened to more or less plane surfaces, it appears strongly flattened on the side of attachment, as described by Doctor Ryder and as shown in figure 3.

This is correct, and Miss Clapp has been quoted at some length in order to give her the credit for discovering the disk and for refuting the errors above noted, and because her clear statement of the facts could not be improved on by me. I am pleased to say, however, that on June 22, 1908, I ascertained that the adhesive disk is to be found in place opposite the micropyle in ripe ovarian eggs when these are allowed to flow from the ovary into water, thus confirming Miss Clapp's statement (1891) that the disk is present at the time of oviposition. When the egg becomes fixed to some supporting body both the disk and the egg become very much flattened on the supporting side. The accompanying text figure[a] shows both these points clearly. *A* is a ripe egg

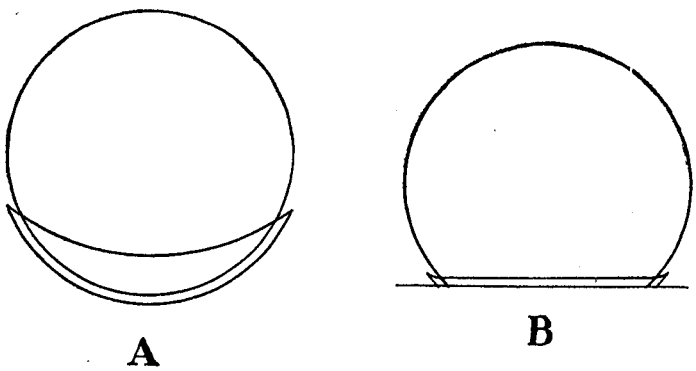

Diagram (after Miss Clapp) showing adhesive disk of toadfish egg. *A*, before, *B*, after attachment. (Much enlarged.)

[a] Copied from Miss Clapp (1899a). This is the "figure 3" referred to in the quotation above.

fresh from the ovary; *B* is the same after attachment. This attaching disk persists not only while the eggshell is intact but throughout larval life, until the yolk sac has been absorbed and until the little toad breaks away from the nest, leaves the disk behind, and takes up a free and independent life. This, however, will be referred to later.

Number of eggs in a nest.—The number of eggs found in nests varies within wide limits, these being from but few more than a score to several hundred, the numbers generally varying toward the upper limit. The smallest number which I have recorded is 22 in a *Pinna* shell, while the larger and more typical numbers are 181, 340, 361 in *Pinna* shells; 301 in another, 144 eggs on the right, 157 on the left valve; 624 in another shell, 381 being attached to the right valve and 243 to the left; 373 in an empty can; while on a piece of board 5 by 11 inches the amazing number of 723 was found. These are careful counts. On the under side of logs at the island elsewhere referred to two of us estimated that there were 350, 500, and 700 eggs in three nests, respectively. Other numbers might be given, but these are typical.

Where such large numbers of eggs as noted above are found, there is always more or less crowding. On a board, as elsewhere described, 723 eggs were counted in a space 5 by 11 inches. These eggs were very much jammed, some having the vertical diameter twice as great as the horizontal, and in some cases the eggs were piled up on top of each other like large shot stacked up two deep, and were adherent to each other instead of to the board. Figure 5, plate CIX, is a photograph of the board showing this crowding of the eggs. Here my observations are in direct contradiction to those of Ryder (1886 and 1887), who says "the female attaches her ova in a single layer," and again, "the eggs are found spread out over an area about as large as one's hand in a single layer, hardly in contact with each other, and to the number of about 200."

The fish polygamous.—By finding such large numbers of eggs and by noting the comparatively small size of the ovary of the adult females, I am led to conclude that several females have taken part in the laying of such enormous numbers of eggs. Figure 1, plate CVII, is a photograph (normal size) of the ovary of a female 9½ inches long. When we recall that the eggs average 5 millimeters ($^1/_5$ inch) in diameter, we arrive at the conclusion that one fish can at the most lay hardly more than 100 eggs. It is well known that domestic fowls lay many together in one common nest, and so it is with the toadfish. A fact that tends to confirm the matter is that eggs in nests are frequently found in two or three different stages of development, often rather near each other in time, but frequently as much as two or three days apart. For example, in a *Pinna* shell brought in on July 19, 1906, each valve had eggs in two stages. On the right valve 50 and on the left 88 eggs had embryos with the outline of the head just beginning to appear, while 183 eggs on the right and 60 on the left had embryos

with black eyes and free tails. Instances of two or three stages in the eggs of a nest might be multiplied, but the general statement may be made that when such large numbers of eggs are found in a nest they are in more than one stage of development and have been laid by more than one female.

Orientation of the embryos.—Ryder stated (1887) that—

> The young adherent embryos are found tohave their heads directed toward the opening of their retreat and their tails toward its blind and dark extremity. This appears to be invariably the case, and it would seem that the direction from which the light comes, in this instance, at least, has a great deal to do in determining the direction of the axis of the body of the future embryo. This position of the young fishes is maintained as long as they are attached.

The last of these statements is correct, but the others are erroneous. In scores of nests which the writer has examined the embryos are found pointing in all directions. This is especially so in nests which are equally lighted from all sides, i. e., the board nest mentioned above. In a nest on the under side of a log projecting from a bank, eggs were found with the embryos pointing in all directions, but the majority had their heads turned more or less toward the point of greatest illumination. In *Pinna* shells, as shown in figure 7, plate CX, the embryos are almost always turned away from the opening of the shell toward the hinge. The writer is in position to state that only in a very general sense is it true that the embryos have any definite direction of axis, and not "invariably," as stated by Ryder. Figures 9 and 10, plate CXI, photographs of different nests, show this. Pieces of wood, 1 by 2 inches, from the log above mentioned have embryos pointing in as many as nine different directions. In her earliest paper (1891), Miss Clapp quotes Ryder, and adds:

> It was observed during the past summer that the embryos *within the egg membrane* do not have their heads all turned the same way, but in every possible direction, and it is only after the young toadfish are hatched that the heads of the whole brood are turned in the same direction.

That this latter statement is incorrect a glance at figures 7, 8, 9, 10, and 11, plates CX, CXI, and CXII, will show. Smith (1885), in the paper previously referred to, says on this subject:

> In the species of *Lepadogaster* the embryos show a marked irregularity of position; that is, the eggs are affixed to their station regardless of the future growth, which may develop with its head or tail in any direction with reference to the place of attachment.

In a paper published in 1890, Ryder, basing his argument on his (incomplete and erroneous) observations that all the embryos of a brood conform in direction to one axial plane, the heads pointing toward the light, declares that the polarity of the young is determined while the eggs are still in the ovisac of the mother. That this is not true the experimental work of Miss Clapp, as set forth in her papers of 1891 and 1899a, proves absolutely. If further evidence is needed, the reader is referred to the various photographs in this paper in which embryos early and late are shown.

Miss Clapp falls into error, however, in the first of the two papers to which reference is made where, in the passage above quoted, she states that "it is only after the young toadfish are hatched that the heads of the whole brood are turned in the same direction." During the larval period the yolk sac is attached to the inside of the egg membrane, and the possibility is suggested that the turning toward the light is effected at the time of hatching, when, according to Doctor Ryder, the attachment of the yolk sac may take place. In the second of the two papers above noted, Miss Clapp herself records the fact that the egg becomes attached at once to the egg membrane, hence such rotation is an impossibility.

Care of the nests.—When the place for the nest has been chosen and properly cleaned and the eggs laid and fertilized, the female departs, leaving to the male the sole care of the eggs and future young.

Storer (1855), quoting Ayres, says that it is the female which guards the nest. His statement is:

> That this is, in all cases, the mother of the young ones, and that she is there for the purpose of guarding them, we have no means of determining; we can only infer it.

On reading this one is led to wonder why he did not take a pair of scissors and by dissection ascertain the sex. Ryder (1886 and 1887), however, declares that—

> It is the male which assumes the care of the brood, and *seems* [italics mine] to remain in the vicinity until the young fish are hatched out and set free.

Miss Clapp (1899) confirms Ryder, and the writer can testify from scores of dissections that the guardian fish is always and only the male.

For the next few weeks the male gives himself up wholly, so far as the writer has been able to ascertain, to this parental duty. He leaves the nest, if at all, only to feed; and the strong probability is that he never absents himself during the period of incubation, getting the small amount of food necessary during this self-enforced period of inactivity by snapping up unwary minnows and crabs passing his retreat. In support of these conclusions the following facts are adduced:

While the males caught in the traps (to be described later) or found free in the water were always fat and well fed, those from nests, with the marked exception of one lot from a particular spot to which special attention will be called further on, while never emaciated nor showing signs of starvation, were not so well fed as the others. So much as to feeding while guarding nests. With regard to their not leaving the nests, the writer can affirm that he has never yet found a nest with eggs without a guarding male. The fish ordinarily resist being evicted from empty shells, but if the shells are occupied as nests with eggs, then the fish have literally to be driven out. The following incident

is typical. A *Pinna* shell nest, with valves partly open, containing a guarding male, was turned upside down and the fish "poured out" twice. The first time he came out head foremost, but braced his pectorals against the valves so as to be dislodged with difficulty. The second time he appeared tail first, but catching again by his fins and, the shell being partly in the water, swimming with his tail, he actually tried to climb back into the shell. So vigorous is the resistance offered that not infrequently many of the eggs are ruined in getting the guardian out. I recall one particularly desirable lot of eggs in early segmentation in which over 50 had been crushed. My negro collector, when asked the cause, gave the explanation above.

One more illustration is so interesting that it can not be omitted. On one occasion I visited an oyster reef which was about a foot out of water at low tide. On this were many old broken-down piles which had once formed a part of a fish house. Beneath these the fish had excavated retreats, and to the under sides were attached larvæ and unhatched eggs. As the tide fell lower and lower the water in the little pools around these "chunks" seeped out through the sand and shells, but in the score of nests examined not a single one had been deserted. In some cases there were no signs of fish, nest, or water until the "chunk" was turned over. At extraordinarily low spring tides the fish must have been left for a short time with practically no more water than enough to moisten the under side of the body, but in no case was a deserted nest found. The writer has never seen a more marked case of devotion to its young on the part of any fish.

This guardianship, as has been stated, lasts until the young are not only freed from their place of attachment, but are able to fend for themselves. I have not infrequently found nests with young showing no trace of attachment of the yolk-stalk—i. e., with this completely absorbed into the belly—which were still attended by the male, who guarded them as devotedly as ever.[a]

At what age the fish become sexually mature I can not say, but not infrequently empty shells were found inhabited by fish from 2 to 9 inches long (averaging about 6 inches). At least one 6-inch specimen was a "ripe" male, while another, 5½ inches long, proved on dissection to be a female with ovaries filled with eggs of fairly large size. As no attempt to escape was made on the part of these fish, it seems probable that the shell-dwelling habit is formed early.

There has been neither time nor opportunity in the course of this research for the writer to go into any particular study of the extensive literature of nest building by fishes, but the following interesting account has come to notice and is in all ways so parallel to that given for the toadfish that it is worth repro-

[a] There is at Beaufort a blenny which lays its eggs in shells and guards them. One dissection showed that the guardian was a male.

ducing. William Anderson Smith (1885), writing of the British suckerfish (*Lepadogaster*), says that *L. decandolii* deposits its eggs under stones and that these are watched by the parents. Of another species he writes:

> I have scarcely ever taken the ova of *L. bimaculatus* except arranged in regular rows in the empty shells of scallops (*Pecten opercularis*).
>
> The eggs are generally accompanied by the parent, curled up inside of the shell watching the progress of her progeny [the context does not indicate that the sex was determined by dissection]; and if the dredge should bring up a shell thus supplied with ova from 8 to 12 fathoms off the scallop ground, if the fish is not in the shell it is almost sure to be in the other contents of the dredge, showing that it had either come out in the capture or been watching close by.

Cleaning the nests.—Connected with the manner of feeding, an interesting thing has been noted. If bits of food put in a *Pinna* shell occupied by a toad were not eaten, the fish would take them in his mouth and "blow" them out some distance from the shell.[a] This is one way in which the nests are kept clean. Another is by the action of the pectoral and caudal fins in "fanning out" all small particles. All nests in the harbor, even in muddy water, are perfectly clean and free from sediment, as well as larger nonfixed particles.

A bit of experimental evidence may properly be adduced here. Aquariums or pans containing shells with eggs were put under running salt water. Fish were put into some (they readily adopt nests other than their own) but not into others. The eggs in aquariums with fish were invariably freer from sediment and made better progress than those which had no guardians. The fanning action could not operate at the bottom of jars 8 inches deep, and so another explanation has to be sought for. Having observed that these fish give off large quantities of mucus which sometimes comes to the surface in visible masses, I have arrived at the conclusion that this mucus entangles the sediment and thus carries it off. Let the explanation be what it may, the facts are that nests with guardian fishes were always cleaner, the eggs showed fewer losses and developed better than those without care takers.

Perhaps it was this same instinct on the part of the fish, of getting rid of all débris, that led to a very curious action which may properly be related here. On July 30, 1906, one of two fish, in an aquarium measuring 8 by 10 inches, picked up in his mouth a sand dollar 4½ inches in diameter, rose to the surface, and tried to throw it out. As the water filled the aquarium to the brim, he would have been successful had not the iron rim by projecting inward one-fourth of an inch prevented. He persisted in his attempts, however, making six or eight trials in the course of two hours. On August 1 the same fish tried the same thing over and over again.

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[a] It may be remarked in passing that the fish will not infrequently blow out the food to take it in again. From repeated observations, I am led to conclude that, since this generally takes place with pieces of fish, the toad is simply trying to get them endwise for easier swallowing.

Brooding and guarding the young.—Intimately connected with the foregoing is a habit which I have noticed repeatedly in this fish and which from its likeness to a similar action on the part of the hen may for want of a better term be called "brooding." The following incidents are transcribed almost literally from notes made at the time.

On July 9, 1907, a number of little fish detached themselves from a nest, in this instance a piece of board. At 11 p. m. the male in the aquarium with them was lying on the board and with spread-out pectorals was brooding the young which hovered under these fins and under his body. When I put in my hand he threatened to bite. On July 13 this board with a number of larvæ still adherent and with a good many free little fishes hidden in holes made by the shipworm, *Teredo navalis*, was removed for examination, whereupon the male stood up on his jugularly placed pelvic fins in a manner familiar in the blennies and young of the sea bass (*Centropristes striatus*), and looked searchingly around, the free young left behind playing under him and between his pelvic fins. On the following day, when the board with the young was again taken out, the adult again went through the same performance, but became perfectly quiet when the board was put back. On the succeeding day, when the board was taken out, the fish tried to bite me. Then he stood on his pelvic fins and literally glared at me with mouth open and teeth showing in a very vicious manner. At this time the toadlets were collected mainly under him and between his pelvics; some, however, were on his head, and one swam into his mouth and then out again.

The nesting habits of this fish and the fixation of the ova are undoubtedly brought about by the great size of the eggs. If these huge eggs were set free in the water, by virtue of their lack of any buoyant apparatus, they would at once sink to the bottom, where, because of their large size and striking (yellow) color, they would attract enemies without number. Further they must adhere to these nests, since the nests are found in shallow water where waves and tides, acting freely on them, would, because of their great bulk, if they were not attached, quickly carry the eggs out of the nest, and so they would be lost.

Correlated with this large size and fixed condition of the ova and larvæ are the large size and great activity of the young when set free. The salmon egg is about the same size as that of the toadfish, but the salmon larva when set free is burdened with a great mass of yolk, which hampers its movements and makes it an easy and attractive prey to its enemies. The little toadfish when detached differs from its parents in magnitude only, and by reason of its large size, finished body, and great activity, can at once begin an independent life.

Silas Stearns's observations (quoted by Goode, 1884) go further than the writer's in the matter of the fishes guarding the young. They are so interesting and circumstantial that they are given here.

When its young have been hatched, the older fish seems to guard them, and teach them the devices of securing food in much the same manner as a hen does her chickens. I have spent hours in watching their movements at this time, and was at first much surprised by the sagacity and patience displayed by the parent fish.

ATTITUDES AND MOVEMENTS.

In 1906, attitudes of standing on pelvic fins were seen to be assumed by fish which were not guarding nests. The fish previously referred to as trying to rid its aquarium of a sand dollar repeatedly postured in this fashion. At a little later date a number of fish assumed the same attitude. Again a large fish (not one of the above) not only stood up on his pelvics, but deliberately yawned, gaping his mouth widely. In the earlier instances cited, the taking of this attitude seems to have been in anger at the removal of the nest and for the better protection of the young by admitting them under the body; in the last case it was probably assumed as a part of the yawning action of the fish. (That fish yawn, the writer can testify from repeated observations; even larvæ with still adherent yolk sacs do so.) For the other instances no explanation is at hand.

Other curious attitudes also were assumed by the fish. One fish in a round aquarium was seen to lie for two hours on his side with his belly against the glass. On the next day the same fish stood on his tail between a large bottle and the wall of the aquarium, and, with his belly against the glass and his mouth nearly closed, breathed through the right gills only. This continued for some hours. The closest scrutiny could detect no motion whatever of the left operculum. This fish and his companions were quite tame and were handled with ease and safety. On the next day both stood on their tails, bellies to the glass, heads laid back, and gill covers barely moving. One of these fish (recognized by a spot on his dorsal) was the one whose yawning has just been described.

Again, two other fish in another aquarium, seven days later, stood vertically, resting on the roots of their caudal fins, clinging to the glass by the fleshy parts of their jugularly placed pelvics. Later, one of these stood on his tail (bent about midway between anus and caudal), and touched the glass with the barbels of his lower jaw only, occasionally moving his pectorals gently. Again, one of these two, some days later, stood vertically clinging with pelvics to the glass, with his caudal fin gently sweeping the floor of the aquarium. Many of the fish were given to lying with the caudal bent abruptly upward at an angle of at least 45 degrees. As to why these attitudes are assumed, the writer has no conjectures to offer.

I have seen a fish crawl into a tin can, seemingly only large enough for his head, and then turn around until both head and tail projected from the opening, the tail perhaps partly covering the head. The fish were fond of crawling into shells or empty Mason jars and then reversing ends until only the head was visible.

Sometimes they would back in until only the head remained uncovered. Storer (1855), probably quoting from Ayres, describes this attitude well. He says:

> If we approach this (cavity) cautiously, we shall probably distinguish the head of the toadfish very much in the position of that of a dog as he lies looking out of his kennel.

In nature the fish are solitary rather than social in habits, but in the aquarium they herd together and lie heads on each other like a lot of pigs. Gill (1907) has well described this habit, and I can not do better than quote him, as follows:

> Where many are together, they may congregate in a heap in some retired nook. The crowding together of many individuals just alluded to is a characteristic habit in aquaria at least. The toadfish is not a schooling or social animal as generally understood, but there are very few others who will associate as closely as it does. All the fishes in a toadfish aquarium may occasionally be found massed together in a regular heap, as close together as possible, in some selected corner, some on top of others. In such positions some may remain quite a long time (perhaps an hour even) and most of them scarcely move; there will be often some restlessness, nevertheless, and from time to time one or more may leave and swim about or possibly seek another corner.

This description is as accurate as a photograph.

Doctor Gill further writes:

> When at rest its attitude is quite characteristic; its head is somewhat tilted, sometimes supported by a stone, a sloping decline of sand or mud, or, it may be, on the body of a companion. The fins, unlike those of most fishes, are often maintained erect, the first as well as the second dorsal being completely upraised, while the caudal may be almost folded; the pectorals are near the sides, but with the lower edges everted and borne on the ground; a slow movement of inspiration and expiration is kept up, the jaws being very slightly open and moved, and the gill membranes slightly puffing and collapsing in harmony; otherwise the fish is motionless. Different individuals, however, may assume very diversiform attitudes, and some coil themselves up so that the tail touches the gills or, maybe, is tucked under a pectoral fin.

All of these attitudes I have seen scores of times.

To a very slight degree the toadfish moves by crawling, using its jugularly placed pelvic fins for this purpose. It may swim, using either pectorals or caudal, or both. When using the pectorals only, the caudal is held still and the motion is slow. The most common mode of progression is by the use of the caudal, helped by the long dorsal. With each right or left stroke of the tail an undulatory movement is set up in the dorsal, which aids materially in propelling the fish forward. This gives the whole body a wriggling motion, as is well portrayed in Le Sueur's (1819) figure, reproduced on page 394 in Doctor Gill's (1907) article.

FEEDING HABITS.

Food.—The toadfish is omnivorous; "all is grist that comes to his mill." But the pièce de résistance of his daily fare is crab, young molting blue crab preferred; any crustacean will do, however, or fish, or almost any kind of offal.

In 1907 a fish trap was hung off the wharf and kept baited for toadfish. There were caught, almost daily, numbers with bellies enormously distended with fish swallowed while in the trap. On being put into the tank the toads disgorged pieces of fish of such large size that one wondered how they could have been swallowed. One giant toad had his belly swollen balloon-fashion to such an extent that for two or three days his tail parts floated high in the water (nor could he get them down) while his nose rubbed the floor of the tank. He finally, however, got rid of both food and gas and seemed to be none the worse for his experience.

On the trip to the oyster rock holding the old log remains of a fish house, elsewhere referred to, large numbers of toads (about 25) were found under the rotting logs partly imbedded in the sand and shells. These fish all had distended abdomens, leading me to hope that some of them at least were ripe females; but under pressure they gave out blue crab remains either at one end or the other. Those that were brought in and dissected proved to be males, the distension in all cases being due to crabs. These were the only guardians I have ever found that were particularly distended with food. That they were so well fed is doubtless due to the fact that as the water receded the crabs sought shelter under the very logs which concealed the toadfish, their worst enemies.

Capture of food.—As to the manner in which the toadfish catches its prey, Silas Stearn's description, as quoted by Goode (1884), is so accurate as to leave nothing to be added:

> It secures its food rather by strategy and stealth than by swiftness of motion. Hiding under or behind stones, rocks, or weeds, or stealing from one cover to another, it watches its victims until the latter are near by, when it darts forth with a quickness quite astonishing, considering its usual sluggishness, and back again to its hiding place, having one or more fish in its stomach and on the alert for others.

Linton (1901) notes that its alimentary canal is chiefly filled with crustacean and molluscan remains and the bones and scales of fishes.

The mouth of the toadfish is eminently fitted for the catching and reception of the kind of food described above. The buccal cavity is enormous, as might be inferred from the size of the great, broad, blunt head. The gape of the mouth is very large and the powerful jaws are filled with bluntly conical teeth (as first noted by De Kay (1842) and later (1855) by Storer) with which the fish can inflict a rather severe and painful bite. Incidents to illustrate the action and utility of the mouth and jaws appear in the following paragraphs.

Disposition.—The toadfish is commonly credited with having a savage and even vicious disposition, an impression which is to some extent due to its unprepossessing appearance. After a somewhat intimate acquaintance with more than 100 individuals, however, I find that, like other animals, some are of good

disposition and some of bad, and, moreover, that given individuals are even subject to moods, as incidents related below will show.

Toadfishes that have been teased always snap viciously at everything near them which moves. A 9-inch specimen after such treatment clinched his teeth so tightly on a bit of oyster shell that he was by it lifted out of the water and into a bucket. Ayres (1842) records a similar experience in the following words:

> One which I caught the last summer and kept for some time would snap fiercely at the finger or a stick held toward him and would sometimes allow himself to be lifted out of the water before he would loose his hold.

I have several times been bitten by these fish so that the blood came slightly; but the teeth are not sharp enough to draw blood ordinarily. Toadfish never hold on when they bite, but snap and let go. Though very sluggish, in biting they move faster than the hand and almost faster than the eye.

Some of the toadfish always remained vicious, others, after being in captivity awhile and fed by hand, became quite tame, some so much so that I could handle them with impunity. Those guarding the nests were more apt to bite than the nonguardians. If the nest, e. g., the shell with the affixed eggs, was taken from the aquarium, the fish was apt to become restless, and if the hand was put in the aquarium, he was likely to snap viciously at it. I have a note of a particular case in which this happened, but immediately thereafter the fish let himself be taken up in the naked hand and transferred to another aquarium. Another fish kept for some time in a tank 3¾ by 7¾ feet became so tame that he allowed me to handle him freely, to carry him in my naked hands to the camera 40 feet away, and to adjust him under it.

While these examples are specimens of the conduct of the fish in general, it is necessary to say that some were vicious, always snapped if they got a chance, and if not, always showed their teeth ready to bite if one came near. Goode (1884) formed a very favorable opinion of the fish, for he says:

> Although it is armed with by no means insignificant spines, which are capable of inflicting serious cuts, when touched they show no disposition to bite, but erect their opercular spines in a very threatening manner.

Feeding in captivity.—Nowhere do the varying dispositions of these fish show more plainly than when they are being fed. Considerable numbers of them were kept, and it was necessary to feed them when one could, for, in captivity, because of their inactivity, they mostly feed sparingly and at irregular intervals. Some, however, fed eagerly, swimming out from their retreats when oysters or bits of fish were thrown into the tank. For those not so tame a different method had to be pursued or some would probably have starved. These would snap a piece of fish held before their mouths in a pair of forceps. Some, however, could only be induced to eat by rapping them over the nose with the

forceps, at which they would snap and take the oyster or piece of fish. One fish, after several days of this kind of experience, would gently close his mouth on the end of the forceps and pull the meat off, or finding none there would (especially if his head had been stroked or tickled with the forceps) close his mouth gently and let go without manifesting irritation.

To sum up the whole matter, my experience is that even such vicious fish, as many of these are, can in the majority of cases be tamed, if they are not teased or otherwise unnecessarily disturbed, if they are fed regularly and by the same person, and if they are not handled roughly and punished when they bite. Further, confinement and hunger are factors which must play a great part in taming fish. Fish guarding shells with eggs are much more likely to bite than those in empty shells, even though ordinarily they may be handled with impunity.

Fighting tendencies.—The toads are very much given to fighting among themselves. On one occasion a big fellow twice tried to swallow one slightly smaller than himself, and had gotten him down as far as back of the eyes, when by catching each by the tail I separated them. After the second separation they remained quiet, the smaller seeming not much worse for the experience. Six days later my attention was attracted by a great commotion in the tank, and I found that a large fish had clinched a smaller one as above described, and so determined was he that he let go only when struck repeatedly on the head with a piece of iron pipe. These were presumably the same pair as the above. Linton (1901) records a similar occurrence as follows:

> I have seen a toadfish in the aquarium in the act of swallowing another of its own species but little smaller than itself.

He also notes finding a partly digested toadfish in the stomach of another.

Just in proportion as the fish were well fed their propensities for fighting increased. During the first week in July, 1907, quite a number were in the large tank elsewhere referred to and were a lively lot. They were especially active at night after the lights were out and the laboratory was deserted. On coming in late at night, not infrequently a tremendous splashing could be heard, and, on striking a light, the fish could be seen fighting all over the tank. Morning after morning the floor around the tank would be wet with water thrown out in their struggles. So far as observations went, there was no attempting to swallow, but simply clinching and breaking away. This was again noted the last week in the same month.

DISEASES.

So far as the writer has been able to ascertain, the toadfish, because of his retiring manner of life, has both few enemies and few diseases. The latter are

chiefly due to parasitic worms, entozoa. From their omnivorous habits the fish are especially subject to these. About 40 per cent of the 48 examined by Professor Binford in 1908 were infected with *Ascaris*. Linton (1905) in his "Parasites of the Fishes of Beaufort" reports the examination of 135 toadfish. From these he obtained more than 190 nematodes, about the same number of cestodes, and more than 100 trematodes. The nematodes are all of one species (*Ascaris habena*), the cestodes of five genera and as many species, and the trematodes (so far as identified) of three genera and three species. Examination of Linton's other publications will show that toadfish in other localities are similarly infested.

In the course of this research it was not infrequently noticed that some of the toadfish kept in confinement had "pop-eye." Whether these fish were thus affected when captured, or whether the trouble originated in confinement, can not be stated, but it should be noted that other fish, kept in the same tank at the same time, and large numbers of various kinds of fishes kept in running water under the writer's care during the five preceding summers, showed no symptoms of this disease.

Direct evidence is at hand, also, to show that wild fish have the same trouble. On July 7, 1907, there was taken in the trap hung off the wharf a large toad which had either the conjunctiva or cornea [a] of its eyes enormously distended, projecting one-half to five-eighths inch in front of the iris. One other fish caught at the same time showed a slight distension of the eye covering, while others had eyes perfectly normal in this respect. Pressure applied by means of a pencil to the eye showed that whatever caused the distension gave the membrane great firmness. Neither the distension nor the pressure of the pencil seemed to cause the fish discomfort, for only after an appreciable length of time did he move away, and then in an undisturbed manner. This was not that form of exopthalmia in which the whole eye is pushed out of the socket. The distending substance was evidently between the eye proper and its outer covering.

On July 10, 1907, two fish were taken from the trap at the wharf. Both these had their caudal fins blood red in those parts where the pigment was not so dense. Whether or not this indicates disease the writer can not say, but it is not an altogether uncommon phenomena among fishes, as he has noticed it in other forms, *Lepisosteus*, for example. At the time it was thought that maybe it indicated sexual maturity, as noted in *Lepidosiren* by Kerr (1900), and dissection showed that one, a male, was breeding, while the other, a female, had eggs nearly ripe enough to flow from the ovary.

[a] I unfortunately did not dissect to ascertain which.

VITALITY.

The vitality of toadfish is extraordinary, almost equal to that of the Reptilia. Incidents might be multiplied, but two will be sufficient to make clear this assertion. Before dissecting them it was my custom first to cut through backbone and spinal cord back of the head, and sometimes in addition to "pith" them. On June 28, 1907, this double operation was performed on a number of fish, which nevertheless during the operation and afterwards opened and closed their mouths, erecting their spinous dorsals, expanded their pectorals, and gave forth the curious sound made by the air bladder, which may be most nearly rendered "oonk" or "koonk." This sound was made by one or more fish while the air bladder was being removed.

While the above paragraph was being written, a toadfish whose spinal cord had been cut, whose belly had been ripped up, and whose stomach had been opened, was brought to me. It was put in a dry dish and set aside. When opportunity offered, some three or four hours later, I took it up and began examining its mouth to get the exact shape of its teeth; whereupon it snapped at my fingers half a dozen times. Goode (1884) remarks on this subject:

> They are very hardy, and when taken from the water will lie for many hours, and soon recover their ordinary activity when restored to the water.

Ayres (1842) had one live for twenty-four hours without water after it had been taken with the spear.

WINTER HABITAT.

What becomes of the toadfish during the winter the writer can not say. According to Ayres (1842) they go into deeper water, bury themselves in the mud, and remain in a torpid condition until spring. Goode (1884) says:

> The bottom temperature of the water frequented by these fish would appear to range from 50° F. to 90° F. In the more northern regions throughout which they are distributed they appear to become torpid or nearly so in winter, and it is stated by Storer (1855) that they are frequently found in the mud by men spearing eels.

SOUNDS.

As indicated in the paragraph on vitality, the toadfish makes a definite sound which may be fairly rendered verbally by "oonk" or "koonk." These sounds are produced by the contraction and relaxation of muscles connected with the air bladder, which has been figured and its structure described by Sörensen (1884). This paper the writer has not had an opportunity of consulting, but Doctor Gill (1907) reproduces the figure and translates from Sörensen, as follows. (The air bladder is small, U-shaped, and hence nearly doubled, the paired limbs of the U projecting anteriorly.)

Above, the division extends backward half as far again as on the underside. The inner surface of the air bladder presents no projecting membranous partitions or the like. The outer membrane is strong, tough, fibrous, and rigid; the inner somewhat thicker than usual. On the sides of the air bladder are found a couple of large muscular bands, especially thick behind, which cover more than half the surface of the organ. On the underside they do not extend as far toward the middle as on the upper surface, where they meet behind. The muscular fibers run transversely but at the same time somewhat obliquely backward (on the ventral side beginning at the middle, on the upper side toward the middle); toward the hinder end of the organ the fibers gradually run transversely. The pleura is strong, but rather thin; it is, however, thicker on the back side, where the muscle bands meet.

With this air bladder the fish is enabled to make the sound above noted, and which is variously rendered as "oonk," "koonk;" or "ung," "kung." The note or sound is always given twice, "koonk-koonk." The fish in the laboratory rarely make this sound, which has considerable carrying power, save at night or when caught and carried about (generally wrapped in a towel for precaution's sake).

ECONOMIC VALUE.

Those who have eaten this fish pronounce the flesh not unpalatable. Rafinesque (1818) says that the fishermen "don't reckon it good to eat, and often throw it away on the beach, yet it is as good as the different species of Phycis or Cusk." De Kay (1842) affirms that it "finds no favor with the fishermen, on account of its unsightly appearance; its flesh, however, when properly cooked, is well flavored."

Storer (1855) writes on this subject as follows:

> The toadfish is not commonly employed as an article of food. Its generally repulsive aspect causes it to be looked upon rather with disgust. That its flesh is delicate and good, however, can scarcely be questioned, though the small size which it attains and the fact that it is never taken in any large quantities prevents it from being of any economic value.

Goode (1884) took a more optimistic view of the commercial possibilities of this fish. He writes:

> The toadfish may be regarded as constituting one of the undeveloped resources of our waters, and it can scarcely be questioned that in future years it will be considered as much more important than at present. No estimates can be given as to the quantity now yearly entering into consumption, and, since it is almost never offered for sale, no price quotations can be presented. Professor Baird also bears testimony to the fact that its flesh is very sweet and palatable, and Mr. Stearns states that its flesh is highly esteemed by many of the Gulf fishermen.

Bean (1891) does not seem to think so highly of it as a food fish, for he dismisses the subject by saying:

> The species is not an attractive one, and although the flesh is sweet and palatable, it is never eaten.

Gill (1907) found it good eating.

So far as the writer knows, this fish is never eaten at Beaufort. In July, 1908, he had some served at the laboratory mess and, discounting prejudice resulting from the unprepossessing appearance of the fish, its flesh was not only not unpalatable but was distinctly good, as good as or better than the majority of bottom fish caught in the harbor. But however good its flesh, Goode's prophecy for this fish can never be realized, because of the small size of the individuals, the limited numbers in which it is caught, and not least because of the great number of bones due to the presence of the long dorsal and ventral fins.[a]

LIFE HISTORY.

The life history properly begins with the formation of the male and female germinative products, the sperm and the egg, but before describing them it will be best to describe the organs of reproduction, the testis and the ovary, respectively, as found in the adult "ripe" fish at the other end of the life history.

ORGANS OF GENERATION.

The ovary.—This is fashioned after the ordinary teleostean type, as may be seen in figures 1 and 2, plate CVII, both of which are natural size. Figure 1*C* is of an unripe ovary which had been preserved in alcohol and photographed in the same. Figure 2 is a ventral view of an ovary excised from a pithed fish and photographed in water *alive*. Anteriorly it is bifurcated into two lobes, which join behind to form the short oviduct by which the eggs are carried to the exterior through the genital pore opening just behind the anus. In figure 1 the anus is shown and to the left of it one of the paired halves of the urinary bladder.

When the eggs are ripe, the ovarian walls are very much distended and semi-transparent, as shown in figure 2, where the large eggs are plainly visible, as are also the small ova—probably of next year's crop—lying between. The fine dark lines running over the ovary are blood vessels with which this organ is abundantly supplied. Extending lengthwise of the left lobe is a strand of tissue which seems to be a raphe. At the anterior end of each lobe are to be seen the remnants of the tissues by which the ovary is tied to the other organs. Internally each lobe is a hollow tube the walls of which are covered with ovarian eggs.

The ovarian eggs are inclosed each in its own short-stalked follicle, which is richly vascularized. When the process of spawning takes place, the eggs burst the follicles and fall into the lumen of the ovary and thence pass to the

[a] Hargreaves (1904), writing of the allied *Batrachus surinamensis* of British Guiana, says that although its outward appearance is very much against it yet it "has the reputation of being the most delicately flavored fish in the whole colony."

exterior as described above. The eggs when extruded have the adhesive disk by which they become affixed to the nest. The formation of this disk and the manner of fixation of the eggs are points on which the writer is unfortunately able to give no information. The eggs are very large, measuring from 4 to 6 millimeters in diameter, the average being about 5 millimeters, as stated by Miss Clapp (1891 and 1899) and by Ryder (1886 and 1887).

The testis.—This organ, like the ovary, consists of paired elongated glands lying in the posterior dorsal part of the body cavity. They are confluent behind to form the sperm duct, which opens in the same place and manner as the oviduct. *A* and *B*, figure 1, plate CVII, show the dorsal and ventral surfaces of the ripe spermaries of a full-grown toadfish and are natural size. The long lobulated organs are the testes, the roundish dark structures are the paired lobes of the bladder, while the short whitish bodies (placed posteriorly and reaching right and left) are accessory glandular structures whose function is not known.

The spermatozoan is very large. The head is round in front, nearly as broad as long, flat behind where it joins the middle piece, which is almost as large as the head. The tail is not very long and the motion relatively slow. The sperms resemble nothing in the world so much as tadpoles with very large heads, and bodies but little smaller, behind which extend thin tails several times longer than the head and body combined.

FERTILIZATION AND EMBRYONIC DEVELOPMENT.

Natural fertilization.—The manner in which fertilization is effected in nature is not known, but it is interesting to note here the correlation between the size of the micropyle and the sperm. The former is so large as to be visible to the naked eye.

Artificial fertilization.—Neither Miss Clapp (1891 and 1899a), in her experimental work on the egg of the toadfish at Woods Hole, nor Miss Wallace (1898) had any trouble in artificially fertilizing the eggs, since ripe males and females were readily obtainable. At Beaufort scores of fish were dissected by the writer in the course of this research during 1906 and 1907, but while ripe males were abundant not a single ripe female was obtained. Fish were caught all over the harbor, the extreme points of capture being 3 to 3½ miles apart. On July 18, 1906, in a tank of fishes from Cape Hatteras, I received 12 toadfish. Two were given away, the sex of one could not be determined macroscopically, nine were males, and one was a female with immature ovaries. At Woods Hole females are more abundant than males, I am informed by Mr. Vinal N. Edwards.

During the summers of 1906 and 1907 not a single ripe female was captured, and but two with ovaries anywhere near maturity. One of these ovaries is shown in figure 2, plate CVII. The other was in about the same stage. On June 22, 1908, Prof. Raymond Binford, of Guilford College, N. C., in searching for *Ascaris*, killed a 6¾-inch toad which on dissection proved to be a female with ripe ovaries containing about 40 eggs. The ovaries were opened and the eggs were run into fresh salt water. A ripe male being at hand it was quickly opened and the testis was minced up and parts put into the same dish with the eggs. After about ten minutes the water with the minced-up testis was poured off and the eggs covered with fresh clean water.

Fertilization was effected about 12 noon. The eggs at 6 p. m. were in the 4-celled stage. Segmentation must have begun about 5, possibly as early as 4.30. At Woods Hole, Miss Clapp (1891 and 1899a) found that segmentation began seven hours after fertilization (artificial) was effected. In the above experiment, segmentation began within four and one-half or five hours after the eggs were impregnated. The explanation is undoubtedly to be found in the great difference in the temperature of the water. Miss Clapp does not give the temperature for her experiments, but at 3.15 p. m. on the day referred to a thermometer hung in running sea water in the Beaufort laboratory registered 81° F. In this difference in temperature of the harbor water at Woods Hole and Beaufort is also to be found the explanation of the ease with which Miss Clapp could get ripe females and of the difficulty I experienced in getting even one.

Owing to the low temperature at Woods Hole the breeding season for the toadfish is restricted to a comparatively short time. Dr. Raymond C. Osburn, of Columbia University, at my request, has carefully gone over the Woods Hole records. He writes me that they show that spawning goes on during the month of June only (except of course in some few sporadic cases), beginning sometimes as early as the first week in June. He writes that the most extensive and authentic records have been made by Mr. J. T. Patterson, who notes that in 1906 the spawning period extended from June 12 to June 25. Speaking for himself, Doctor Osburn says:

> It is my own experience that the eggs are mostly hatched by the first week in July; that is, they have broken the egg membranes. I know this because I have often looked for them here after coming the first of July, and I have never yet succeeded in finding eggs that were entirely fresh at that time.

In a letter to the present writer, dated July 24, 1906, Vinal N. Edwards, the veteran collector of the Fisheries Laboratory at Woods Hole, says that he does not find any toadfish with eggs after the first of July. He adds, however, that in the fall, when he sets his fyke nets, he catches large numbers of large fish full of spawn, but they carry it all winter.

Some older records for the Woods Hole region are as follows: Storer (1855) found eggs or young in June, July, and August; Goode (1884), at Noank, Conn., in 1874, founds eggs on July 14, and young one-half inch long on July 21, which had, on September 1, reached a length of 1 inch. Ryder (1886) says:

> Oviposition occurs about the middle of July in the latitude of Woods Hole. How long it lasts has not been determined, but judging from the condition of the roes and milt of the adults at that time, it seems probably that they do not spawn later.

According to Bumpus (1898):

> Oviposition occurs as early as June 3, and it may occur at any subsequent time throughout the month.

The higher temperature at Beaufort, however, allows the breeding season to be long drawn out. I have found advanced embryos the first week in June and eggs in segmentation late in August. Thus the spreading out of the time of oviposition makes it easy to find spent females and correspondingly hard to find ripe ones. I may add that no other ripe females have been found this season (1908).

Formation of the germ disk.—The germ disk was quite definitely formed as a fairly distinct white patch about three hours after impregnation. The streaming of the protoplasm to form this was in part preceded and in part accompanied by the collecting of yellow oil globules at the micropylar region. These oil drops, some large and some small, form in a layer under and visible through the germ disk in just the same fashion as the writer found in the egg of the pipefish, and as has been reported for a large number of teleosts. For a discussion of the matter see Gudger (1905). Miss Wallace (1898) also reports oil globules in the egg of this fish. The streaming of the protoplasm continues after the segmentation has begun, thus the germinal disk grows constantly larger for awhile by these additions of protoplasm. Ryder's (1886 and 1887) error in saying that there are no oil drops in the eggs of the toadfish is hard to explain save on the supposition that they disappear by the time those stages on which he worked are reached.

Segmentation.—As already stated, segmentation begins seven hours after fertilization at Woods Hole, five hours after that act at Beaufort. The germinal disk divides in a vertical plane into two cells, then along another plane, at right angles to the second, into eight cells. The segmentation into two and four cells results in blastomeres about equal in size and symmetrical in place. But beginning with eight cells and continuing on until division is ended, the segmentation is very irregular, growing more so with each division.

Notwithstanding the large size of the yolk, the blastoderm never piles up high with a clearly defined circumference as is found in the Salmonidæ, whose eggs are about the same size, and as the writer found to be the case in the pipefish (Gudger, 1905), whose eggs are only one-fifth (1 mm.) as large. On the

contrary, even during the early stages of segmentation—8, 16, and 32 cells—the blastoderms flatten out, the cells on the periphery presenting an appearance which can only be likened to that taken by a pellet of soft mud when thrown against a smooth wall. To say that the blastoderms present an extraordinarily irregular appearance, but feebly expresses the fact. In some cases it looks as if the segmentation had begun at the center and worked outward, as Watase (1891) has shown in the squid. The explanation of the whole matter is to be found, I think, in the fact that segmentation begins before the flow of the protoplasm into the germinal region has ceased.

To the best of the writer's knowledge, the only work other than experimental done heretofore on the segmentation of the egg of the toadfish is to be found in Miss Clapp's paper published in 1891. Here she figures stages from two to sixteen cells, inclusive, the later blastoderms being very irregular.

Figure 3, plate CVIII, shows the right valve of a *Pinna* shell containing eggs in segmentation one-half natural size. This reduction was made in order that this half of the nest might be shown in its entirety. The photograph portrays a nest typical in all respects, the irregular manner in which the eggs are affixed, the crowding together—some eggs being on top of others as cannon balls are piled—and last, but by no means least, the fact that the eggs are in two stages. For the most part they are in late segmentation, but on the upper right-hand part of the shell some two dozen are still in early division, as the small size and somewhat rounded outline of the germinal disk show. Figure 4, plate CVIII, shows another nest with eggs in segmentation intermediate between the two stages shown in the previous figure. Here the eggs are shown twice their natural size in order to bring out details more clearly. Recalling to the reader's attention the fact that the micropyle is practically always found opposite the point of attachment of the egg, it is interesting to note that some of the blastoderms are not "opposite the point where the ovum is attached" as Ryder (1887) states, although this is generally true. Of especial interest is the fact that there are in this nest some half dozen eggs with divided blastoderms. Should these have come to maturity it is my opinion that they would have formed twins. (For a much magnified figure of such a blastoderm see the writer's paper on the pipefish, 1905, plate VI, figure 26, and for the histology of the same, plate VIII, figure 54, and plate IX, figure 55.) Miss Clapp, in the paper referred to in the preceding paragraph, figures such a divided blastoderm in the 8-celled stage.

Invagination.—The next stage in the history of the eggs whose development we are studying is that in which, segmentation having ended, the blastoderm flattens out into a thin cap of cells covering about one-fourth the upper half of the egg. Shortly thereafter it is the rule in teleost eggs that the edges of this protoplasmic cap begin to turn in under the cap and between it and the yolk. Technically this is called invagination, the in-pushing cells making a distinct

rim to the edge of the cap and inclosing a clearer space known as the segmentation cavity. This condition of things, however, does not seem to exist in the egg of the toadfish.

Miss Wallace (1898) has shown in a short but highly interesting paper that there is no true invagination in this egg, but that the apparent thickening, the appearance of a germ ring or invaginating blastoderm, visible as the protoplasmic cap grows down over the yolk, is due in part to an ingrowth of cells from the ectodermic layer, but chiefly to the greatly thickened periblast filled with giant nuclei.

The writer regrets that he can present no photograph of this stage, as these structures can only be brought out clearly in eggs killed for the purpose, while his photographs are all of living eggs. He has had no opportunity to verify by means of sections the conclusions above stated. Eggs properly "killed" seem to show a very distinct germ ring, and, had he had not been aware of Miss Wallace's work, the writer would, from surface views, unhesitatingly have described the condition as a case of invagination.

Formation of the embryonic shield.—The cap of cells described above continues to spread over the upper hemisphere of the egg, growing thinner all the while. Presently at one point on the rim there appears a slight flattening tangential to it, causing the cap to become bilaterally symmetrical in one plane only, this plane being the axis of the future embryo. According to Miss Clapp (1891), the notch or bay described below is formed at the central point of this flattening during this stage. So far, however, as I have examined my material I have found nothing to corroborate her statement. No photograph of this stage is presented for the same reason as given above.

Differentiation of the embryo.—During all the events described above the blastoderm has been growing larger and extending over the yolk. After passing the equator of the egg, the opening, the morphological blastopore, grows smaller and eventually closes. Growth seems to go on less rapidly at the posterior end of the axial thickening—i. e., that connected with the rim of the blastoderm, the anterior free end extending out into the center of the cap—which results in the formation of a little bay at the hinder end of the forming thickening. Then, as the spreading of the cap over the yolk continues, the blastoderm grows backward away from the embryonic rod, leaving it connected with the edge of the cap by a slender cord of cells. This formation of the embryo is, I believe, peculiar to the toadfish. It was first demonstrated from surface views by Miss Clapp (1891), whose work was verified and extended by her pupil, Miss Wallace (1898), who cut sections of the egg in this stage.

At Woods Hole the axis of the embryo first becomes visible on the seventh day, according to Miss Clapp (1891). Miss Wallace (1898), however, detected an "axial thickening" on the fourth or fifth day. Artificial fertilization not

having been effected at Beaufort, I can not give the time definitely; but from three separate broods of early eggs found in the harbor it can be stated that between forty-eight and sixty hours after impregnation the embryonic axis begins to form.

These structures are for the most part too delicate to be shown in photographs of living eggs. Figure 5, plate CIX, shows the board nest frequently referred to. It contains eggs in two stages of development, spreading blastoderms and rod-like embryos, and likewise the crowding always found in the eggs of a large nest. The board and eggs are natural size and all the eggs are shown save a few at each end. If studied with so low magnification as that afforded by even an ordinary reading glass, the young embryos, as yet possessing no trace of fishlike characters, may be seen as axial rods. Close scrutiny will reveal the fact that one end—the future head end—is slightly larger than the other.

Figure 6, plate CIX, shows half natural size another board nest of large size. The embryos here are considerably older than the preceding. The head end has noticeably enlarged, the ventricles of the brain are visible (under a low power), the eye vesicles are forming, the pectoral fin buds are not visible but are clearly marked off at this stage. In short, the embryonic fish is outlined.

Even a momentary glance at the positions of the embryos will completely negative Ryder's (1886 and 1887) statements that the embryos "invariably" point in one direction.

By taking the nests out of the aquariums and examining them from day to day the development can be followed step by step. The eye vesicles are formed, the blastopore closes, the pectoral fins grow in size, the tail becomes free, the heart is formed and begins to beat, a vascular system is formed and spreads over the yolk, and, finally, growing dissatisfaction with its narrow quarters is expressed by the little fish through writhings and shiftings of the tail from side to side.

THE LARVAL TOADFISH.

Early stage.—The condition of things described in the preceding section is not destined to continue longer. Presently the time arrives when, the shell having grown weak (rotten is the way my notes put it in numerous cases), the little fish bursts that part over its head and, taking in a mouthful of salt water, passes this back over its gills and is ushered into a new world as the just-hatched larva of the toadfish.

Usually the shell bursts first over the head and back, setting the head parts free; then the split, continuing backward, sets the tail free. Sometimes, however, the shell bursts over the tail first. In this latter event one will see a wildly waving tail, which by its lashings continues the split forward and uncovers the head. Eventually the shell splits down in several directions and not only uncovers the embryo but the upper half of the yoke as well.

As clearly as I can determine (artificial fertilization not having been possible), the bursting of the shell takes place eleven days after fecundation. Ryder (1887) says that on Chesapeake Bay the incubatory period lasts from ten to fifteen days. According to Patterson (quoted in Osburn's letter to the writer): "In 1906 young fish at Woods Hole broke the capsule in twenty-six days." The difference in the time of hatching at Woods Hole and Beaufort is plainly due to the difference in temperature of the water, the higher temperature at the latter place greatly hastening development.

Figure 7, plate CX (one-half natural size), shows one-half of a nest of eggs in the early larval stage. Whether it is a photograph of the shell shown in figure 3, plate CVIII, I can not say positively, since my records are not clear on this point, but I believe that it is. The tadpole-like appearance of the young spoken of by writers is very apparent. As in most shell nests at this stage the embryos point in one general direction, but toward the hinge rather than the opening of the shell, and consequently away from instead of toward the light, as Ryder (1886 and 1887) positively asserts.

Figure 8, plate CX, shows the same board nest shown in figure 5, plate CIX, and represents the larvæ in natural size and in a stage of development slightly older than the preceding. Here the embryos point in all directions, as stated in the first part of this paper. The tadpole-like structure is very apparent, due to the broad, flat head with its opercular flaps, just back of which are the pectoral fins, the largest organs with which the fish is provided at this stage of its development.

There may be plainly seen in this figure the empty shells still adhering to the nest. The eggs have either died and been removed to prevent the spread of disease or they have been taken away for preservation in alcohol for further study. The empty shells with the adhesive disks are very resistent to decay, but finally the gluey substance by which they are affixed becomes loosened and they may readily be removed.

The pectoral fins have been referred to. Their formation precedes in time and position the formation of the pelvics. These latter originate at this period as two folds just back of the pectorals. As the fish develops these become "translocated," as Ryder (1886) puts it, to their permanent jugular position. Both Ryder (1887) and Miss Clapp (1899) have figures of the just-hatched toadlet which show these fins and also make clear the fact that there is no definite caudal fin at this stage. Miss Clapp's admirable drawing of this stage has, however, three serious defects, i. e., the larva has neither mouth nor gill slits, both of which in a very rudimentary condition are present, and the extremity of the tail turns downward instead of upward, as Ryder correctly shows.

Under favorable conditions the embryos make steady progress. The head and mouth parts grow more perfect, the gill covers and pectorals become more

thoroughly functional, the vascular system spreads over the yolk and brings in digested food with the concomitant rapid enlargement of the embryo, the pelvic fins rapidly grow forward to their permanent position, and the other fins, dorsal and caudal, are formed. Presently the bands and markings begin to appear faintly. The embryos, which at the beginning of this stage looked more like tadpoles, larval frogs, than larval fish, now begin to look not merely fish-like, but decidedly toadfish-like.

Late stage.—There is no marked event to set apart the early and late larval stages as the bursting of the shell delimits the former from the purely embryonic forms. So for the sake of convenience I will (somewhat arbitrarily) choose the appearance of the color bands as making the distinction, since their appearing does to some degree divide the larval life into fairly definite stages.

These markings first appear in the tail region as three faint bands of grayish color, one at the root of the caudal and two across the median portion of the tail. A little later a fourth band appears in the region of the spinous dorsal, and finally a smaller band running transversely to the rays of the caudal adds much to the appearance of that organ. The two transverse bands on the tail gradually extend into the long dorsal and ventral fins and, aided by the diversified coloring of the head and by the St. Andrew's crosses in the iris of the eyes, give the little fish a really beautiful appearance. An inspection of figure 13, plate CXIII, numbers 1 to 7, will make clear all these points. In this photograph the larvæ, specially "killed" and preserved in alcohol, are enlarged two diameters.

Figure 9, plate CXI, represents a nest of late larvæ twice natural size. Unfortunately the fish at this stage were almost the color of the nest (a *Pinna* shell), and they do not show up very clearly. The growth of the larvæ, however, from the stage shown in the preceding paragraph is very apparent.

Somewhat older are the toadlets shown in figure 10, plate CXI, which is an instantaneous photograph (natural size) of the nest shown in figures 5 and 8. Not only is the focus better than the preceding photograph, but the contrast between the color of the board and that of the young is so strong as to bring out the latter very distinctly. Both the mottlings on the head and the bands across the body are very distinct. The larvæ are very toadfish-like with their broad heads and large pectorals. In passing it should be noted that the heads of the fish point in all directions. The young are very active, lashing right and left with their tails continually, and in this observation I am in disagreement with Ryder (1887), who says that, while the young are still adherent, the little fish keep up a rapid motion of the pectorals, to aid in carrying away the water from the gills, while the tail is comparatively still. I find that the pectorals rarely show any motion, while the tails are more frequently in motion than at rest, until the last few days before the young detach themselves. At this late period their

tails are more frequently still than in motion, while the pectorals keep up a slow but continual fanning motion, broken at intervals by a few impatient strokes.

Figure 11, plate CXII, is an instantaneous photograph (natural size) of the nest shown in the preceding and in other photographs. Here the young are ready to break away. They are in continual motion, lashing with their tails, swinging back and forth, even twisting in their efforts to break loose from their anchorage. This is apparent in the figure in the blurred effects, which are due to the motion of the little fish while the plate was being exposed. While one is looking one or more little fish may break loose and swim rapidly away, seeking at once a place of safety under the board or in holes in it. As best I can determine, at Beaufort detachment is effected twenty-four to twenty-six days after fertilization. An allowance of two or three days must be made for variations in the temperature of the water, the degree of virility of each little fish, and external stimuli, such as fear or some mechanical shock, exciting the larvæ to greater action. Ryder (1887) approximates the fixed condition at from three to four weeks at Cherrystone, Va. At Woods Hole the young became free in 1906 on the forty-second day, according to Patterson's notes forwarded to the writer by Osburn.

I am satisfied that these larvæ begin to feed before they detach themselves from the nest. Small crustacea, and indeed anything which would serve as food for them, would be drawn into their mouths by the action of the opercula and, being caught by the gillrakers, would be passed down their gullets to the stomach.

A curious phenomenon found only, so far as the writer's knowledge goes, in the young of the toadfish, must now be described. The egg remains spherical so long as the egg membrane exists intact, but immediately after the larva bursts this the yolk begins to elongate and presently a constriction appears. This constriction appears at first to be due to the yolk pouring over the torn shell, but as time passes and the shell is burst wide open, it is apparent that it is due to other causes.

Before going into the explanation of this curious constriction, it will be proper to give a fuller description of the phenomenon itself. On looking at some eggs but a few hours after hatching, at say 5 p. m., to make a hypothetical case, we find the little embryo sitting on top of the rounded yolk; some hours later we find it on the summit of a pyriform eminence, to use Ryder's (1887) expression; next morning we may find the yolk-sac still elongated but having a slight constriction at or near the middle (like a pillow or bolster with a rope tied around it), or drawn out into a pillar-like body sometimes as long as or even longer than the embryo itself. Later still the yolk may round up and then again go through the same series of changes described above, not necessarily, however, in the same sequence, but with the order perhaps varied or some steps in the series omitted. The changes in form of the yolk bag are, however, more or less rythmical.

Finally, about the time that the color bands make their appearance, the yolk sac takes a certain very definite appearance. The constriction appears at the upper part of the yolk and divides it into a small upper and a large lower bulb (Ryder, 1886). The lower bulb sits inside the remnants of the egg shell, the upper is partly inclosed in the down-growing body walls. As the fish grows larger and can accommodate within its body more yolk, the constriction travels toward the base or point of fixation of the egg. Presently the yolk sac takes on the hour-glass shape to which Ryder (1887) refers and which he figures so well. Finally all the yolk has been driven into the body of the larval fish and there is nothing left save the placenta-like mass of blastoderm filled with blood vessels. Figure 13, plate CXIII, numbers 1 to 6, shows the various changes in the yolk sac as the constriction travels toward the base. This photograph is made from "killed" eggs in alcohol.

The explanation—the only one, so far as I know, ever proposed—is to be found in a little-known oral communication of Ryder to the Philadelphia Academy of Natural Sciences on November 4, 1890. In this he makes known the notable discovery that in the yolk sac of the young *Opsanus tau* there is a layer of *smooth* (italics mine) muscle fibers underlying the epidermis and presumably originating from the splanchnic mesoblast. This muscular layer in turn is composed of layers of spindle-shaped fibers. One layer runs around the yolk bag in equatorial fashion, the fibers of the other run at right angles to the first. Given these facts, the explanation of the changes taking place in the form of the yolk sac is at hand. This is a most interesting point, and, in so far as the writer knows, nothing like it has ever been discovered in any other fish, and great credit is due Ryder for working it out. Ryder surmises that possibly it may have a double function, i. e., not merely that of forcing the yolk into the abdomen of the embryo, but likewise of strengthening the yolk bag so that no injury results from the energetic movements of the fish in its attempts to set itself free. To the present writer this seems to be beyond question the correct interpretation.

THE FREE-SWIMMING YOUNG TOADFISH.

The little toads which have just torn themselves away from their anchorage, if looked at from above, appear to differ from adults only in size; but if viewed on the ventral surface they show the placenta-like stalk to which reference has been made in the preceding paragraph, and to which not infrequently the adhesive disk is still attached. In a few days the disk (if present) drops off, the placenta-like stump is absorbed, leaving only a knob-like projection in the jugular region. Later this disappears and our little fish is no longer a larva but a toadfish, differing from its parents only in size and the stage of development of its reproductive organs. Numbers 5, 6, and 7, figure 13, plate CXIII, show the various

stages in the final absorption of the yolk, the formation and disappearance of the lower yolk bulb or placenta-like stump. The fish are enlarged two times.

Figure 12, plate CXII, is from an instantaneous photograph of part of the brood from the board nest of which a series of photographs has been shown. These toadlets (natural size) are in the stage described above, and, in their markings, their bendings of the tail, and their crowding together, show the typical toadfish characteristics.

THE ADULT TOADFISH.

What is the rate of growth in the toadfish? How long is required for it to reach maturity? What is the normal and what the maximum sizes of the fish? These are questions pertinent to this research, but unfortunately not so easily answered as asked.

The little toads at hatching at Beaufort are from 16 to 19 mm. long (⅔ to ¾ of an inch). Storer gives a length of ½ or ¾ of an inch for those at Woods Hole. Greene (1899) says the young of the Pacific form, *Porichthys notatus*, are about 1 inch long when they become free-swimming. According to Smith (1907), on March 26, 1904, a specimen 1.37 inches long was taken in a seine at Beaufort. This must have been hatched late in the preceding season. I have taken them in June and July about 2 inches long. Not infrequently specimens 3 to 6 inches in length are taken in *Pinna* shells. Goode (1884) gives the length of the season's brood in September at 1 inch and adds: "Individuals, apparently of the second year's growth, were also common, and would average three-fourths of an inch in length." Doctor Gill (1907) says of this, "A statement contradicted by the context and probably a *lapsus calami* for 3 or 4 inches." For myself I am thoroughly satisfied that the 3 and 4 inch individuals met with are of the preceding year's brood.

A very incomplete series of measurements of specimens taken at Beaufort in seines by the writer in 1903 and 1904 runs from 3½ to 8 inches in length. These, however, are smaller than those previously referred to as caught and made use of in this work. The following are recorded in my notes because of their unusual size: Males, one 10, one 11½, and another 12½ inches in length; females, one 10, another 10½, a third 12 inches long; sex not determined, one 12-inch specimen. It is greatly to be regretted that a complete list of measurements of all specimens was not kept. The writer's judgment, however, is that they would measure 7 to 12 inches from tip of nose to end of caudal, with an average of about 9 inches.

Mitchill (1815), the first American describer of this fish, says the length is about 12 inches, breadth about 4, depth 2. Yarrow, writing of Beaufort toadfish, in 1877, says that a length of 4 to 8 inches is the most common. Le

Sueur (1824) could find no specimens longer than 5½ inches. De Kay (1842) gives the average size as 6 inches, but had seen them up to 1 foot long. Goode (1884) says of the "northern variety" (*Batrachus*, now *Opsanus, tau*) that it rarely exceeds 10, 12, or at the most 15 inches in length, and quotes Silas Stearns, that the southern species (*Batrachus*, now *Opsanus, pardus*) frequently attains the length of 18 inches. Jordan and Evermann (1898) give the length as 15 inches, meaning, I take it, that this is the maximum. Miss Clapp (1899), writing of the Woods Hole toadfish, says that a specimen 12 inches long is seldom met with. Smith (1907) fixes the maximum size for Beaufort specimens at 15 inches. The writer's experience is that a 12-inch specimen is rather rare, and that the average length of sexually mature fish is from 7 to 10 inches. Hence if a fish in one year attains a length of from 3 to 4 inches it will probably require two to three years to attain sexual maturity and three to four years (since growth takes place more slowly as the fish becomes older) to attain the average maximum size.

The largest fish of this species ever seen by the writer was 14½ inches long, a veritable giant of his kind. He was anesthetized and carefully measured. These measurements are herewith reproduced: Length, tip of nose to end of caudal, 14½ inches; width across head, 4⅞ inches; width between eyes, 1¾ inches; girth of head, 4⅞ inches; girth of body at anterior base of pectorals, 11⅞ inches; girth of body at posterior base of pectorals, 11½ inches; girth of body at anus, 6¾ inches; mouth (wide open) width, angle to angle, 3¼ inches; height, top to bottom, 2⅝ inches.

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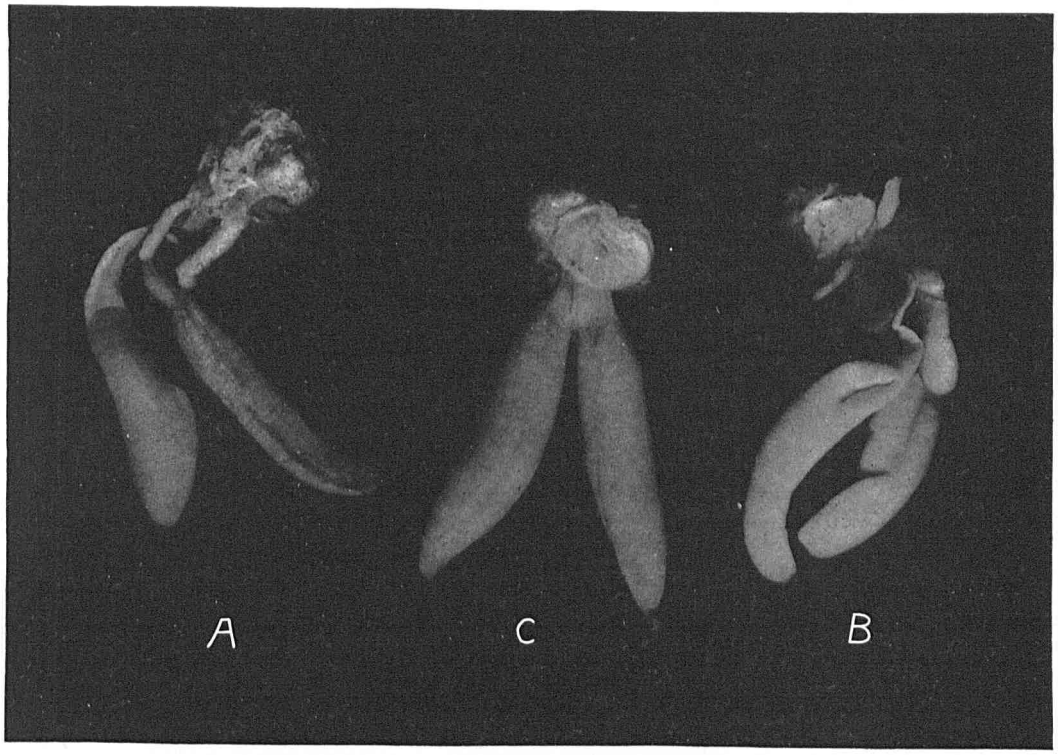

FIG. 1.—Reproductive organs of the toadfish. A, dorsal; B, ventral aspect of ripe testis from adult male; C, dorsal view of immature ovary. Photographed in alcohol.

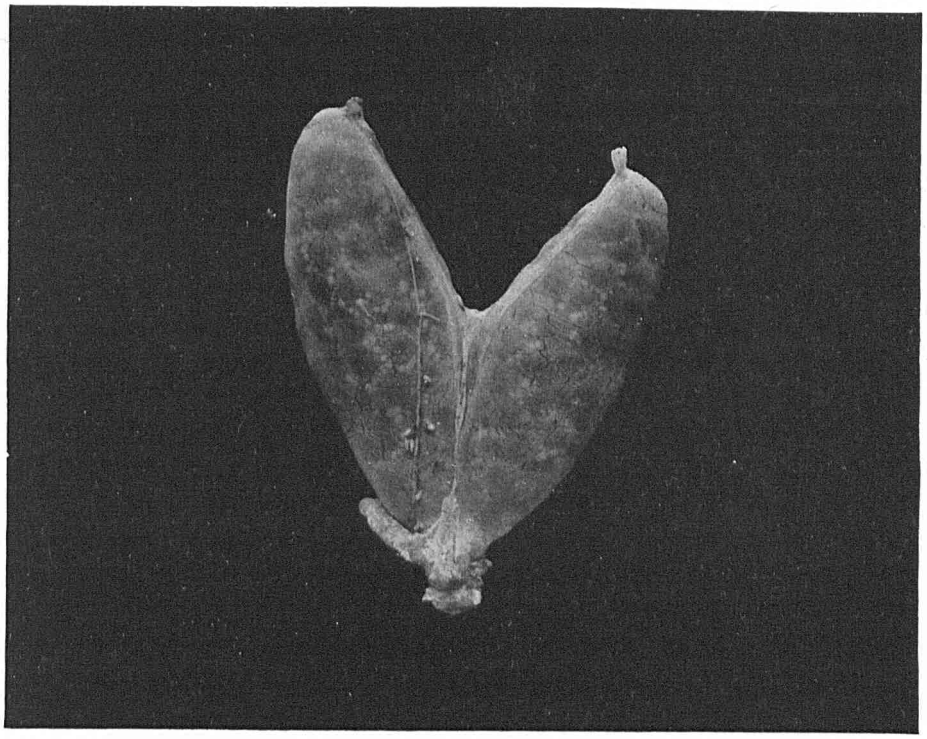

FIG. 2.—Ventral aspect of living ripe ovary of toadfish. Photographed in water.

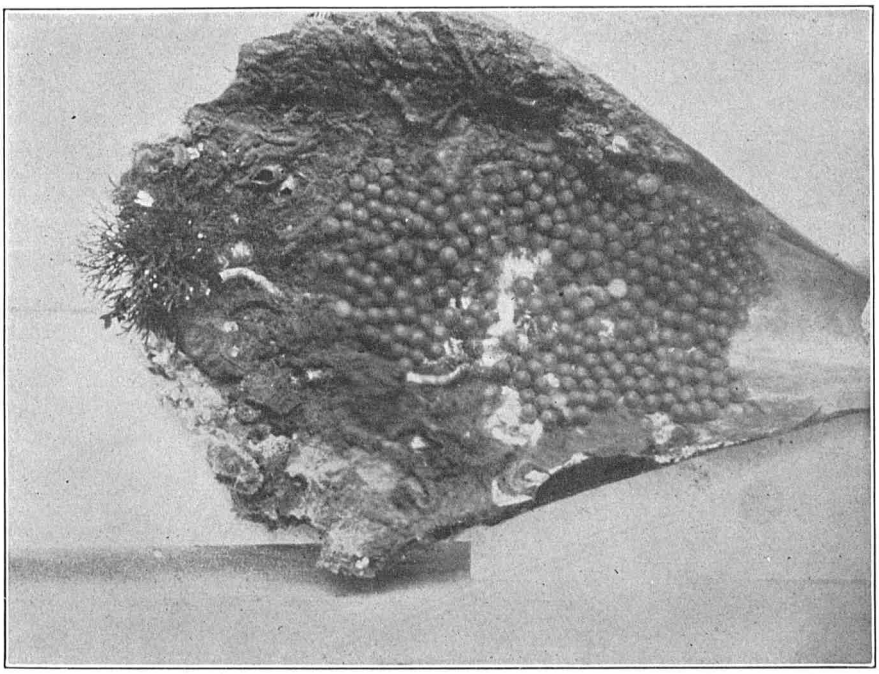

FIG. 3.—One-half of *Pinna* shell nest, showing live eggs in segmentation. ×½.

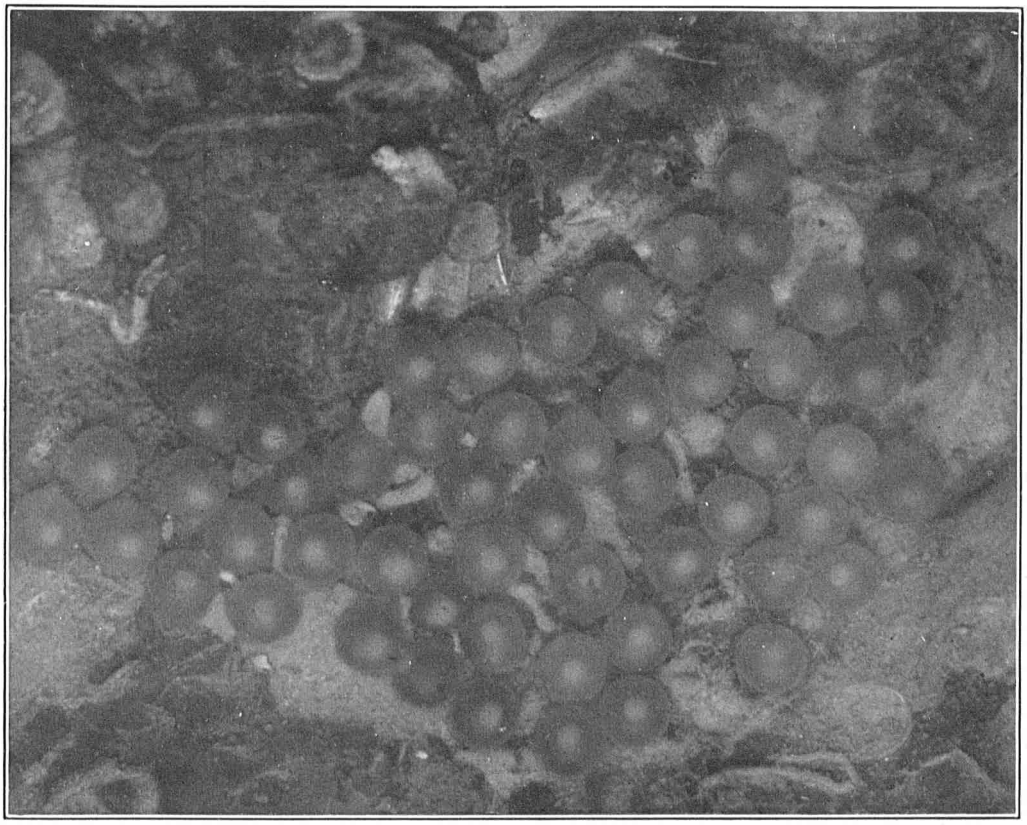

FIG. 4.—Eggs (×2) in late segmentation. Photographed alive in water.

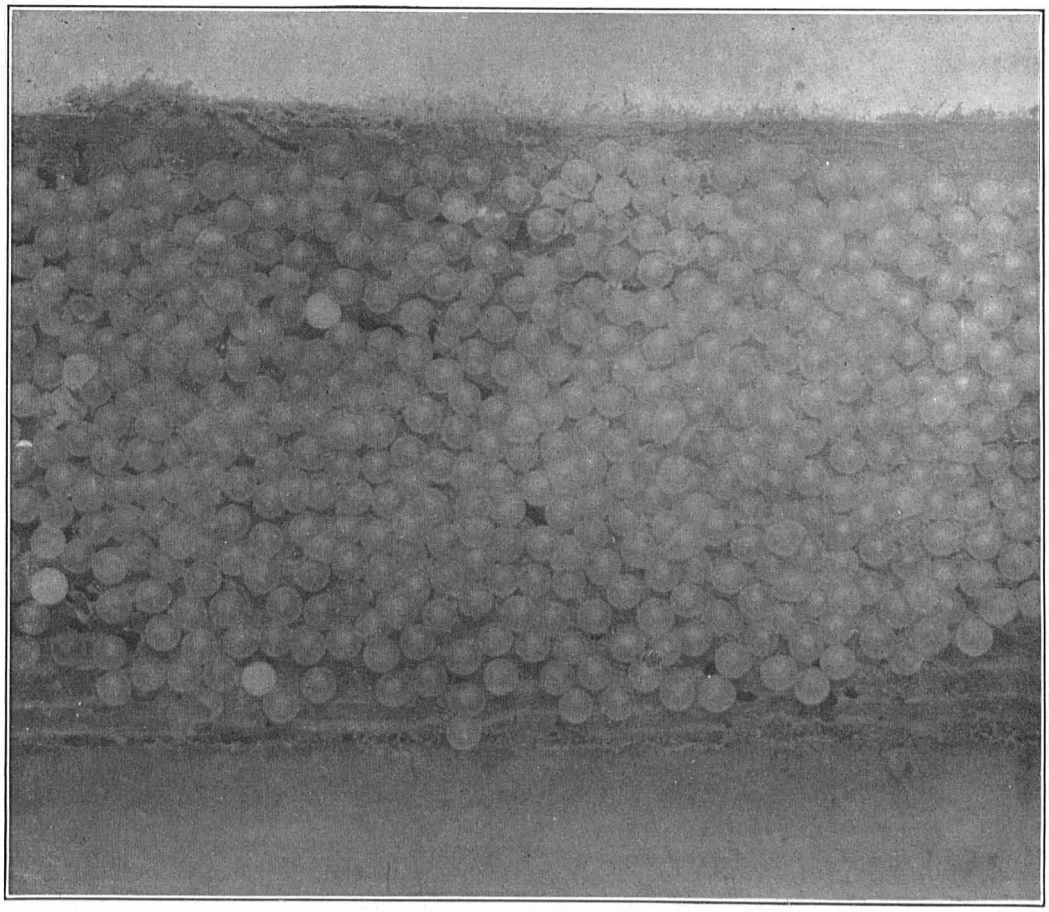

FIG. 5.—Board nest, eggs with late blastoderms and early embryos. Natural size.

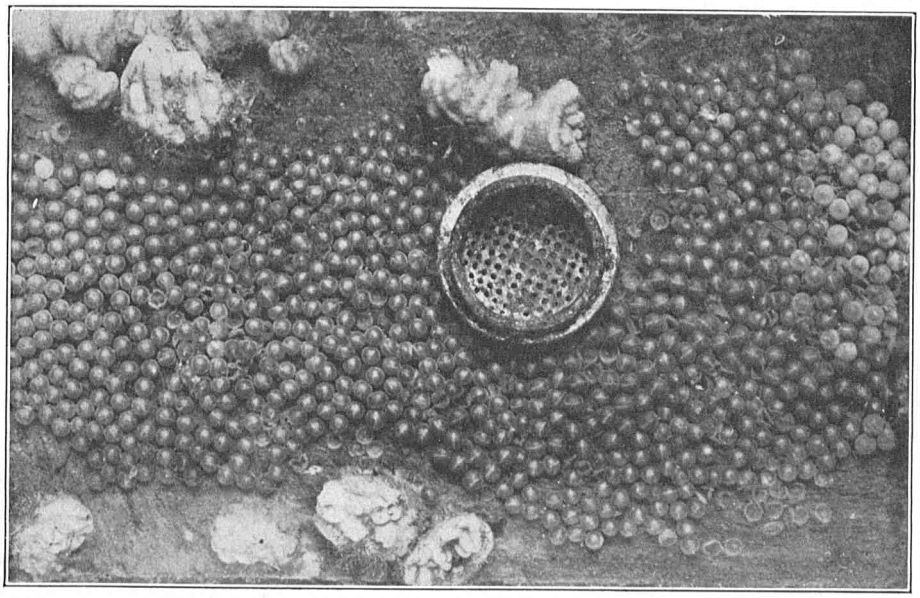

FIG. 6.—Nest showing embryos having a marked enlargement at one end. ×½. (White eggs to right are dead.)

FIG. 7.—*Pinna* shell nest, showing tadpole-like larvæ. ×½.

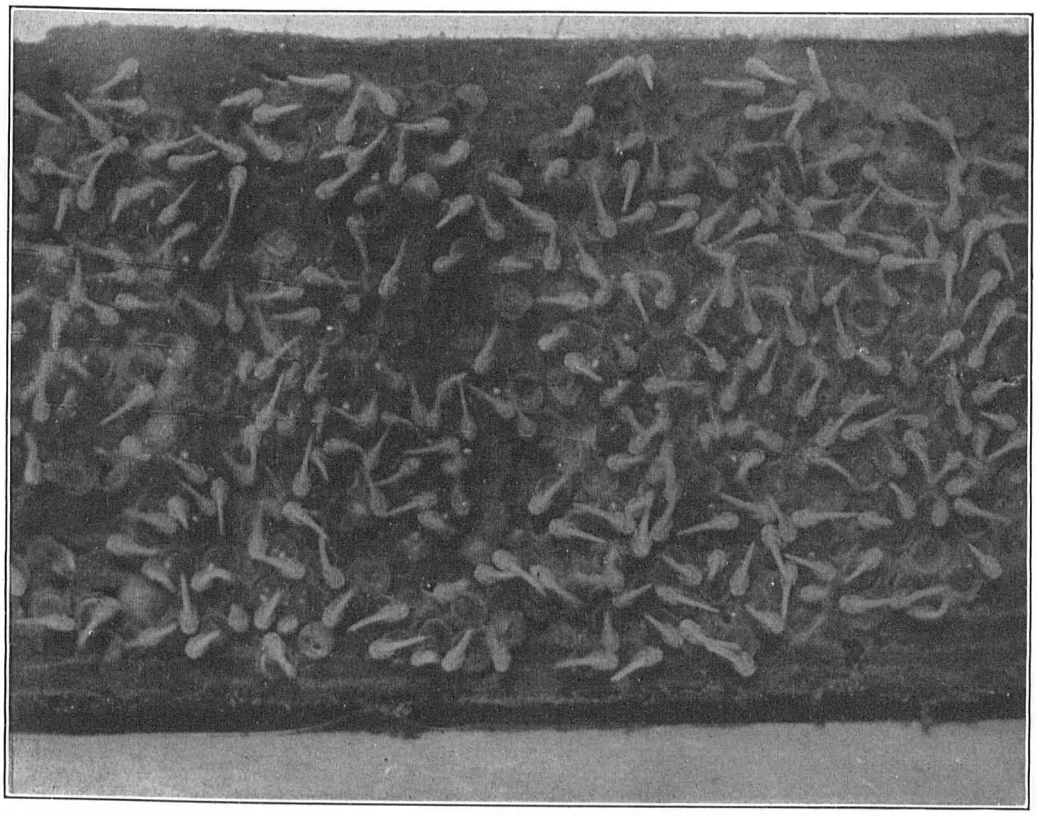

FIG. 8.—Board nest. Larvæ slightly older than in figure 7. Natural size.

FIG. 9.—*Pinna* shell nest, late larval toadfish. ×2.

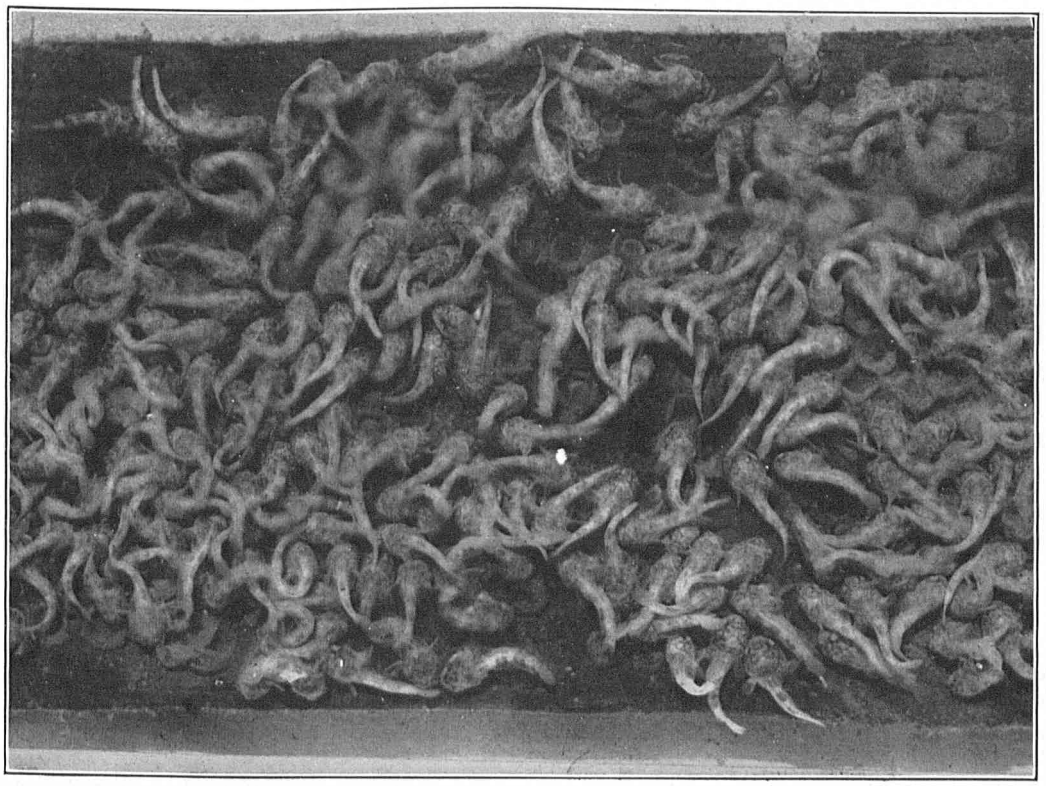

FIG. 10.—Late larval toadfish, showing color markings. Natural size. Same nest as figure 5, plate CIX, and figure 8, plate CX.

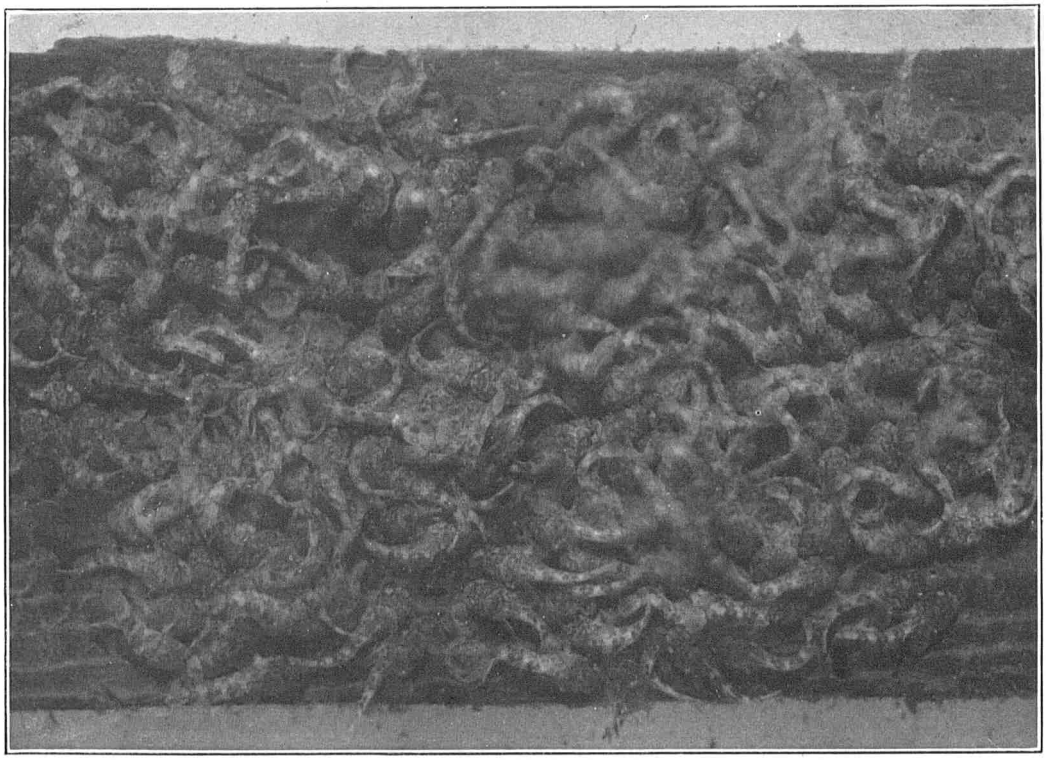

FIG. 11.—Same nest as figure 10, plate CXI. The young are nearly ready to break away.

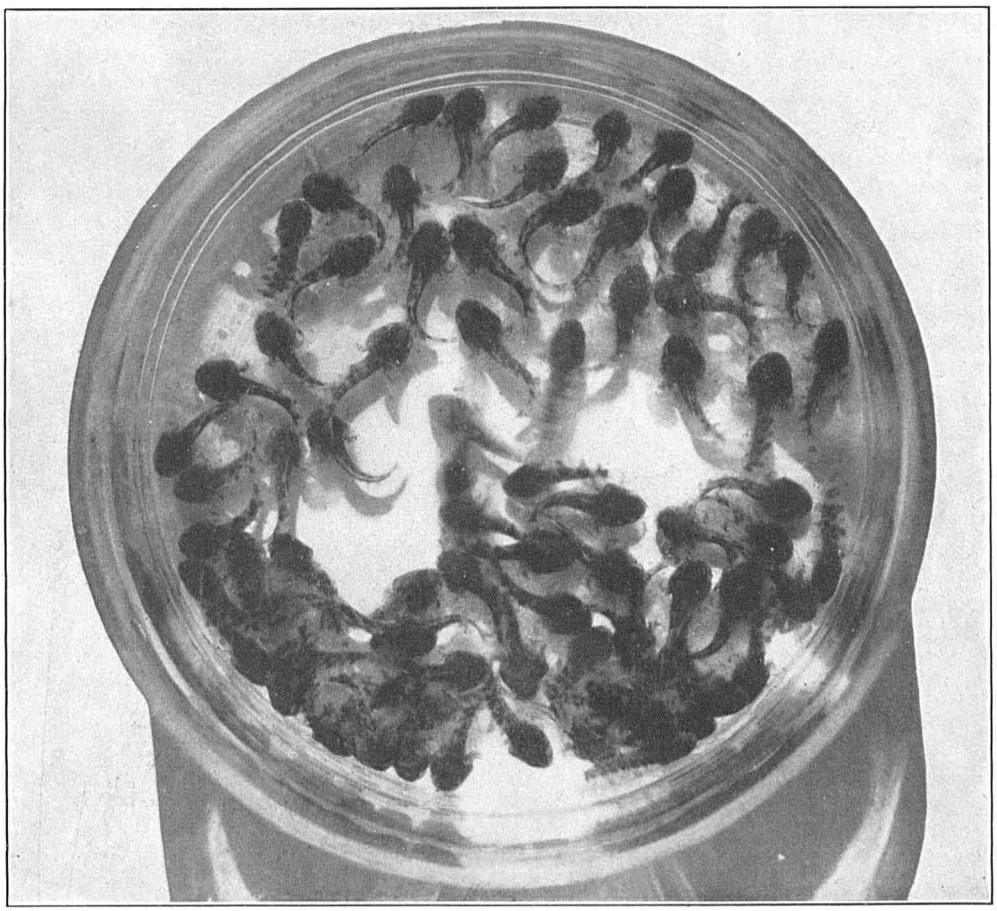

FIG. 12.—From an instantaneous photograph of free-swimming young toadfish in water.

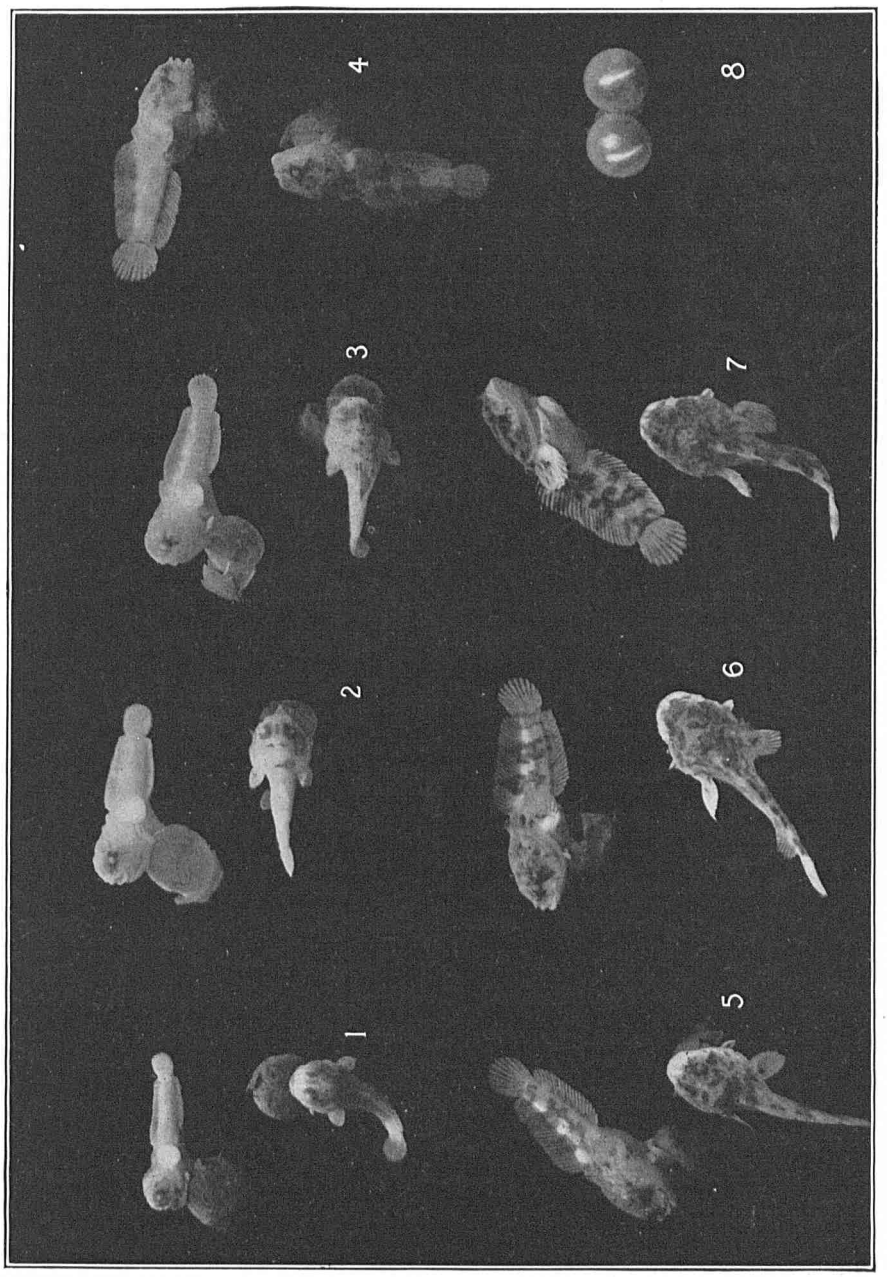

FIG. 13.—Larval toadfish (×2), showing formation of the color bands and disappearance of the yolk. Photographed in alcohol.

METHODS OF STUDYING THE HABITS OF FISHES, WITH AN ACCOUNT OF THE BREEDING HABITS OF THE HORNED DACE

By Jacob Reighard

Professor of Zoology, University of Michigan

Paper presented before the Fourth International Fishery Congress, held at Washington, U. S. A., September 22 to 26, 1908 and awarded the prize of one hundred dollars in gold offered by Theodore Gill for the best methods of observing the habits and recording the life histories of fishes, with an illustrative example

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METHODS OF STUDYING THE HABITS OF FISHES, WITH AN ACCOUNT OF THE BREEDING HABITS OF THE HORNED DACE.

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I. METHODS.

The studies upon which this paper is based have been made in the field, on fishes in their natural environment. Captive fish have been used only when necessary to supplement field observations. As the result of this work, extending over somewhat more than fifteen years, there have been developed certain methods which it is the purpose here to describe. These are, of course, essentially field methods. The studies that produced them related to the natural history of the dogfish (*Amia calva* Linnæus), work begun in 1891 and published in 1903; the habits and development of the black bass (1903); the habits of coral-reef fishes at Tortugas, Florida, published in 1909; and more or less complete observations about ready for publication on *Lampetra wilderi*, *Catostomus commersoni*, *Catostomus nigricans*, *Moxostoma aureolum*, *Campostoma anomalum*, *Pimephales notatus*, *Semotilus atromaculatus*, *Rhinichthys atronasus*, *Notropis cornutus*, *Hybopsis kentuckiensis*, and half a dozen sunfishes of the family Centrarchidae. Work by the writer's students on the breeding habits of local fishes (Reeves, 1907, B. G. Smith, 1908) has also been utilized.

GENERAL PRINCIPLES IN FIELD STUDY OF FISHES.

Habituation of fish to observer.—When an observer approaches a fish for the first time it nearly always happens that the fish is disturbed by the sight of him or by some sound that he makes, and forthwith retreats into deep water or into some nearby cover. The inexperienced observer usually considers such a fish as lost to observation for good and very likely passes on in search of some less wary subject. In doing this he is governed by the popular impression that fish are rovers, not bound to any one locality, and that it would therefore be useless for him to await the return of this particular fish to the locality in which he first saw it. If it were a bird or a mammal he might at least follow it in its wanderings, but with a fish this is manifestly impossible.

In passing to a new subject for observation the inexperienced worker makes a fundamental error, for, save under exceptional conditions, fish are

local in their habits. A fish frightened from a particular spot will ordinarily return to it if the observer have but the patience to wait. While waiting, he must not move, but must hold himself as immobile as a tree, so that to the fish, very likely watching from some lurking place, he becomes a part of the landscape. After a longer or shorter time the fish will return, but is likely to be again frightened by a nearer look at the intruder. His second return will follow after a shorter absence, and his third, if again frightened, after a still briefer time. Thus gradually the fish will become habituated to the presence of the observer and will take no further note of him. Then the observer may move about slowly. Let him not move even his head or his hand quickly or the fish will be again frightened, and the whole procedure will need to be recommenced. But if he is careful to begin with moderation he may gradually increase the range and rapidity of his movements until he has come quite near the fish and is moving at his accustomed rate. During this time he may talk or make other sounds in air, for sound waves in air do not disturb fish in water; but he must take care not to set up vibrations in any solid body so situated that these vibrations will be transmitted directly to the water. Thus, if he is in a boat or standing on a wharf he must not strike it violently. If on shore, he must do nothing to cause vibrations of the ground. If wading in the water, he must be careful to lift his feet slowly, so that there will be no splash or dribble, and to set them down with equal care. After a time he will find that the fish resumes the occupation in which it was engaged when first disturbed, and he may then observe it at his leisure; but the time that will be required before the fish will take no further notice of the observer, the nearness of his possible approach, and the extent to which he may expose himself to view or move about will vary with the kind of fish under observation and with its condition.

There is a very great difference in the readiness with which different species of fish become habituated to the presence of the observer, so that some may be said to be much more timid than others. This is well illustrated on the coral reefs. As an observer approaches such a reef by wading, all the many species which frequent it disappear at once into the shelter of the tortuous recesses of the reef. If the observer stands motionless and waits, the fish soon reappear, not all kinds together, but first the less shy species and last the more timid. Among the shyest of our local fishes are the suckers of the genus *Catostomus* and the black bass, while among the boldest are the common sunfish and related species. Not only does the rate of habituation to the presence of an observer vary from species to species, but, as I (1903) have had occasion to observe in the fresh-water dogfish, *Amia*, it may vary also from individual to individual. The successful observer of fish in their native haunts must therefore take account of this difference in shyness of different fishes and must be

governed accordingly. In studying the suckers it is usually necessary to remain very quiet and hidden behind some suitable shelter; but if the suckers happen to frequent the neighborhood of a bridge where there is frequent passing they become gradually used to the presence of human beings, and may then be watched without observing any unusual precautions. The black bass may be observed only by taking the utmost care not to disturb it, while the common sunfish (*Eupomotis gibbosus*) may, under most circumstances, be approached without difficulty.

In addition to the differences between species with reference to the readiness with which they become habituated to the observer, there are differences in the same species at different seasons. The areas suitable for the breeding activities of most species are of limited extent. On these areas the individuals of the species congregate at the breeding season, and it is then that they are most readily approached. If in addition to frequenting a particular breeding ground a species is in the habit of building nests, its activities are then centered about areas of still smaller extent, and it becomes proportionately easy to observe them. The breeding season therefore offers the best opportunities for observing the habits of fishes, not only because the fish are then gathered into limited areas, but also because they are easily approached on these areas and readily return to them when frightened away.

The tie which binds breeding birds to the nest and young has been made use of by Herrick (1902) in his remarkable studies of the "Home Life of Wild Birds." He has sawed off the supporting branch and thereby transferred nests from inaccessible trees to places more convenient for observation. The parent birds after recovering from their brief fright returned to their duties, while he watched them from a tent set up within two or three feet of the nest. He found that this parental instinct which, like a chain, binds the bird to its nest and makes it follow wherever the nest is carried, varies in strength at different times and in different birds. The nest should be moved for purposes of study at that time at which the parental instinct is at its strongest.

The like is true of fishes. A fresh-water dogfish may be readily frightened from its nest before the eggs are laid in it, but is much less easily frightened after the nest has been filled with eggs or the young fish hatched. The common sunfish becomes so tame when it has eggs in the nest that, as Thoreau (1849) long ago found, one may stand astride of the nest, stroke the fish on the back, and feed it from the hand. One may even lift the fish from the water in the hand, and when it is returned it will resume its parental duties. In like manner Miss Reeves (1907) found of the breeding rainbow darter (*Etheostoma coeruleum*):

> They quickly become accustomed to one's presence and are not then disturbed by one's wading among them. I have touched them with my boot tips or stroked them with a small wire without their moving. It is then possible to stand directly over them and even to examine them with a hand lens without in any way modifying their normal behavior.

Determination of species.—When the fish have become habituated to his presence the observer must, of course, learn to distinguish unerringly the species which he is studying from other species with which it might be confused. Workers who distinguish alcoholic fish at a glance may be puzzled to separate species of living fish in the water. Here it is impossible to count scale rows, pharyngeal teeth, or fin rays. On the other hand, the colors of the fish and their mode of movement and the fact that species difficult to separate are not usually associated make it comparatively easy to distinguish living fish in the water. Yet the literature contains many instances of errors which have arisen from the wrong determination of fish in their natural habitat. Safety lies in much collecting and repeated comparison of the fish in the hand with that in the water. After a time the observer of fish acquires something of the skill of the field ornithologist, who recognizes by its method of flight the bird that is so distant as to be a mere speck in the sky or by the wag of its tail or the tilt of its head the one that is almost hidden in the bushes. So the ichthyologist finds that living fish present characters that make their field determination easy and that are not set down in the books. But he must discriminate, not only between species, but between male, female, and young, and this is a much more difficult matter. Lack of critical method in discriminating between the sexes has led to very many errors recorded in the literature of the breeding habits of fishes. Until very recently there was perpetuated the error that the female of the black bass builds the nest and cares for the young, and a like error existed in respect to the dogfish (*Amia*).

Analysis of observations.—When the observer of fish habits has successfully approached his subjects and has learned to distinguish between males, females, and young, he is usually confronted by such a bewildering maze of behavior that he sees but little clearly and is sorely tempted to patch out that little by conjecture as to the rest and to aid his patching by analogies drawn from other groups of animals. There is here but one safe rule of procedure, familiar enough in other fields of science, but too little applied in the field study of animal habits. It is that the observer must proceed analytically; he must take one element of the behavior at a time and study that until he can describe it accurately. What is the precise position of the male and female in a pair of spawning fish? To answer this question accurately the observer must ask himself many others. What is the position in each fish separately? In each sex, what is the position of the tail, the head, the dorsal fin, the anal fin, the pectoral fin, the pelvic fin? Each of these questions must be answered by a separate observation, many times repeated, and only when they have been answered and the answers put together does one know the position of the two sexes in the spawning pair. Only by securing answers to innumerable and apparently unimportant questions, only by constant "Fragestellung" does one make progress in the field study of

animal behavior. Every accurate and complete account of such behavior is made up by putting together such answers.

Repetition of observations.—Many observations are necessary on each point. A single observation rarely suffices to answer any one of the many little questions that the observer puts to himself. The rapid movements of fishes in a more or less turbid medium, the surface of which is rarely wholly smooth, make observation difficult and increase the chances of error. The writer has in the case of some difficult points repeated his observations a hundred or more times before he has felt sure of their correctness.

Importance of field experimentation.—Field observations should be checked, wherever possible, by field experiments. The analysis of the problem, as advised in the third section above, sometimes brings to the front questions that can not be answered by direct observation, so that recourse must be had to experiment. Thus the building of the nest of *Amia* has never been observed, for the probable reason, as the observations of the writer show, that the work is done at night. In order to learn whether this work was done by the male or female, the writer introduced males into a considerable bay access to which was barred to the females by a net stretched across its mouth. By this device he learned that the nests are built by the males. In work on the breeding habits of *Lampetra* he has been able to make still more considerable use of the experimental method. There is no doubt that the use of the method may be extended to other forms.

Making of records.—Records of all observations should be made on the spot. It is not sufficient to observe what takes place and to write up notes in the evening or at some more remote convenient time. The memory can not be trusted to retain accurately the details of happenings so complicated as those that fall under the eyes of the observer of living fish. It would seem hardly necessary to insist on a precaution so obvious were it not that the observer of fish is placed under sore temptation to defer the writing of his notes. The scenes that he has before him are of absorbing interest and require his closest attention to follow them and unravel their complications. He is loth to spare any time to note taking. And not only does the taking of notes consume time; it causes the loss of observations, at least for the time being; for while the observer is recording one occurrence another follows it, and is lost to him. This loss can only be made good by repeated observation, and while the opportunity for such repetition may be long in coming, it is better to have an accurate record of a part of what has happened than to have an inaccurate record of the whole. Therefore, detailed notes should be made on the spot. There is another reason for this procedure, namely, that the writing down of an observation forces the conscientious observer to be accurate, and shows him wherein his observations are incomplete. A field note, once written, suggests some other query, so that

the writing of such notes is not merely a record of what has been seen; it is in itself a guide and a stimulus to further observation.

Field records should be not only written, but, as far as possible, pictorial also. Both sketches and photographs should be made. The technique of such work is discussed in another place in this paper. One other point needs to be insisted on here—that it is impossible to make notes in too great detail. The experienced observer is apt to find his notes doubling in volume with each succeeding year, not only because he sees more, but because he learns the wisdom of making full notes. He finds that his first year's notes leave him in painful uncertainty about many points that he feels he should have made clear. Thereafter, in succeeding years, he increases the detail of his note taking.

Compilation of observations.—A connected account should be written immediately upon completion of the field observations. The experienced field observer will go into the field with a plan of observation in mind and will proceed in accordance with this plan to work out first one part of his plan and then another. It may seem that in the field one must take things as they come and record events in the order of their occurrence, and indeed it often is desirable to do this. Yet in the experience of the writer it is in most cases better to proceed according to some plan, to analyze the problem and to take up each part of it in turn. If the observer does this, he naturally neglects for the time being those happenings that do not fall in that part of the problem that he has immediately in hand. What he thus misses at one time he must get at another. Not only are the best results obtained in this way, but events often crowd so fast one upon another that there is no other possible mode of procedure.

If now the field observer proceeds in his work in accordance with a prearranged plan, he will find it of great advantage to write a connected account of his observations at the earliest possible moment. He should do this, if possible, before the period of observation has expired. In this way he will detect gaps in his plan and will be able to fill them in; he will perhaps find the plan itself defective and be able to modify it before it is too late. If it be here objected that the writer is laying down rules which ordinarily govern the laboratory worker, and that these rules are not at all applicable in field work, he can only reply that he has applied them in field work and always with the result of obtaining better results in shorter time.

TIMES AND PLACES OF OBSERVATION.

Allusion has already been made to the fact that the breeding season offers the best opportunities for the field observation of the habits of fishes. The fish are then congregated at the breeding places, which are usually areas of shallow water; their instincts often bind them strongly to a very restricted area; they

become readily habituated to the presence of the observer. In addition to these advantages the habits of fishes are of more interest during the breeding season than at other times, and a knowledge of them is of the greatest consequence from the practical standpoint. At other seasons many fishes are in water so deep that they can not well be observed; or they are in other ways inaccessible. Nevertheless, in so far as fish are accessible outside of the breeding season, the principles that have been discussed in the preceding paragraphs may be applied.

Not only is it possible to observe the breeding habits of fishes in the field, but in the case of many species the breeding continues when the fish are confined in aquaria. In this respect there is a very great difference in species. In spite of repeated efforts I have never succeeded in observing any part of the breeding habits of dogfish (*Amia*) when the fish were under the least restraint. Dogfish that I confined in inclosures of netting on the natural spawning grounds refused to breed, even when the inclosures were 4 square rods in area. The Michigan grayling in its native waters did not breed, in the experience of the Michigan Fish Commission, when confined in a portion of the stream separated from the remainder by gratings at its ends, even when the part of the stream available for the fish was many rods in length. On the other hand, I have observed in aquaria the breeding operations of *Lampetra wilderi*, *Catostomus commersonii*, *Semotilus atromaculatus*, *Rhinichthys atronasus*, and *Eupomotis gibbosus*. It is well known that the European sticklebacks breed readily in aquaria, although I have never succeeded with our American *Eucalia*. Undoubtedly the most noteworthy work in observing the breeding habits of fish in aquaria was that of Carbonnier (1869, 1870, 1872, 1872*a*, 1874, 1875, 1876, 1876*a*, 1876*b*, 1879, 1881) at the aquarium of the Trocadero in Paris. A number of Indian, Chinese, and other exotic fishes bred there as though under no restraint.

To secure apparently normal breeding of fish in confinement the temperature of the water and the food of the fish must be regulated so as to be as nearly as possible that of the natural environment. Such regulation can be accomplished only approximately, so that the breeding habits of fishes in confinement are probably not quite normal. For this reason it is best to make observations on fish in their native waters wherever this is possible and to resort to fish in aquaria only when no other method is available, or for special purposes.

MEANS AND DEVICES FOR OBSERVATION.

Note-taking materials.—For taking notes the writer prefers the aluminum notebook covers, within which loose leaves of note paper are held by a spring. In addition to the well-known advantages of the loose-leaf system, the aluminum covers afford a hard surface for writing, and they keep the note paper from becoming crumpled in the pocket or wet by perspiration. Thus they are preferable for all sorts of field notes, but are of especial use about water, since they protect the notes from wetting. A fountain pen filled with a thin carbon ink affords a permanent and legible writing.

Field glasses.—Field glasses may with great advantage be used where the shyness of the fish precludes a too near approach of the observer. Even prism glasses (stereo-binoculars) may be used, and the writer has found those magnifying about six diameters to be admirable. Field glasses are not only often indispensable for viewing fish from a distance, but they are very useful in studying them near at hand, for then they act as magnifiers, by means of which small fish may be very considerably enlarged and the details of larger ones brought out.

Water glasses.—A very useful form of water glass is that in use on the Florida reefs. It consists of an ordinary wooden pail the bottom of which has been replaced by a circle of ordinary window glass luted into place with hard paraffin. A more convenient form of water glass for many purposes is that designed by the writer and described in his "Photography of Aquatic Animals" (1908). This is essentially a shallow box of galvanized iron into which there is cemented a bottom of plate glass. The rim of the box has an outwardly projecting lip, which lessens the slopping in of water. A bail of band iron is attached by the ends to the inside of the box in such a way that it can be folded down into the interior when not in use. Stout wires soldered across the corners of the box on the inside serve for the attachment of cords. A cover of galvanized iron fits over the plate glass on the outside and serves to protect it during transportation. The whole device is shown in figure 1, plate CXIV, with the cover at the left. This pattern the writer has used in sizes of 1, 2, 3, and 4 feet on a side. Under ordinary circumstances the water glass is allowed to float and the observer then has both hands free for taking notes or for using his field glasses. The bail serves as a means of carrying the apparatus about, and in the smaller size fits conveniently over the shoulder, so that the glass may be carried on the back, while the observer wades with both hands free. It serves the further purpose of supporting a shade of black cloth, as shown in figure 2, plate CXIV. A shade of this sort cuts off the light reflected from the sky into the eye of the observer and makes it possible for him to see much more clearly than would otherwise be possible. Where the water is so shallow that the heavy glass would sink so as to strike the bottom or interfere with the fish beneath, it may be supported on legs, as shown in figure 2. These legs are rods of iron which run through thimbles at the corners of the box and may be set at any height and held in place by thumb screws. The figure shows an observer studying the habits of the brook lamprey by the aid of such a water glass. The lampreys (*Lampetra wilderi*) were engaged in nest building and spawning beneath the glass and were not only studied but photographed by its help.

Of the various sizes of this type of water glass, that of 1 foot square is most convenient for ordinary field work where it must be carried from place to place by the observer, but this size is too small for photographic work. For this purpose the 2-foot glass shown in figure 2 is better adapted and is still not too burdensome to be carried by hand. The larger sizes are suitable only for

special uses, as on the coral reefs or where it is desired to photograph a considerable area of the bottom from a considerable distance.

The reflecting water glass designed by the writer (1909) offers some advantages over the ordinary form of water glass for certain kinds of work. It is a rectangular box of galvanized iron (fig. 3, pl. cxv), about 2 feet long and 6 inches by 8 inches at the ends, which are closed. Within the box at each end, as shown in accompanying diagram, is a mirror placed at an angle of 45 degrees with the long axis of the box and firmly fixed in a metallic setting. The reflecting surfaces of the two mirrors are parallel and directed toward each other. The box is heavily weighted with lead at one end so that when placed in water it floats in an upright position, with about 10 inches of the upper end projecting above the surface. Opposite the lower mirror in the side of the box is an opening filled by plate glass bedded in aquarium cement (fig. 3, pl. cxv). Through this window light enters from objects outside the box and these objects are reflected in the lower mirror. At the upper end of the box, on the side opposite the first window, is an opening through which the observer may look at the surface of the upper mirror, and in this mirror he sees reflected the surface of the lower mirror with the objects on the outside of the box shown in it. The observer may thus stand upright in the water, holding the water glass in front of him, and by looking into the upper mirror see submerged objects as he would see them if his head were beneath the surface. He sees the submarine landscape as it appears to a fish or to a diver through the glass window of his casque A handle soldered to either side of the box enables the operator to turn it in any direction and to hold it steady. Into the opening at the upper end of the box there may be fitted a plate of metal to which are attached two tubes lined with chamois skin and of such a size that the objective end of a pair of field glasses fit snugly into them (fig. 3, pl. cxv, right). By inserting field glasses into these tubes the observer may examine with them the objects shown in the upper mirror. Except for the limits set by the opacity of the water, fish may thus be studied from a distance as birds are studied in air. It should be added that the use of field glasses is rarely necessary with this form of apparatus, as the observer is usually

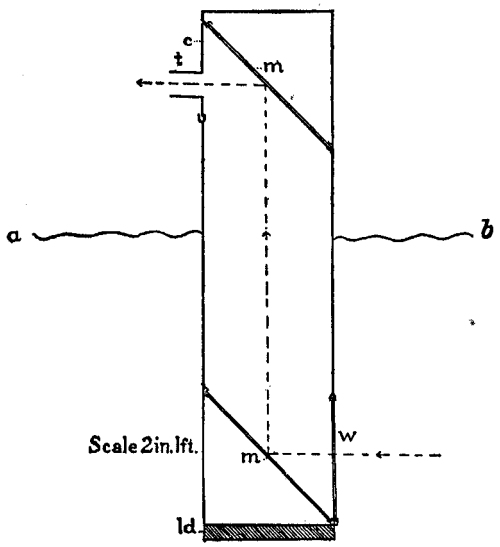

FIG. 1.—Longitudinal section of the reflecting water glass designed by the writer. *w*, Window on one side of the submerged part; *m*, mirrors; *c*, cover over the upper opening; *t*, tube for field glasses; *ld*, lead weight. The dotted line with the arrowheads shows the course of light from an external object to the eye. The line *a*—*b* represents the water's surface.

able to approach near enough for purposes of accurate observation with the naked eye. If field glasses are used the mirrors in the reflecting water glass should not be ordinary glass mirrors silvered on the back, since these produce double images which interfere to a slight extent with the working of field glasses. They should be of metal or of glass silvered on the surface, yielding a single image.

The principle of the reflecting water glass is shown in the diagrammatic figure 4, in section from the narrower side. The glass is seen entire in figure 3, plate II.

Photographic methods.—The writer has elsewhere (1908) described fully the methods which he and others have devised for the photography of aquatic animals and need here only outline these.

Photographing fish in aquaria is a method often of great value in obtaining records of their habits. The method is fully described in the papers cited in Reighard, 1908. Figure 4, plate CXV, shows the male of the common shiner (*Notropis cornutus*) with the details of scales, fin rays, and pearl organs clearly brought out. It was made with a reflecting camera from a specimen in an aquarium. Other examples of such work are figures 10 to 16, plates CXVIII, CXIX, and CXX.

Fish and fish habitats may also be photographed, by the methods already described by the author (1908), while the fish remain in their natural surroundings. To accomplish this two modes of procedure are available, as follows:

(*a*) The camera may be pointed from the air at the object beneath the surface of the water and the photograph taken through the surface of the water. In order to accomplish this it is nearly always necessary to cut off by a suitable screen the light reflected into the camera from the sky and other distant objects. This light is usually stronger than that which comes from the subject to be photographed, and if it enters the camera it affects the photographic plate in such a way as to obliterate the image formed on it by any object beneath the water's surface. One method of using such a screen and the results are shown in figure 5, plate CXVI. Here a dark screen stretched on a wooden frame is held by hand in an oblique position, so as to cut off the reflected light from the sky while allowing the full sunlight to fall on the object to be photographed. The object is in this case the nest of a small-mouth black bass. The large stones which form the bottom of the nest are shown clearly within the reflected image of the screen. Outside this image the reflected light from the sky has entered the camera so that in the picture almost nothing is visible beneath the water's surface.

Figure 6, plate CXVI, is from a photograph obtained by this method and shows brook lampreys in the act of spawning. Sometimes it is necessary to use not only a screen to cut off the reflected light, but at the same time a water

glass for the purpose of rendering the surface of the water smooth enough for a photograph to be made through it. Figure 2, plate CXIV, shows such a combination of water glass and screen as used for photographing the lampreys of figure 6. The broad white bands in figure 6 are the edges of the water glass. It is to be noted that within these bands the picture is clear while outside them it is not clear. The lack of clearness in that part which lies outside the borders of the water glass is due to the running water, which is there much disturbed, as shown in figure 2, plate CXIV.

(*b*) The second method of photographing objects beneath water in their natural environment is to inclose the camera in a water-tight box and immerse this, and for this purpose a reflecting camera should be used. The principle of such an instrument is illustrated in the accompanying figure, which shows it in longitudinal section. The light entering the camera is reflected by a mirror, *m*, to a ground glass, *gl*, in the top of the camera and the image formed by it is viewed by the photographer as he looks down through the hood, *hh'*, on top of the camera. This image is of full size, and owing to the action of the mirror is erect. While looking at it the operator may focus the camera and thus keep the image always sharp, no matter how much the object may move. The mirror is hinged at its upper edge at *x*, and the operator can, by pressing a release button, cause it to swing upward until it reaches the position *m'*. It then covers the lower surface of the ground glass in such a way as to prevent the entrance of light through it. The light, hitherto reflected upward from the mirror, now passes backward and may form an image on the sensitive plate, *p*. In front of the sensitive plate there is a shutter, *s*, of the focal-plane type. This is essentially a roller shade of black cloth which may be wound on an upper roller, *r*, and made, by the action of a spring, to unwind very rapidly from the upper roller and wind on a lower roller, *r'*. In passing from one roller to the other the curtain passes in front of the plate. In one place in the curtain is a transverse slot and through this the light falls upon the sensitive plate as the slot, *sl*,

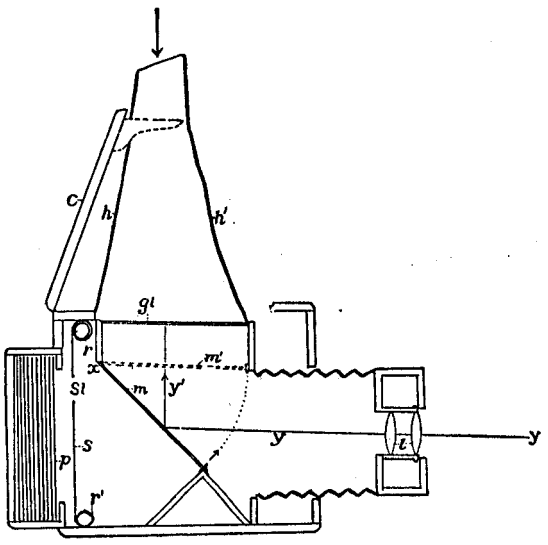

FIG. 2.—A reflecting camera shown in section, with magazine plate holder attached. *gl*, Ground glass; *h h'*, hood; *l*, lens; *m*, mirror in position during focusing; *m'*, mirror, showing position during exposure; *p*, sensitive plate; *r* and *r'*, rollers of focal plane shutter; *s*, the shutter; *sl*, slot in shutter; *x*, hinge on which mirror turns; *y y y'*, ray of light traversing the lens and reflecting from the mirror to the ground glass.

passes across its face. The rate at which the curtain moves and the width of the slot may be regulated. When the operator with the mirror set at *m* has focused the object and brought it into the desired position on the ground glass, he presses the button which releases the mirror. At the instant the mirror reaches the position *m'* it releases the mechanism which actuates the shutter, and the roller with its slot travels across the face of the plate, so that the exposure is made. It is unnecessary to dwell here on all the advantages of this form of camera. The feature of importance is that the camera permits the object to be kept in focus up to the instant of exposure and then permits the exposure to be made without removing the ground glass and inserting the plate, as is necessary in the ordinary form of camera.

In using this form of camera for photographing objects under water the writer inclosed it in a water-tight box of galvanized iron. This box, shown in figure 7, plate CXVII, is provided at one end with a plate glass through which the picture is taken. In the top of the pyramidal portion of the box which covers the hood of the camera there is a second plate of glass which does not show in the figure and through which the operator looks into the hood of the camera and examines the image on the ground glass. The camera is focused from the outside with the right hand by means of a milled head, from which a stem extends through a water-tight stuffing box to connect with the focusing screw of the camera. The exposure is made by pressing a pin which is on the opposite side of the box from the milled head shown in the figure and which also extends through a stuffing box to the interior of the water-tight box, where it actuates the mechanism by which the mirror of the camera is set in motion. The top of the box is held in place against a rubber gasket by eight thumbscrews by the use of which the joint between the box and the lid is rendered water-tight. When the box is in use its bottom must be heavily weighted with lead to submerge it.

In figure 8, plate CXVII, is shown the method of using the reflecting camera when inclosed in the water-tight box. The photographer is wading near a coral reef. The body of the box inclosing the camera is submerged, but the pyramidal top of the box inclosing the hood of the camera projects above the surface of the water. Through the glass in the top of the hood the photographer is viewing the image on the ground glass, while he focuses the camera with the right hand and is prepared to make the exposure with the left hand. When the exposure has been made the water-tight box must be taken from the water and opened in order to change the plate before making a second exposure.

If the water-tight box is made strong enough to resist the pressure of the water the photographer may descend in a diver's suit and may, with the apparatus described, make photographs at considerable depths. If the camera box is set on a tripod time exposures may be made with an apparatus of this type, but

some changes would then be necessary in the mechanism by which the shutter is operated from the outside of the water-tight box.

II. ILLUSTRATIVE EXAMPLE OF METHODS OF OBSERVATION.

BREEDING HABITS OF THE HORNED DACE (*Semotilus atromaculatus*).

In the selection of the horned dace, rather than commercial or otherwise more important fishes, to illustrate the present discussion, chiefly two considerations have controlled: (1) That the matter here presented has not hitherto been published, and (2) that the behavior of the horned dace is so complicated that it affords an excellent illustration of the methods the writer has found successful in the study of the behavior of fishes in the field. The horned dace is, however, not without economic importance. It is sometimes eaten, but its chief value lies in the fact that, more than any other fish in the region in which it occurs, it furnishes bait to the angler. The present account of its breeding habits embodies the results of the observations of many years, or rather of many seasons, but the record is not a final one. It is an outline or sketch, a preliminary account from which details are purposely excluded.

There is no published description of the breeding habits of the horned dace, although its conspicuous nests must often have been observed. Kendall and Goldsborough (1908) publish notes prepared by Superintendent Charles G. Atkins, of the United States Bureau of Fisheries Station at Craig Brook, Maine, on the breeding habits of *Semotilus bullaris*. They report that they have themselves seen the nests of this form and give a diagrammatic picture of such a nest with the fish on it. More detailed observations are greatly to be desired, especially since the nest-building behavior described for *Semotilus bullaris* appears to be intermediate between that described in this paper for *Semotilus atromaculatus* and that observed by the writer in *Hybopsis kentuckiensis* and not yet published.

Observing the fish at nest-building time.—The observer who approaches one of the gravelly brooks of southern Michigan during the latter part of April or in May is likely to have his attention attracted by certain elongated heaps of gravel scattered at intervals along the bottom of the stream (fig. 9, pl. CXVIII, and fig. 3, text). These catch the eye, because the stones that compose them are clean, as though scoured, and show their blotches of bright colors. The heaps consequently stand out in sharp contrast to the surrounding bottom, which is everywhere covered with a uniform brown ooze. Each of these heaps has the form of a low, rounded ridge, commonly a foot in width and 2 or 3 inches high, but varying in length from a foot to 16 or 18 feet. The ridges run with the stream, and at the downstream end of each is an oval pit (*P.*) 2 or 3 inches deep and as wide as the ridge. Below the pit again is seen a trail of clean sand, which at its begin-

ning is as wide as the pit, but as it is followed downstream gradually narrows to a point (*S. T.*, in fig. 9, pl. CXVIII, and fig. 3, text).

As the observer approaches one of these structures he may see the flash of a fish departing from the pit, and he is then apt to move on in the belief that nothing more is to be seen. But if he lies prone on the bank and keeps perfectly still the fish will return. This may happen after ten or fifteen minutes, or it may not happen for an hour, and during all this time the observer must remain motionless, not moving so much as a hand or foot, for if he moves the fish at once flees to shelter and does not reappear for some time. It again departs if the movement is repeated, but each absence is shorter than the preceding, and after a time, if the movements are not too abrupt, the fish remains on the nest in spite of them. For him the observer has become a part

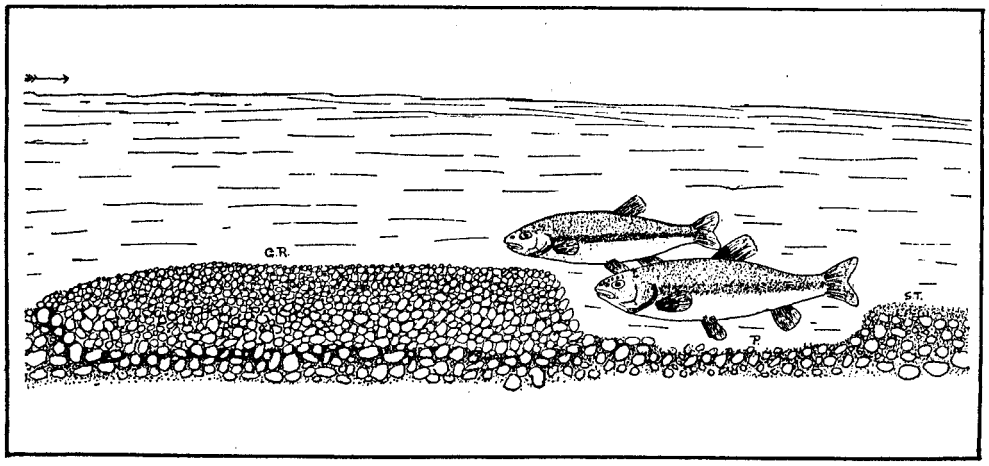

FIG. 3.—Showing in longitudinal section the nest of a horned dace with the male and female fish on the nest. The stream flows in the direction indicated by the arrow at the upper left corner of the figure.

of the landscape, to which he pays no more attention than to a tree. The fish that returns (fig. 10, pl. CXVIII) is usually 8 or 10 inches long, of a beautiful apple-green color above and of a rose red below. If a small fish, there may be a stripe of dark brown between the two colors, where they join along the middle of his side. At the base of the dorsal fin in front is a black spot (fig. 12, 13, pl. CXIX), and above this an orange spot, while the caudal and paired fins are yellow. If the observer is very near, or if he uses field glasses, he may see along the sides of the head above the eye and nostril a row of 4 or 5 white horn-like spines (fig. 10, pl. CXVIII, and text fig. 5, p. 1130). These are pearl organs, so called because in some related forms they have the rounded glistening look of pearls (see fig. 4, pl. CXV, on the snout). By them and by its colors the observer may recognize the fish as the male of the horned dace.

The nest-building process.—Presently the fish will be seen to put its head to the bottom of the pit and by vigorous movements of its tail appears to try to force its way into the bottom, as in figure 11, plate CXIX, in which it is seen to have seized a pebble. Presently it rights itself and is then seen to have picked up a good-sized stone from the bottom of the pit (fig. 12, pl. CXIX). With this it swims to the lower end of the ridge of gravel and there drops it (fig. 13, pl. CXIX), so that it falls on the end of the ridge or rolls down into the pit. In either case it helps to lengthen the ridge. Sometimes a stone too large to be taken into the mouth is pushed along the bottom (fig. 14, pl. CXIX). The fish now carries stone after stone in this way until the ridge is visibly lengthened. Sometimes instead of a single larger pebble the fish takes into its mouth a mass of smaller pebbles, with a considerable amount of sand. When this happens, he does not drop his burden on the end of the ridge, so as to lengthen it, but proceeds some little distance farther upstream, until his head at least is well above the ridge. Then with a movement of his head first to one side and then to the other he distributes the mouthful of small pebbles over the top of the ridge, so as to form a top dressing. As the pebbles leave his mouth it may be seen that the sand which was taken up with them is washed downstream and falls to the bottom below the nest, where it forms the trail already seen (fig. 4, text, at right). This trail is added to by the sand stirred from the bottom of the pit by the fish whenever he picks up a stone. As the ridge lengthens it slowly encroaches on the pit and tends to fill it. But as this occurs at the upper end of the pit the fish slowly pushes his excavation downstream, lengthening the pit at the lower end, so that it does not become filled. The whole ridge thus lies in a long trench, which has been excavated as the fish slowly drops downstream and has been filled by the ridge as fast as made. Only the pit in which the fish lies has been left unfilled at the lower end of the ridge. If the observer is fortunate enough to arrive as the dace is beginning its nest, he may see it dig a little pit in the level bottom and pile the stones on its upstream edge (fig. 13, pl. CXIX). By gradually lengthening this pit and at the same time filling it he completes his nest.

The structure of the completed nest is shown in perspective in figure 9, plate CXVIII, and as it appears in longitudinal section in the diagrammatic figure 3, page 1126. At the right of text figure 4, page 1128, it appears in plan. The bottom of the stream is here composed of gravel, with sand intervening between the stones. In this the long trench has been excavated and partly filled with the stones that have been removed in digging it. These stones may be distinguished from those that still remain undisturbed in the bottom by the fact that they are clean and the sand has been washed from between them. They form a low ridge, which projects from the trench somewhat above the

level of the bottom. The unfilled part of the trench—the pit in which the fish are seen—lies at the lower end of the ridge. The sand washed by the current from between the stones that have been moved in making the ridge collects in a trail below the pit and is seen there in the figures.

As the fish continues to work at the nest the observer may slowly, very slowly, raise himself into a sitting position, and if he is careful the fish will not be frightened by this. Then, after a time—a half hour, perhaps—he may slowly rise to his feet, and in the course of time may slowly approach the nest until he is within 8 or 10 feet of it. How much of this he may do and how rapidly he may do any of it can only be learned by trial in each case, for it depends on the individuality of the fish and upon the particular stage of his activities. To the fish the relatively immobile observer becomes, after a time, a part of the landscape and no attention is then paid to him.

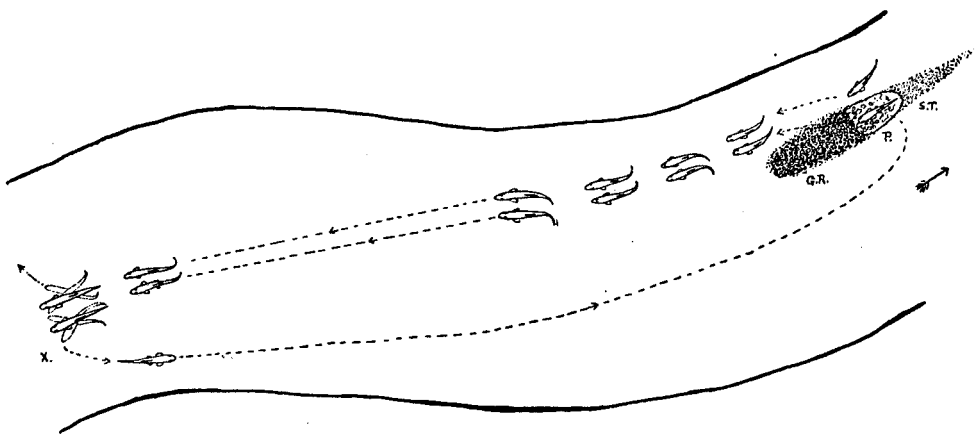

FIG. 4.—Showing the ceremonial behavior of the horned dace when a strange dace approaches the nest. The owner of the nest is seen in the pit, *P*. Above this is the gravel ridge, *G. R.*, and below it is the sand trail, *S. T.* The direction of the current is indicated by the arrow at the right. The course of the two fish upstream to the point *X* and the return of the owner to his nest are indicated by the broken lines with the arrowheads. The heavy lines indicate the banks of the stream.

Protection of the nest against other fishes.—Other fish approach from time to time as the dace works at his nest. Minnows of other species frequently attempt to enter, but if smaller than the dace they are pursued and driven out. Frequently other male dace approach the nest. If these are smaller than the nest builder they are pursued and then invariably flee. Such small males are distinguished from the larger ones by the presence of a dark lateral stripe (fig. 11 to 16, pl. CXIX and CXX). If the male dace that approaches the nest is of the same size as the nest occupant a battle frequently ensues. The two strike at each other with their heads in apparent efforts to inflict wounds with the sharp pearl organs. They often struggle together fiercely in these encounters, but neither fish appears to suffer any injury. The sole result seems

to be to produce temporary discomfort in the fish that is hooked, and this usually results in the departure of the intruder.

The attempt of a male to appropriate the nest of another fish of equal size does not always result in an encounter. Frequently it happens that as the strange male approaches the nest the occupant ranges himself alongside and the two fish swim upstream with great deliberation for a distance of 15 or 20 feet (text fig. 4). In their course they move slowly and swing their tails from side to side in unison, as though keeping step with them. At the end of their course they settle to the bottom and bring their heads together gently, as though bowing to one another. They then usually separate their heads and bring their tails together, as though about to swim away from one another. They then commonly again bring their heads together and finally separate, the owner to return to his nest, his companion to some near-by shelter. This performance, which with some variation is so often seen that it must be regarded as a part of the normal behavior, may be interpreted as a deferred combat. The two fish move along side by side, like two boys threatening each other but each afraid to strike. When they have gone a certain distance they approach each other and make certain threatening movements in unison and then they separate. This mode of behavior, which has the appearance of a ceremonial, is illustrated diagrammatically in text figure 4, where the nest is seen from above with its owner in the pit. The outlines of the stream are represented by the heavy black lines, while the direction of the current is indicated by the large arrows. The nest shows the gravel ridge, the pit at its lower end, and the sand trail below the pit. The movements of the two fish in their upstream course, as well as after they have stopped, and the return of the owner to the nest, are represented by the successive outlines, and their direction is indicated by arrowheads.

Spawning behavior of male and female.—While the male dace is building his nest the females are waiting in some near-by shelter. At any time during the progress of the nest building they may be seen to approach the nest, usually one at a time, but sometimes in troops of three or four. The females may be distinguished from the males by their smaller size (fig. 10, pl. CXVIII), for while they may be as long as the males they are nearly always smaller and frequently not more than one-fourth as long. They are further distinguished by the absence of the bright colors on the body and of the black and orange spots in the dorsal, as well as by the absence of pearl organs. From larger males they are distinguished by the presence of the lateral stripe. In all these respects they resemble young males, but from these they may be told after a little practice by the fact that their abdomens are distended with eggs (fig. 10). As a female approaches the nest for the first time the male turns toward her and she then usually flees without actually entering the nest. Presently she returns, again

approaches the nest and comes a little nearer, but again flees as the male turns toward her. As female after female thus approaches the nest their coyness gradually diminishes, until one, bolder than the rest, enters and does not flee as the male approaches. She gives no assistance in building, for that is the work of the male. As she enters the nest the male first turns toward her and then, as she comes nearer, takes up his position at the bottom of the pit at the lower end of the gravel ridge, as shown in figure 3, page 1126. He lies usually nearer the bottom of the pit than shown in the figure and often turned somewhat on one side, and in this position he waits until the female has taken a position just above him or at his side. Even when the female has come so far she often again flees, and in that case is pursued by the male, who attempts to bite or hook her. Usually when she has come near enough the male gets his head and his expanded pectoral fin of one side beneath her, and then with a movement often too rapid to be followed by the eye he tosses her into an upright position and at the same time encircles her body with his own. When this has happened the two fish are in the position shown in figure 15, plate CXX, and text figure 5, page 1130. Then the male immediately straightens his body and releases the female. The length of time required for the male to clasp and release the female varies, but is always very brief. It appears to take about as long as is required to close and open the hand when that movement is performed as rapidly as possible. This seems to be usually one-tenth of a second, but is often more.

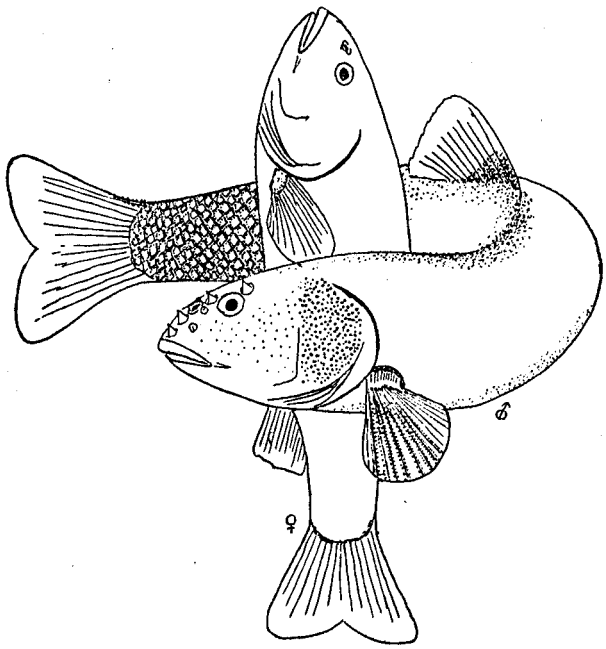

FIG. 5.—Male and female horned dace during the spawning act. On the male, which is the fish with the body curved, are shown above the eye and in line with the nostril, four spine-like pearl organs and below these two smaller spines. Small organs are seen on the operculum and dorsal surface of the pectoral fin and on the caudal edges of the scales on the tail.

When the two fish are in the position shown in text figure 5, the surface of the opercle of the male is seen to be pressed against one side of the female, while the side of his body back of the dorsal fin is pressed against her other side. At the same time the upper surface of his pectoral fin of one side is

pressed against her ventral surface. The female always has her head up and her tail down as shown in the figure, but the positions of her dorsal and ventral surfaces with reference to the body of the male may be the reverse of that shown. The movements of the fish are so rapid that it requires many observations on each part of each fish before the observer can be sure of accuracy.

A close examination of a breeding male of the dace is necessary to show the means by which he retains his brief hold of the female in spite of the slipperiness of the skin of both fishes. If he be so examined, it is found that those parts of his body which are in contact with the body of the female during the embrace are beset with minute, sharp pearl organs, and are thereby rendered rough, like a piece of sandpaper (fig. 5, text). The opercular region, covered with close-set pearl organs, has a shagreen-like feel. The sides of the body and tail from the caudal edge of the dorsal fin backward are provided with minute organs which occur in rows along the slightly everted edges of the scales and roughen the surface over which they are found. Finally the upper surfaces of the pectoral fins are provided with close-set organs of moderate size which form rows along the fin rays. By means of these organs the male, whose body would otherwise be smooth and slippery, is enabled to make effective his brief hold of the female. This is the more necessary to him since his scales are devoid of the tooth-like points which occur along the free edges of the scales (ctenoid scales) of many fishes and render their bodies rough to the hand.

While the female is held in the embrace of the male she emits a few eggs, and with field glasses these may often be seen falling slowly through the water until they rest on the gently sloping end of the gravel ridge or on the adjacent bottom of the pit. Probably not more than 25 to 50 eggs are emitted at one time. The released female then floats for a moment belly up as though dead, while the male appears to examine the falling eggs. (Fig. 16, pl, cxx.) The female now speedily recovers and disappears along the neighboring bank, but after a short time returns to the nest and repeats the spawning. She continues this intermittent egg laying until all her eggs have been deposited. She may thus place her eggs in one nest, but more often she deposits a part of them in one nest and a part in another. Meantime, during her absences, other females have entered the nest and laid their eggs, so that when the eggs of any nest are examined they are found to be of several different sizes corresponding to females of different sizes that have entered the nest.

When the females are not in the nest the male continues to carry stones and thus lengthens the gravel ridge. The eggs that have fallen on the end of the ridge or into the pit just at its base are thus covered by the added stones and included in the ridge. As one female succeeds another and as the gravel

ridge at the same time lengthens, it becomes filled with eggs. The position of these eggs is shown in figure 3, page 1126, by the black dots among the stones of the gravel ridge. The eggs are undoubtedly fertilized at the moment they are laid, but owing to the fact that the seminal fluid of the male is colorless its emission can not be observed.

Security of nest structure.—The structure of the nest (fig. 3, p. 1126) is such as to afford the eggs protection, for, as already pointed out, the base of it is composed chiefly of larger stones, which the male drops directly on the end of the ridge, so that they roll down toward its bottom. Among these larger stones the eggs are lodged. The surface of the ridge is, on the other hand, composed chiefly of smaller pebbles which there fill the chinks between the larger stones. By this arrangement the eggs in the spaces between the larger stones in the base of the ridge are separated from the free water above by the fine gravel which closes these spaces at the top and are thus protected.

When the nest of the horned dace has been completed it is a conspicuous object on the bottom of the stream, because the pebbles that compose it are clean and stand out in sharp contrast to the ooze-covered pebbles of the surrounding bottom. But within a very few days the sediment from the stream covers the nest pebbles also and the nest becomes then almost indistinguishable. Meantime the builder of the nest, now that his breeding ardor has run its course, has abandoned his work, and the nest with its contained eggs is left to its fate. Here the eggs undergo their development, and after a time, which varies with the temperature of the water, the young fish hatch from them. The eggs or the newly hatched fish may be obtained at any time by scooping up a part of the nest gravel and agitating it with water, when the eggs, which float for a moment in the agitated water, may be poured off. The newly hatched dace do not differ greatly in their general features from the adult, but no accurate description of them has been made. How long they remain in the nest is not known, nor has their method of exit from it been observed. They must soon make their way out through the spaces between the pebbles and through the overlying ooze, but the precise time and method of accomplishing this are not known. Very small dace and those of every intervening size up to the adult are found in the same streams with the parent fish and differ from them apparently only in the smaller size of the prey which they capture and in occupying a slightly different habitat.

The nest of the dace affords an absolute protection of its eggs and young against the smaller carnivorous fishes, and this protection arises from two sources. The presence of the male dace on the nest keeps these little enemies at bay while the eggs are being laid and while they are being covered by pebbles. This protection extends over some days at least. Besides this the covering of stones over the eggs effectually excludes small fish after the male dace has left the nest.

At the same time the top covering of small stones filters out much of the sediment which would otherwise sift down upon the eggs and smother them or carry to them the fatal spores of fungus.

The horned dace and the other minnows that build stone nests are relatively small fish, toothless, and without spiny fin rays, so that they have no effective means of repelling the attacks of their enemies. They would therefore be unable to protect their eggs by guarding them in open nests after the manner of the larger and more formidable fresh-water dogfish and black bass. By building stone nests which inclose and protect their eggs, certain of these minnows, including the horned dace, seem to have followed the most effective method open to fish which are physically incapable of personally defending their offspring.

Destructive agencies.—Yet the nests of the horned dace are not impregnable castles. Against the smaller carnivorous fishes they afford ample protection, for the stones of which they are built are too heavy to be moved by *Rhinichthys*, *Pimephales*, *Etheostoma*, and the like. On the other hand, the nests may easily be disturbed and even robbed by larger fishes. *Campostoma* and *Catostomus* habitually uproot small stones in the process of feeding, and it is possible that in this way they uncover and devour the eggs of the horned dace, though I have not observed this. But there is another way in which the structures built by the horned dace are frequently torn to pieces and their contained eggs probably devoured, and that is by the nest-building operations of other fish. When a horned dace nest has been completed by its builder and abandoned, a second dace frequently selects the same site for his nest and proceeds to build with the materials used by his predecessor. Or a *Campostoma* may use the gravel ridge of a horned dace nest as a suitable place in which to excavate his pit, or a *Hybopsis* may carry away some of the dace materials in building his nest. These fish all build at about the same time, and their pits, ridges, and stone piles occur on the same areas. By this process of the repeated occupation of the same area by other fish of the same and other species, the nests of the horned dace are often disturbed, and in such cases the contained eggs are probably in part destroyed. The extent to which this happens varies in different streams. In certain streams areas which I have kept under observation have been utilized as nesting sites two or three times in succession, and the first dace nests built in them have been thereby wholly or in part destroyed. In other streams most of the dace nests have been left undisturbed. Again the top dressing of fine gravel by no means suffices to exclude all sediment. Sediment and fungus spores reach the eggs. In many of the nests that I have examined, living eggs were found in the new-built parts, while the older parts contained only dead eggs matted together and covered by fungus.

SUMMARY OF OBSERVATIONS OF THE BREEDING HABITS OF THE HORNED DACE.

1. The horned dace breeds in southern Michigan from late April to early July.

2. Breeding males are distinguished from females by their larger size, brighter colors, the presence of pearl organs, and abdomen not distended as in the female.

3. The breeding takes place in clear streams, which vary in width from 1 or 2 feet to 4 or 5 rods, on bottom of coarse gravel, and usually at the heads of rapids.

4. The male fish builds nests without assistance from the females.

5. The nests are constructed, each chiefly by an individual male, by picking up and carrying stones in the mouth.

6. Each male thus excavates, parallel to the course of the stream, a long trench, usually a foot wide and 2 or 3 inches deep, but varying in length from 1 to 16 or 18 feet.

7. As he excavates this trench he fills it with the gravel removed in making it, so as to form a ridge of gravel which extends 2 or 3 inches above the top of the trench.

8. The trench and ridge are extended downstream, and the fish always occupies the unfilled portion of the trench at the lower end of the ridge. This I have called the pit.

9. The sand washed from between the stones in moving them accumulates in a trail below the pit.

10. In forming the ridge most of the coarser gravel is deposited so as to form its base, while the finer gravel is used chiefly as a top dressing on the surface of the ridge.

11. The male guards the completed nest, and often defends it by giving battle to other males.

12. Frequently when the nest of one fish is approached by another male dace of equal size there ensues, not a combat but a "ceremonial" which may be interpreted as a deferred combat.

13. The females may enter the nest and lay their eggs at any time during the process of nest building, and the eggs thus laid are covered in the subsequent operations of the male. Consequently they are included in the gravel ridge and this ridge is filled with the eggs of many females.

14. When a female enters the nest to spawn, she is thrown by the male into a vertical position and encircled by his body; in this spawning attitude the head of the female is always up and the opercle and pectoral fin of the male are pressed against one of her sides while his tail behind the dorsal fin is pressed against her other side.

15. The embrace of the female by the male lasts for a fraction of a second, during which a small number (probably 25 to 50) eggs are laid and fertilized.

16. The female when released usually floats belly up for a moment, and in all cases leaves the nest. She subsequently returns many times to the same nest, or enters another nest, and on each occasion deposits a small number of eggs. This continues until her eggs, laid in one nest or several, are all deposited.

17. The sharp pearl organs on the head of the male are used as weapons, while the smaller organs on his operculum and on the sides of his tail, together with those on the dorsal surface of his pectoral fin, are used in retaining his grasp of the female during the act of spawning.

18. When the male has completed his nest he deserts it, and it rapidly becomes covered with silt and not easily distinguished from the surrounding bottom.

19. The eggs hatch within the nest, and the young make their way out through the chinks between the stones.

20. The nests of the horned dace are of advantage to the species in affording protection to the eggs against sediment and against the attacks of the smaller carnivorous fishes.

21. The nests of the horned dace are often destroyed by the nest-building activities of other dace and of other species of larger minnows (*Campostoma anomalum*, *Hybopsis kentuckiensis*), and the eggs are frequently attacked by fungus.

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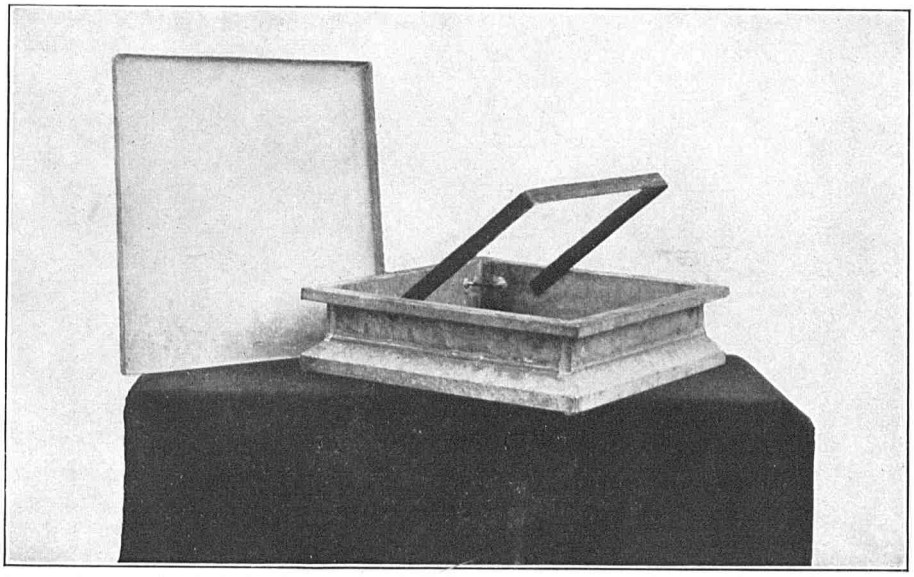

FIG. 1.—Water glass designed by the writer to be used for observation or photography of objects under water. The cover is shown at the left.

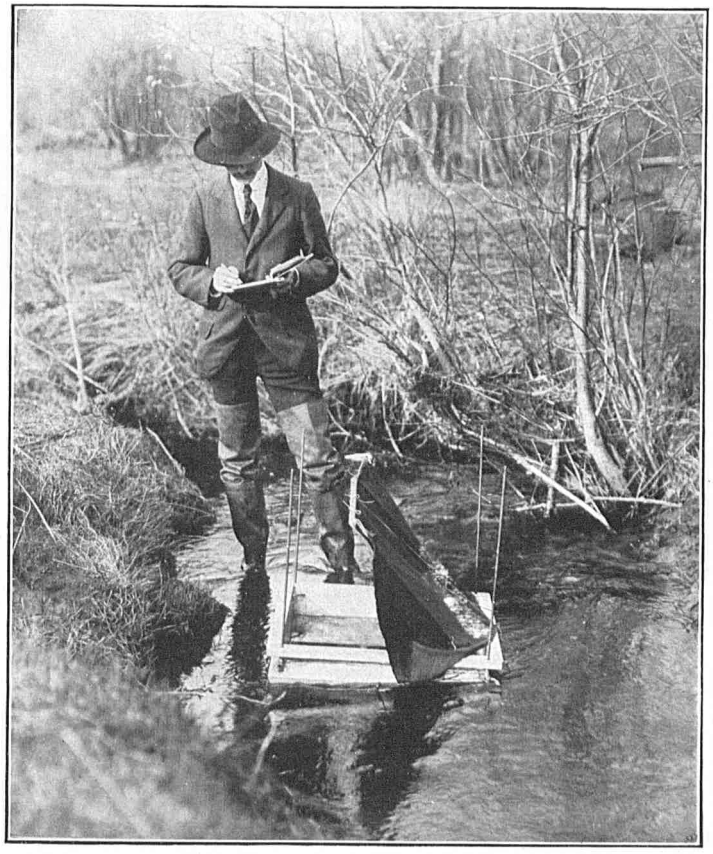

FIG. 2.—Two-foot water glass supported on four legs and provided with screen, as used for studying and photographing lampreys (*Lampetra wilderi*).

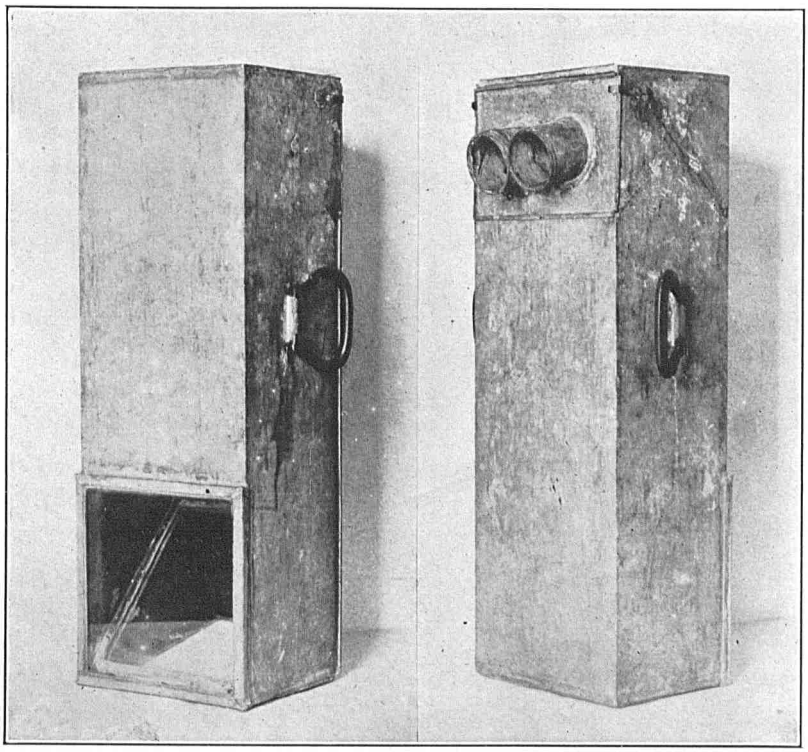

FIG. 3.—Reflecting water glass used by the writer. For description see text. Compare figure 4, text.

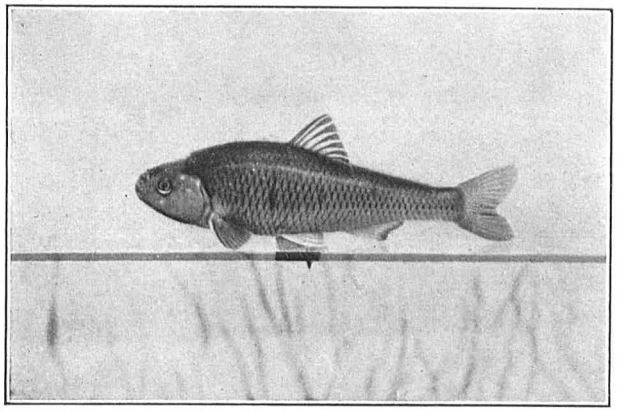

FIG. 4.—Male of the common shiner (*Notropis cornutus*), photographed in an aquarium out of doors with a reflecting camera.

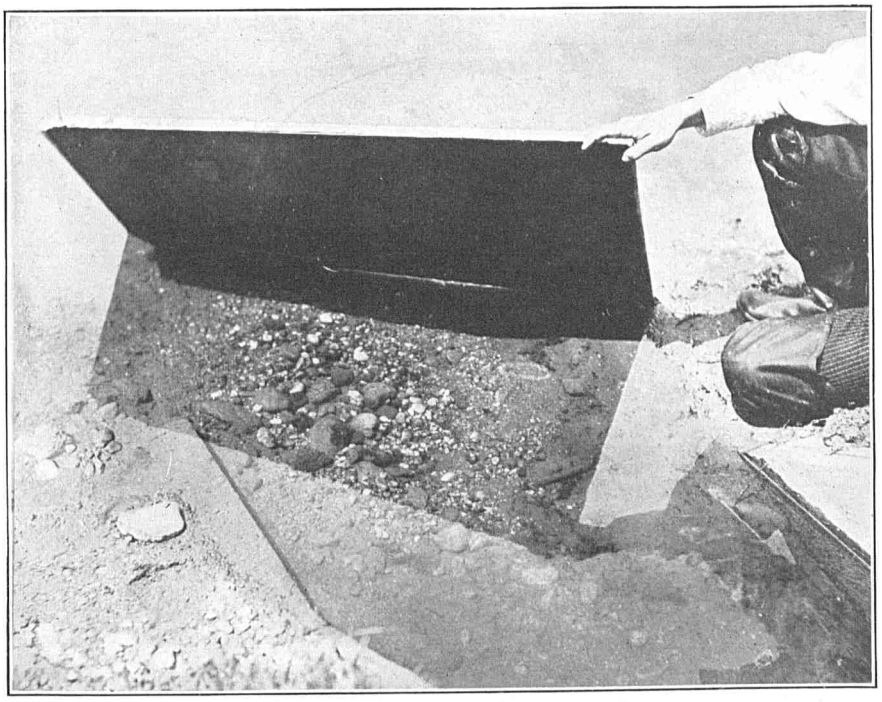

FIG. 5.—Photograph of the nest of a small-mouthed black bass (*Micropterus dolomieu*) taken with the aid of a screen, the camera above water.

FIG. 6.—Brook lampreys (*Lampetra wilderi*) on the nest, photographed through the water glass shown in figure 2, plate CXIV, in about 8 inches of running water.

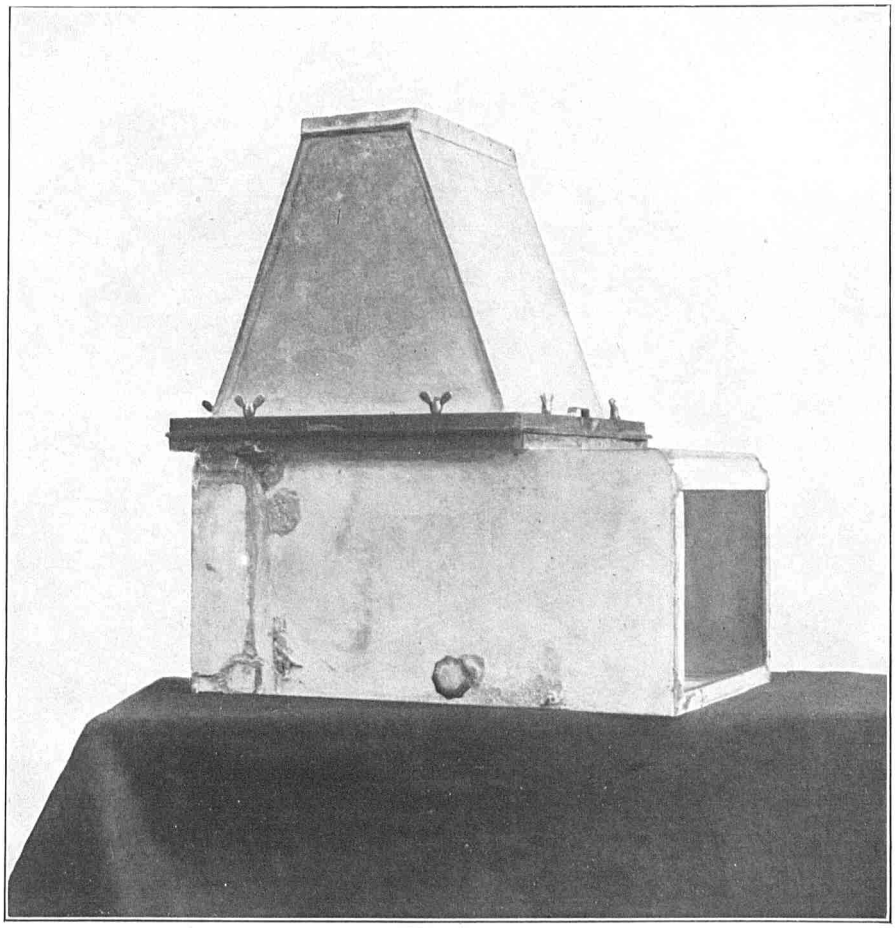

FIG. 7.—Galvanized-iron box with plate-glass front, designed by the writer to contain a 5 by 7 reflecting camera for use under water.

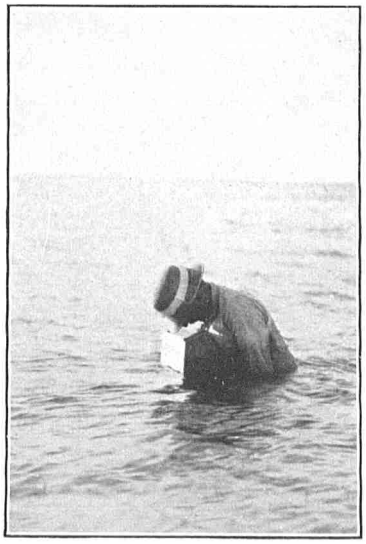

FIG. 8.—Photograph showing the method of using the reflecting camera inclosed in the water-tight box for subaquatic work. The upper part of the box covering the hood rises above the surface, while the lower part, containing the camera proper, is under water. The operator is looking into the hood through the plate glass in the top of the box. With his right hand he focuses, with his left makes the exposure.

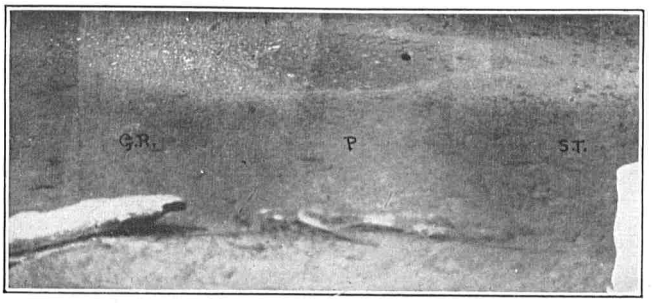

FIG. 9.—Photograph of the nest of a horned dace (*Semotilus atromaculatus*), taken with a reflecting camera and by the aid of a cloth screen used as shown in figure 6, plate CXVI. The reflected image of part of the screen is seen over the right and left parts of the nest. In the upper part of the picture at the right above *S. T.* is the sand trail; to the left of this, above *P.*, is the pit, in the bottom of which are large pebbles; farther to the left, above *G.R.*, is the gravel ridge with its top dressing of fine pebbles. The end of the ridge, its structure of coarse pebbles, is within the pit at the left.

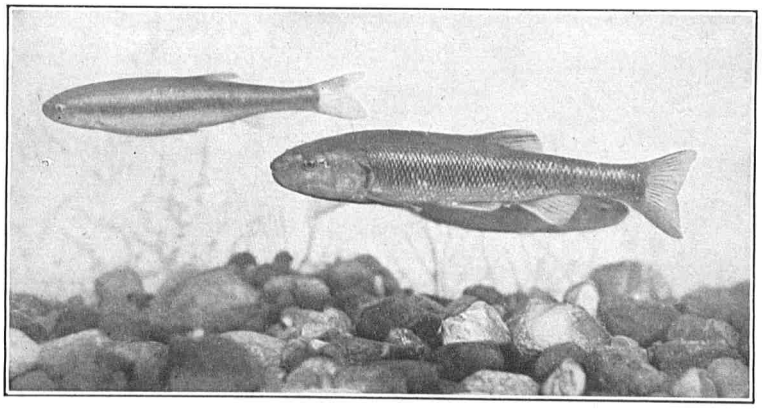

FIG. 10.—Male and two females of the horned dace (*Semotilus atromaculatus*). One female is above at the left, the other behind the male. The head of the male bears four pearl organs. Photographed with a reflecting camera, the fish in an aquarium out of doors.

FIG. 11.—Male horned dace picking up a stone. His lips are grasping it.

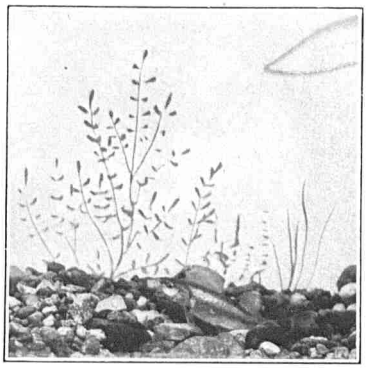

FIG. 12.—Male horned dace about to drop a stone which he carries in his mouth.

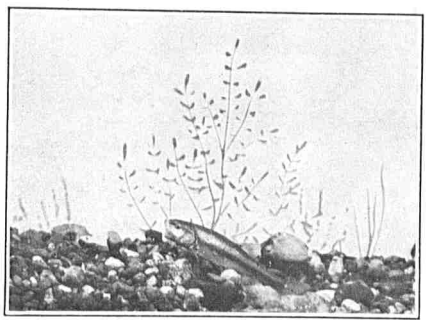

FIG. 13.—Male horned dace which has just dropped a stone, but has his mouth still open.

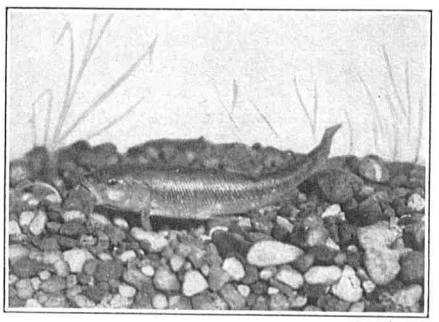

FIG. 14.—Male horned dace pushing along the bottom a stone too big to carry.

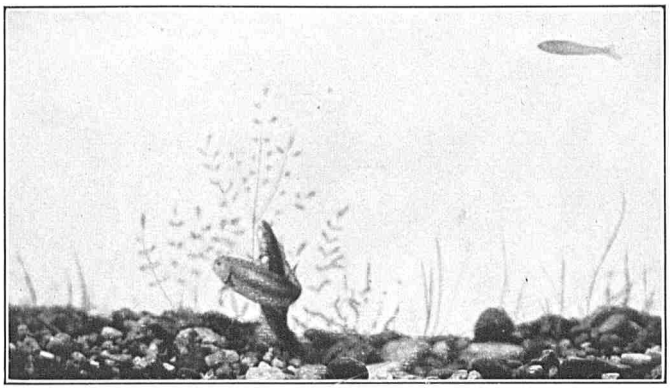

FIG. 15.—Photograph of dace in the act of spawning. The female is in the upright position. The male has either not completed his embrace of the female or has just relaxed it. Photograph made with a reflecting camera, the fish in an aquarium out of doors.

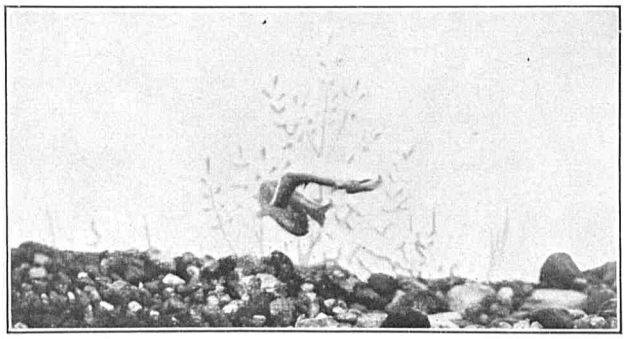

FIG. 16.—Male and female of the horned dace just after completion of the spawning act. The female floats belly up as though dead. The male appears to examine the falling eggs, which are in front of his head and in front of the stones beneath him as well as in the intervening clear water. Photograph made with a reflecting camera, fish in an aquarium out of doors. The vegetation shown in this and the other figures was painted on the back of the aquarium.

A METHOD OF STUDYING THE LIFE HISTORY OF FISHES

By Charles F. Holder

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

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A METHOD OF STUDYING THE LIFE HISTORY OF FISHES.

By CHARLES F. HOLDER.

The owners of the island of Santa Catalina, Cal., latitude 33°, at my suggestion established a small zoological station, which was thrown open free to students who would come with letters from teachers. The aquarium cost about $10,000. The tanks were placed out in the room so that they could be examined from all sides and the light reach all parts. For all purposes this plan is the most satisfactory, though it does lose the glamor of the "dark, unfathomed caves," which, as often seen in aquariums, are unnatural. Nearly all fishes that live near the surface like the sunlight as it sifts down through the water, so in the zoological station the tanks are bright and clear, and the fishes can be seen, slightly magnified, from all sides, and studied or admired.

No better opportunity to study the life history of fishes can be imagined, and as the fauna resembles that of the Bay of Naples, or, if possible, is richer, the field is an interesting one and almost totally missed by zoologists who take tables at Naples, paying for them, when they could have a greater opportunity here for nothing. Through the courtesy of the owners I have had the entrée to this aquarium and have made many interesting observations.

In observing the habits of fishes I have taken, for example, the shiner, a surf fish, keeping it before me constantly. During the breeding season I observed the birth, which was tail first, of the remarkably large young, and had them before me until they reached the adult stage. The development of the Garibaldi was more interesting, as it is at first a beautiful metallic blue, iridescent, and gradually, as it grows, assumes an orange-red tint, until when nearly 2 years old it is almost entirely orange. I watched the changes, kept the fish in different tanks, and tried them with different foods and colors. I had a tank built about 3 feet long, 8 inches wide, and 2 feet high, which I used in photographing fishes at different ages and stages of their development. The tank could be arranged with the weed in which the fish live in a state of nature, and was placed on the roof of the aquarium in the sun. It was so narrow that the prisoners could not get away from the camera, hence were easily photo-

graphed. I have a series of nearly all the fishes of this region, and I commend this method of individual tanks for old and young fish and eggs, and the photographing of them at intervals, as a simple yet conclusive method of examination and study.

From the side of the tank every motion of a fish could be observed, while in an adjoining room were specimens of the same fish in alcohol or formalin for study. Here I saw the swell shark and the California Port Jackson shark deposit their eggs; later I saw the young making their way out of the corkscrew eggs, then had them photographed as they were hatched, the entire history of the fish being observed and recorded.

I paid particular attention to the protective resemblances. I arranged tanks with colored bottoms and watched and timed the adaptation of color in sculpins and the beautiful kelpfish. In the latter is found one of the most beautiful of all fishes that depend upon protective resemblance. It not only imitates the kelp perfectly in tone, shade, and color, but hangs in it, head down, imitating the leaf in shape and position. I followed the fish from birth to the laying of eggs; found that the female was nearly twice as large as the male, and I think I had the first opportunity to notice the building of the nest, which I reported to the American Naturalist. The male had glorious nuptial colors. I watched the female carefully, and the moment she sank to the bottom, exhausted from an effort of twining a silken egg cord about the weed, the male sprang ahead, poised over the eggs, his body violently quivering as he showered over them a cloud of spermatozoa. The following is an account I published in the American Naturalist:

One of the most interesting fishes found in the great kelp beds along the shores of Southern California is the so-called kelpfish, *Heterostichus rostrata* Girard. In color it closely resembles the seaweed in which it habitually lives. During the past year two adult kelpfishes and a smaller fish of another kind occupied one of the tanks in the Santa Catalina Island Aquarium. The larger kelpfish, a female, was about 9 inches in length; the male measured about 5 inches. I was attracted to them by the savage attacks of the male on a stranger, and investigation showed that he was in nuptial colors and was attending the female. The offending fish was removed, giving the kelpfish the entire tank.

All the colors of the male kelpfish were highly accentuated and brilliant. What had been white was now lavender and silver; the dark angles of the zigzag barring took on darker tints and were emphasized by countless lines of lavender, yellow, blue, and gold; patches of silver, old rose, lavender, and white appeared here and there the entire length of the fish, making it a most gorgeous creature. The long vibrating dorsal fin was erect, and the fish was unusually alert as if sensible of the importance of the situation and its responsibilities.

In the tank were several small bunches of a deep maroon seaweed 4 or 5 inches high; and as I watched the female, large and heavy with spawn, she approached the weed and appeared to examine it, passing around it several times. Then I saw that her ventral surface was pressed against the weed and that its branches were being caught together by a viscid pure white cord having the diameter of a thick thread. It

clung tenaciously to every branch it touched. Along the cord were large numbers of small eggs. When 4 or 5 inches of the cord had been attached, the fish would rest, the male taking her place and hovering over the eggs, which he guarded with a viciousness altogether unexpected in so small a fish. He withdrew when his mate resumed egg laying. She frequently pushed her way through the clump of weed, but more often passed around it, the silken tenacious cord binding it together in a globular or oval mass about the size of a hen's egg. The entire nest * * * was formed in about two hours, the fish dropping to the bottom of the tank after each effort and lying there for ten or twenty minutes.

I had taken a series of photographs of the nest, and by removing the eggs to a glass globe, in turn placing them in the interior of the large tank so that they would not be disturbed, I soon had the young for examination.

This seems to me the simplest method of observation, namely, open, free, well-lighted tanks, with large skylight, so that the natural conditions of the ocean are more or less obtained; aeration from above, so arranged that it can be increased in the case of surf fishes, or decreased for deep-water forms; special tank for photographing fish at various stages of development, etc., at once simple and productive of results of value to students or laymen.

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EFFECTS OF CHANGES IN THE DENSITY OF WATER UPON THE BLOOD OF FISHES

By G. G. Scott

Department of Natural History, College of the City of New York

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

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By G. G. SCOTT,
Department of Natural History, College of the City of New York.

The fact of variation in the number of human blood corpuscles in health has been known for some time. Stierlin (1889) found variations in individual men of 1,650,000 per cubic millimeter and somewhat larger variations in women. Viault (1890) noted a marked increase in cases of residents at high altitudes. Some physiologists suggest that the increased number is probably not due to increased formation of red corpuscles but for one thing to evaporation of water from the surface and loss of water from the blood. Yet others have found in animals kept at low pressures that there occurs an increase in the number of corpuscles. Hill (1906), reviewing this work, notes an increase in hemoglobin and adds that it is a reaction on the part of the organism to compensate for low oxygen pressure at high altitudes. Although the other side of this question, the changes in the organism due to increased atmospheric pressure (caisson disease), has been investigated, the principal effect noted has been the presence of air bubbles in the blood and other tissues, the fatal effect of which is well known. The effect on the corpuscle count has not been noted.

Dr. F. B. Sumner, director of the biological laboratories of the Bureau of Fisheries at Woods Hole, Mass., who is interested in the cause of the death of salt-water fishes in fresh water and whose investigations will be referred to, suggested to the writer that he study the effect on the blood of fishes subjected to changes of density in the water. Part of my time has been devoted to this problem during the last three summers, with facilities and material afforded by the Bureau of Fisheries.

Sumner (1905) found that well-marked changes in weight resulted in certain cases where the density of the water in which fishes were kept was increased or decreased. He showed that although at first thought these changes might have been expected on the assumption that we were dealing with an osmotic action through semipermeable membranes, yet in other cases the changes did not follow

these laws and the phenomena appeared to be complicated by physiological and chemical factors of an obscure nature. In one case (the carp) it was shown that the changes took place through the gills. In another paper (1907) the same author confirmed the last named result by experiments with the tautog. He also found seasonal differences in the osmotic phenomena and says that "these differences may perhaps be due to differences of temperature but are more probably due to seasonal variations in the physiological condition of the animals."

While not entering into the work in detail, such a course necessitating constant reference to figures, I will give the results of a few experiments and discuss the same.

I wish to corroborate the work of Sumner as to gain in weight of *Fundulus heteroclitus* when placed in fresh water. In this case the fishes were kept in separate dishes and the record of each individual fish was kept. They were taken out and weighed at intervals. The percentage of gain was obtained in each case and for each period. It was found that there was considerable variation. Thus in one experiment there is noted a gain of 13 per cent in one individual, while in the case of another fish of the same lot there was a gain of 2.1 per cent. The average gain was 5 per cent, or if we disregard the case of 13 per cent gain, the average was 4 per cent.

But it may be questioned what right we have to throw out the case of 13 per cent gain. In the first place, this is from two to six times as great as the gain in each of the other cases. What is more important, however, is that it is not a normal case—that is, the fish was not in normal condition, for on referring to the record it is found that at the end of six hours it had turned on its side and a few hours later was dead. This was true of other similar cases. Wherever there was an extraordinarily large initial gain it was noted that early death took place. Again, when in the course of the experiment a marked gain in weight occurred, it was found that this was soon followed by death. It thus appears that there is another factor here than merely osmotic phenomena—that there is a physiological (vital) reaction against osmotic pressures, and as death approaches, this physiological reaction ceases and the phenomena following for a short time at least are osmotic.

Now what is the effect on the blood when this species of fish is placed in fresh water? A familiar experiment in histology is to observe the effect on the corpuscles of distilled or tap water and of concentrated salt solutions. There are distinct effects which end in the destruction of the corpuscles. But do similar changes take place when the living organism (i. e., a salt-water fish) is placed in fresh water? An experiment was devised whereby one lot of *Fundulus heteroclitus* was kept in normal sea water and a second lot in fresh water. After certain periods of immersion (two hours, etc.) blood smears from fishes in each of the

two lots were made on the same slide at the same time and stained simultaneously with Wright's blood stain, were then dried, and mounted in balsam at the same time. A careful examination with the twelfth oil immersion showed no measurable differences in the corpuscles themselves. This was true in other similar tests. In other words, whatever changes these different solutions have on blood it may be said that these changes do not reach the corpuscles themselves.

A series of experiments was made to ascertain whether there was any change in the corpuscle count due to changes in water density. In the case of mountain sickness it has been shown that at high altitudes there is a physiological reaction on the part of the organism to the effect that per cubic millimeter there are more corpuscles manufactured to take up more oxygen, and thus supply the organism with its normal amount. If fishes are placed in fresh water, is the blood diluted? This would be shown by a decrease in the number of corpuscles. To test this, hemocytometer tests were made upon the blood of normal *Fundulus heteroclitus*. The average blood count of eight was found to be 2,749,000. Four fish placed in distilled water for 1¼ to 2¼ hours were examined in the same way and the average blood count was found to be 2,171,000. In two experiments with distilled water there was at first a decrease in the number of corpuscles counted, then a gradual increase, which increase later passed up to and above normal. The last-named experiment indicates that there is at first a reduction, due to influx of water. After the reduction in number of corpuscles there is an increase, which indicates a reaction on the part of the organism to get back to the normal condition. Experiments in which *Fundulus heteroclitus* was subjected to fresh water show, in the main, that the gain in weight which is at first noticeable disappears after a few days and the weight of the organism falls below normal and the decrease continues. This is undoubtedly due to starvation. It may be objected that these fishes can not live very many days in fresh water. In distilled water, no, but in ordinary tap water, yes. On July 10, 1908, I placed ten *Fundulus heteroclitus* in a large rectangular dish containing about 20 liters of fresh tap water. In the bottom was placed some gravel from the shore near by, the gravel having been thoroughly washed. Most of the fishes died during the next three or four weeks, but one fish was alive and apparently in good condition on September 8, 1908, after sixty days. It should be said that the tank in which this specimen was kept was washed out thoroughly once a week and the fish fed. A rough test of the water with silver nitrate and nitric acid was made toward the end of the period, and a slightly greater amount of chlorides was indicated than was present in the fresh tap water. This agrees with Sumner's statement that a slight addition of salt water to fresh water was sufficient to keep the fishes alive, and therefore the death of fishes in dilute solutions was probably not due to lowering of osmotic pressures. To show the

extreme diluteness of salt in the above case, I may add that it took the same reading with the specific gravity hydrometer as did tap water.

In another series of experiments the percentage of hemoglobin was determined with Dare's hemoglobinometer. Although this was less satisfactory, yet the average percentage of hemoglobin of 18 normal *Fundulus heteroclitus* was found to be considerably more than the average in the case of 29 specimens of the same species kept in fresh water for a certain length of time. Have we, however, a right to say that the corpuscles are thus deficient in hemoglobin? Since we have good reason for believing that there is an influx of water and that this takes place through the gills, the reduction in number of corpuscles and a lowering of percentage of hemoglobin shows that the blood has been diluted. We can also obtain the specific gravity of the blood. This was done, by the Hammerschlag method, in which a drop of blood is placed in a solution of benzole and chloroform and enough of each added so that the drop is suspended. The specific gravity of the mixture then would be the same as that of the blood and could be learned by the small hydrometer used for such work. The specific gravity of blood of 20 *Fundulus heteroclitus* was found to be 1.0510. In an experiment in which 22 *Fundulus heteroclitus* were kept in fresh water from two to eight hours the average specific gravity of the blood was 1.047+. In an experiment in which dogfish (*Mustelis canis*) were used, the average specific gravity of the blood of three was 1.0466. After about two hours immersion in fresh water the average specific gravity was 1.0417. Four determinations were made with each fish in the first part of this experiment and similarly in the second part. There was practically no loss of blood except that used in the determination, which fact is mentioned to anticipate the objection that the reduced specific gravity is due to loss of blood, as in the case of hemorrhage in man, when the specific gravity of the blood drops.

It is an established fact that the more dilute a solution is as compared with distilled water the nearer is its freezing point to that of distilled water. By the aid of a Beckman thermometer I obtained the freezing point of distilled water and by the same means the freezing point of the blood serum of a number of dogfish. The average lowering of the freezing point of blood serum of 7 dogfish taken from sea water was found to be 1.934°. Now if there is a slighter depression in the freezing point of blood serum of dogfish kept in fresh water for a certain period, then that means that the blood of such dogfish has been diluted, for such blood is nearer the condition of distilled water than the normal serum. The depression of the freezing point of the serum of 11 dogfish kept in fresh water for one hour was obtained. The average for five experiments was found to be 1.548°. We have already seen that the depression of the freezing point in case of normal dogfish serum was 1.934°. Hence we find that there was dilution of the blood.

In conclusion it may be said that when fishes are kept in fresh water there is a decrease in the number of corpuscles per cubic millimeter, a lowering of the hemoglobin percentage, a lowering of the specific gravity, and a lessening of the depression of the freezing point, all of which shows a dilution of the blood. But, on the other hand, is there shown a concentration of the blood when fishes are placed in a more dense medium? In the case of 19 *Fundulus heteroclitus* kept in sea water, the density of which was increased to about 1.040 by the addition of 25 grams of sea salt to each 1,000 of sea water, the average percentage of hemoglobin was found to be 77 per cent, as compared with 51 + per cent in the case of 18 normal fishes.

As to the number of corpuscles per cubic millimeter, the following experiment was devised: The average number of corpuscles in 8 individuals has been found to be 2,749,000 per cubic millimeter. A fish placed for an hour in a solution of sea water and sea salt so that the specific gravity was 1.050 showed a corpuscle count of 3,072,000 per cubic millimeter. After 2½ hours immersion in sea water and sea salt whose specific gravity was 1.068 the corpuscle count of another specimen was 3,912,000 per cubic millimeter. The average blood count of 14 *Fundulus heteroclitus* kept in a solution of sea water to every liter of which was added 25 grams of sea salt was found to be 3,539,000, while in another case the blood count of two fishes in a solution of sea water to every liter of which was added 45 grams of sea salt was found to be 4,217,000 per cubic millimeter.

At the same time in another experiment record was kept of the weight of the fishes and it was found that they lost steadily in weight while the corpuscle count increased. The same general results were obtained in all the experiments of this nature. From a great many experiments I can corroborate the statement of Sumner as to loss in weight when placed in more dense solutions. As to the change in specific gravity, fishes taken at the same time as those used in getting the normal specific gravity were experimented upon. On placing a lot of 10 in a solution of sea water and sea salt to raise the specific gravity to 1.045 for a period of nearly three hours, the specific gravity of the blood was found to be 1.054. During that time the fishes had lost 7.5 per cent in weight. On remaining in same solution nearly six hours, the average specific gravity was 1.060 and the fishes had lost 11 per cent in weight.

In another experiment with a solution of 1.040 specific gravity there was noted a gradual increase in specific gravity of the blood during the first day. This increase persisted in the case of those examined during the next day, while in 8 specimens examined two days later there was a decrease toward normal in the specific gravity noted. Although this one experiment is inconclusive, it indicates a reaction toward the normal. There is such a thing as normal specific gravity of the blood, and any marked departure is pathological. Hence the

lowering of the specific gravity noted above might be interpreted as a reaction of the organism toward the normal condition. The water necessary to dilute the blood could be drawn in from the tissues.

An experiment was devised to test the relation between temperature and the lowering of the specific gravity of the blood. Three lots of fish were used.

Lot A.—Sea water at temperature of laboratory, 18° C.

Lot B.—Fresh water at 27° C.

Lot C.—Fresh water at 7° C.

The fishes were kept in these solutions from one to six hours. At the end of that period the average specific gravity of blood of—

Lot A was 1.0506, 18° sea water.

Lot B was 1.0463, 28° fresh water.

Lot C was 1.0501, 7° fresh water.

In other words, the cold water had prevented the decrease in specific gravity.

Now it is known that temperature is an important factor in osmotic exchanges and also in physiology of circulation. Therefore, whether the more sluggish movement of the blood through the gills is responsible for the difference between B and C or whether the lowering of temperature produced a condition in the gill membrane making osmotic changes more difficult can not be determined at present. We have seen from the previous experiments that if fishes are placed in a more dilute solution the blood is diluted; if placed in a more concentrated solution the blood is concentrated. It is not believed, however, that in the time during which the fishes were subjected to these various media there was any increased formation of red corpuscles or any destruction of the same.

Are the phenomena described above purely osmotic, and thus physical in their nature, or is there something more—that is, physiological or vital—concerned here? Certainly some of the phenomena observed above lead toward the latter interpretation. The great adaptability of the organism is well shown in the case of the specimen living in fresh water for two months, and again in the case of a few fish which lived for over a month in a solution the concentration of which was increased 50 per cent. It must be remembered that *Fundulus heteroclitus* is found not only in sea water but also in brackish water and inlets of fresh-water streams. Whether the above changes are true of the teleosts which are strictly marine, I can not say.

INTERNAL PARASITES OF THE SEBAGO SALMON

By Henry B. Ward, Ph. D.

Professor of Zoology, University of Illinois

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

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INTERNAL PARASITES OF THE SEBAGO SALMON.

By HENRY B. WARD, Ph. D.,
Professor of Zoology, University of Illinois.

In connection with other investigations of the United States Bureau of Fisheries in Alaska in 1906, I had the privilege of spending two months in study of the parasites of the Pacific salmon. The following year, for comparison of the interesting results of this work with similar studies of Atlantic salmon, I was designated to join a party engaged in a biological survey of Lake Sebago, Maine. During six weeks in this region I examined for parasites a number of the Sebago salmon and secured a series of parasites from other fish in the lake and adjacent waters.

The large amount of valuable material obtained on these two trips has engaged my entire attention during the interval since it was secured, and even yet some questions have not been satisfactorily answered. It forms a most interesting contribution to the parasitic fauna of these important fishes and at the same time throws some light on the general relations between an animal and its parasites, which I hope may be of interest to the scientist and of value to the practical fish culturist. This report falls naturally into three parts—first, a historical summary, which concerns chiefly the European or Atlantic salmon, since this species is the only one that has been studied previous to the present date; second, a report on the findings in the case of the Sebago salmon, which is very closely related to the European species, together with a discussion of the conclusions which may be drawn from these data; and third, a similar report on the Pacific salmon, which is less closely related and rather widely removed geographically from the other two forms. In the present paper are included only the first and second sections of the entire report.

HISTORICAL SURVEY.

PARASITES OF ATLANTIC SALMON.

Rudolphi says that in 1726 Frisch observed a salmon parasite, later known as *Bothriocephalus solidus*, and in 1735 published some record of its occurrence in a paper entitled "De tæniis in pisiculo aculeato, qui in Marchia Brandenburgia vocatur 'Stecherling.'" This is the first account of a salmon parasite to which I have found any reference, and I have been unable to ascertain more precisely the data in this case or to verify the reference.

The oldest record of a salmon parasite that I have been able to verify is found in a paper by Spöring (1753), in which he defends the thesis that inhabitants of fluviatile regions are more annoyed by tapeworms than those of other places, no doubt because of the use of half-raw fish. Of weight for his argument is the list of half a dozen fish, including *Salmo salar*, in which, according to his observations, tapeworm[a] larvæ are present. The view that man was indebted to the salmon for infection with fish tapeworms was generally current in early times and, though supported by no scientific evidence, persisted until finally thoroughly disproved by Zschokke (1890). Now it may be regarded as fully established that man does not acquire a single parasite in any way by the use of salmon as food.

O. F. Müller (1776, 1777, 1780) was the first to describe and name according to scientific principles some of the parasites from *Salmo salar*. He named *Fasciola varica*, afterwards called *Distoma varicum* by Zeder; *Echinorhynchus salmonis*, changed to *E. inflatus* by Rudolphi; *E. lævis*, later changed to *E. nodulosus; Tænia solida*, which later became *Bothriocephalus solidus* Rudolphi, and *Tænia salmonis*, later called *B. proboscideus* Rudolphi.

Goeze (1782) gave the first description of *Echinorhynchus quadrirostris*, later more correctly diagnosed and named *Tetrarhynchus appendiculatus* by Rudolphi (1809). Goeze also gave a good description of the encapsulated nematode larva common in salmon, which he referred to *Cucullanus*, though doubtfully. Rudolphi afterwards named this form *Ascaris capsularia*.

The first formal list of parasites from *Salmo salar* is that given by Rudolphi in 1810, who lists as parasites already recorded for this host eight[b] species, as follows:

Bothriocephalus proboscideus.
Bothriocephalus solidus.
Tetrarhynchus appendiculatus.
Distoma varicum.
Ascaris capsularia.
Dub. (?Cucullanus).
Echinorhynchus inflatus.
Echinorhynchus (?) nodulosus.

It is of interest to note that Rudolphi records opposite every one of these named from six to eight earlier references to the particular species. Five of them were originally observed by O. F. Müller, two by Goeze, and one is a doubtful species.

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[a] Braun (1894), who cites the case, says *Ligula* larvæ, but as this genus has not been recorded for *Salmo salar* I take it to apply only to certain of the host species listed. The original author of course did not distinguish even genera in his observations.

[b] In the appendix (vol. II, part 2, p. 376) Rudolphi lists another find under the name of *Distoma crenatum*. This material was examined by Lühe (1901, 401) and pronounced not a hemiurid, but further determination could not be made.

In a later paper (1819) Rudolphi added to the list no new parasite, *Distoma appendiculatum* Rudolphi being merely another name for *D. crenatum* of the appendix in the earlier work. In this list *Echinorhynchus fusiformis* Zeder is only a change of name from *E. inflatus* of the earlier list; *E. nodulosus* is omitted; *Bothriocephalus solidus* is interpreted as introduced by accident when its proper hosts chance to be eaten by the salmon. Thus the true list of salmon parasites is actually reduced, and numbers only seven in this later list of Rudolphi.

In 1851, Diesing in his "Systema Helminthum" recorded for *Salmo salar* ten parasites, as follows:

Distomum varicum.
Stenobothrium appendiculatum.
Schistocephalus dimorphus.
Dibothrium proboscideum.
Echinorhynchus pachysomus.
Echinorhynchus proteus.
Agamonema capsularia.
Ascaris capsularia.
Ascaris clavata.
Cucullanus elegans.

Although one notes at once the unfamiliar appearance of the list due to numerous changes in the names employed, yet only the last two are actually new forms. Thus, in spite of the frequent attention given to the salmon, the list of its parasites had only increased from five to ten species in the seventy-five years since O. F. Müller first made scientific records of its parasitic fauna in Denmark.

In 1878 von Linstow in the "Compendium der Helminthologie" listed 16 parasites for *Salmo salar*. New are:

Distomum ocreatum Rudolphi.
Distomum reflexum Creplin.
Bothriocephalus cordiceps Leidy.[a]
Tetrarhynchus grossus Rudolphi.
Tetrarhynchus solidus Drummond.

In his "Nachtrag" (1889) the same author includes five new species of parasites recorded for *Salmo salar* since the appearance of the earlier record, namely:

Agamonema communis Diesing.
Distomum miescheri Zschokke.
Bothriocephalus sp.? Zschokke.
Leuckartia sp.? Moniez.[b]
Tetrabothrium minimum von Linstow.

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[a] As indicated in the discussion (p. 1166), this is an error in citation.

[b] Moniez (1881) found three cestodes in the pyloric cœca of a salmon obtained in the fish market at Lille (France), on which he based a new genus, *Leuckartia*. Except for the lack of a scolex, the specimens agree well with *Bothriocephalus infundibuliformis*, better *Abothrium crassum*, to which they may well belong.

Without tracing in detail the further progress of the record, it may be said that at the present date the list includes 47 species, which are enumerated later in this paper. It is of importance for a consideration of the distribution of the salmon parasites, the especial object of this paper, to review the later studies in this field in their geographic arrangement in order to compare clearly the parasites found in one area with those which are present in another. The salmon which have been most intensively studied are those of the Rhine.

Our knowledge of these forms is due largely to a series of papers by the distinguished Swiss helminthologist, Fr. Zschokke, of Basel, which cover the work of many years. The first record of Zschokke (1889) included examinations of 45 fish, of which 42 were found infected with parasites. All the fish were caught in the Rhine in November, December, and January, and the following parasitic species were listed:

Parasite.	Organ infected.	Ratio of infection.
		Per cent.
Distomum varicum Zeder	Œsophagus	11
Distomum reflexum Creplin	do	2
Distomum miescheri Zschokke	do	2
Bothriocephalus infundibuliformis Rudolphi	Pyloric cœca	20
Bothriocephalus sp. (larva)	Encysted	2
Tetrarhynchus solidus Drummond	do	2
Tetrarhynchus grossus Rudolphi	do	2
Rhynchobothrium paleaceum Rudolphi (larva)	do	29
Agamonema capsularia Diesing	do	77
Ascaris clavata Rudolphi	do	4
Echinorhynchus sp	do	4

Not a single parasite lay in the alimentary canal below the pyloric cœca. Monticelli notes that most sharks lose their parasites after a long stay in an aquarium, and Zschokke has observed that marine fish otherwise heavily infested lose their intestinal parasites very rapidly when subjected to fasting in captivity. The Rhine salmon behaves with regard to parasites just like a fasting sea fish. Its parasitic fauna manifests an almost purely marine aspect. Fresh-water elements are scanty and insignificant. Clearly, then, the Rhine salmon takes little or no food during its fresh-water migration. Data on individual species close the paper.

The parasitic fauna of the Atlantic salmon was discussed in extended fashion later by Zschokke (1891) on the basis of his own previous studies and those of earlier authors. In all he had examined the viscera of 129 fish caught in the Rhine. The alimentary canal contained in all cases the thick yellowish or yellow-brown mucus, but never any recognizable remnants of food materials, although once plant fibers and undigested remains of a *Gammarus pulex* were found. As in similar previously reported cases, so here also the occurrence of these fragments should be regarded as purely accidental.

Only four of the 129 salmon examined were free from parasites, and in all 20 species of the latter were recorded from the infested fish. The list of parasites recorded is as follows:

Ascaris adunca Rudolphi.
Ascaris angulata Rudolphi.
Ascaris clavata Rudolphi.
Ascaris (Agamonema) capsularia Diesing.
Ascaris (Agamonema) communis Diesing.
Echinorhynchus acus Rudolphi.
Echinorhynchus agilis Rudolphi.
Echinorhynchus proteus Westrumb.
Distomum varicum Zeder.
Distomum reflexum Creplin.
Distomum miescheri Zschokke.
Schistocephalus dimorphus Creplin.
Bothriocephalus infundibuliformis Rudolphi.
Bothriocephalus osmeri (larva) von Linstow.
Bothriocephalus sp. I (larva).[a]
Bothriocephalus sp. II (larva).
Rhynchobothrium paleaceum (larva) Rudolphi.
Tetrarhynchus solidus Drummond.
Tetrarhynchus grossus Rudolphi.
Tetrarhynchus macrobothrius von Siebold (=Stenobothrium appendiculatum Diesing).

Five of these species (*Ascaris capsularia*, *Distomum varicum*, *Bothriocephalus infundibuliformis*, *Rhynchobothrium paleaceum*, and *Tetrarhynchus macrobothrius*) are abundant, almost regular in their occurrence, while the other forms are relatively rare in the Rhine salmon. The common parasites were also usually abundant in the individual host; thus 20 to 40 specimens of *Ascaris capsularia* were often found in a single host. Of *Distomum varicum*, from 30 to 50 individuals were taken from the œsophagus of one fish. In some cases *Bothriocephalus infundibuliformis* was present in large numbers, but usually in one or a few weak, starved specimens. *Rhynchobothrium paleaceum* and *Tetrarhynchus macrobothrius* occurred in from 20 to 25 individuals in a single host. All other parasites were found in small numbers, often only a single specimen of any one species.

Among the 129 Rhine salmon investigated 4 were free from parasites, 55 sheltered a single species of parasite, and 43 but two species, while 20 had three species, 6 had four species, and 1 had five species of parasites.

[a] The various bothriocephalid larvæ which occur in the salmon are discussed in a separate paper by Zschokke (1890). On the basis of morphologic data he inclined in this paper to the view that five different forms, indicating as many species, might be distinguished. Later studies showed the first to belong to *Bothriocephalus osmeri* von Linstow. This is the form he listed at first (1889) as *Bothriocephalus* sp. The second is sp. I of the table, the third and fourth are united as sp. II of the table, and the fifth becomes sp. III of the table (see p. 1168).

In not a single case was a parasite found in the alimentary canal below the pyloric cœca. Indeed, parasites which in other hosts inhabit only the intestine, were found in the Rhine salmon to infest stomach and œsophagus, as if better protected there than in the vicinity of the anus. The Rhine salmon loses its intestinal guests like any fasting fish, and through the exclusion of food any new importation of worms is prevented. From the absence of parasites behind the pyloric cœca one may conclude indirectly that *Salmo salar* really fasts in the Rhine. When this species enters the river it is richly laden with parasites. It loses its intestinal guests and these are not replaced by any new supply. There remain only the natural inhabitants of the anterior regions of the canal and those which can withdraw thither. Even these protected species diminish in number of species and individuals as the salmon remains longer in fresh water and climbs higher in the stream, until finally there are left only encapsulated forms. The journey up the Rhine has proved at the same time a means of eliminating the intestinal parasites. Some investigators, although without knowledge of these facts, have yet endeavored to explain the migration of many fish as due to the necessity of freeing themselves from parasites acquired in the ocean.

Salmon caught in Holland, in the lower reaches of the Rhine, are richly infested with parasites. Several species were regularly found in large numbers and the parasitic fauna recalls strikingly that of the ocean salmon. *Distomum varicum* was very abundant in the œsophagus and *Bothriocephalus infundibuliformis* in the pyloric cœca. But fish from the upper reaches of the Rhine presented a radically different picture. The parasites in œsophagus and stomach were very rare. *Distomum varicum* had disappeared and *Bothriocephalus infundibuliformis* appeared only as single, weak, emaciated specimens. Often the entire alimentary tract yielded no trace of a parasite.

The parasitic fauna of the Rhine salmon decreases in proportion as the fish ascends the stream.

A study of the seasonal distribution of parasites in the Rhine salmon evidences that the number of species present becomes reduced in the winter months, and the number of individuals also falls off markedly. The minimum is reached in November and December, the months of spawning, when the fish has penetrated farthest upstream. It has lost its unbidden guests on the long journey. The maximum of parasitic infection is found in the summer months, May to July, when the schools of salmon enter the river. Naturally the journey exerts no influence upon those parasites which inhabit closed organs.

The question next considered is the origin of the salmon's parasites, whether marine, limnetic, or indifferent in character. The analysis of the forms recorded indicates that the Rhine salmon does not exhibit a single true limnetic parasite,

and its most abundant guests are typically marine. In spite of a long and repeated sojourn in the river it does not infect itself with a single fresh-water parasite, a fact that indicates strongly the complete fasting of the salmon while in the Rhine. In other migratory fish the marine elements become greatly reduced or even disappear entirely. Yet tabular comparisons show that in contrast with the Rhine salmon all other migratory fish infect themselves in fresh water more or less strongly with parasites, thus indicating that whereas the salmon fasts in the Rhine, its near relatives feed abundantly on wandering from the ocean into the river.

It was possible to examine also 34 salmon from the Baltic Sea; all of them were infected, and a total of 12 species of parasites were recorded from them, as follows:

Ascaris adunca Rudolphi.
Ascaris (Agamonema) capsularis Diesing.
Ascaris (Agamonema) communis Diesing.
Ascaris aculeati von Linstow.
Echinorhynchus acus Rudolphi.
Echinorhynchus pachysomus Creplin.
Distomum varicum Zeder.
Distomum appendiculatum Rudolphi.
Bothriocephalus infundibuliformis Rudolphi.
Bothriocephalus sp. II (larva).
Bothriocephalus sp. III (larva).
Triænophorus nodulosus Rudolphi (larva).

The Baltic salmon is much more heavily parasitized than the salmon of the Rhine. Seven parasites are common to both, and of these five are more abundant in the Baltic salmon and two only more abundant in the Rhine salmon, while six parasites of the former do not occur in the latter. The relative infestation of the two forms is shown in the accompanying synopsis:

Fish.	Number examined.	Not infected.	Infested with parasites of given number of species.				
			1.	2.	3.	4.	5.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Rhine salmon	129	3.1	42.6	32.5	16.5	4.6	0.77
Baltic salmon	34	0	50	23.5	17.6	8.8	0

Of parasitic species found in the Baltic salmon, *Bothriocephalus infundibuliformis* was present often in enormous numbers, and the same was true of *Distomum varicum.* On the other hand *Ascaris capsularis* did not manifest the frequence or the abundance already noted for the Rhine salmon. Everything indicates a rich and uninterrupted consumption of food by the Baltic

type in contrast with the fasting Rhine fish.[a] Parasites are also found in the intestine behind the pylorus, where the Rhine salmon remains free from parasites. Among the intestinal parasites of the Baltic salmon also are included no true limnetic species. Such only lie encapsulated in various organs. This indicates that the infection with the true fresh-water parasites, *Cucullanus*, *Triænophorus*, *Ascaris aculeati*, actually occurs in the rivers. The Baltic salmon comes into fresh water as richly laden with parasites as the fish caught in the lower stretches of the Rhine in Holland. While the parasitic fauna of the Rhine salmon decreases in proportion as it ascends the stream, that of the salmon in many other rivers is enriched by numerous limnetic elements. The natural explanation lies in the fasting of the Rhine salmon, whereas its relatives in other streams do not cease taking food. The Baltic salmon, having returned to the ocean, loses the limnetic parasites of the open intestine but retains those located in the closed organs of the host.

The material is too scanty to determine a seasonal distribution, if any exists, and in fact the food of the Baltic salmon undergoes little change throughout the entire year, so that no general modification would be expected in the parasitic fauna, variations being merely of an individual or casual type.

Upon a careful study of the individual species the parasitic fauna of the Baltic salmon manifests a more varied aspect than that of its relative. There are 2 pure marine forms, in contrast to 8 in the Rhine salmon, 2 pure limnetic species as against not a single one in the other host, 6 parasites found in both marine and fresh-water fishes, and 3 parasites found only in the Baltic salmon, with a fourth which can not be assigned with certainty to either type of environment. It is very striking that the purely marine *Tetrarhynchi* so abundant in the Rhine salmon have not yet been demonstrated in the Baltic fish. These relations are indicated in the appended table of parasites from the European salmon, collated from various authors.

The Rhine salmon shelters a purely marine parasitic fauna, while the Baltic salmon reckons many limnetic forms among its parasitic guests. This remarkable condition finds its explanation in the continued feeding of the latter type,

[a] One should not forget in estimating this factor as presented by Zschokke that in one important respect conditions are not identical. The Baltic salmon are still in salt water; not until they enter some estuary and begin the ascent of some river do they meet the fresh water environment to which the Rhine salmon investigated by Zschokke are subject. To secure an exact parallel one should compare the Baltic salmon with such of the Rhine variety as may be captured in the North Sea. Zschokke refers in a later paper to some taken from this body of water and notes in their case also that the average degree of infection with parasites is greater than in the case of those fish taken from the Rhine stream itself. This fact only emphasizes the immediateness and definiteness of the effect on the parasitic fauna of the salmon which is produced by the fresh water environment and abstinence from food.

even in fresh water, and the resulting enrichment of its parasitic fauna with limnetic forms when it returns to the sea.

The parasitic record reflects clearly the manner of life led by any host.

In all, 33 species have been recorded from this salmon, making the list of its parasites one of the longest known for any fish. The list of these is then given, as follows:

Ascaris adunca Rudolphi.
Ascaris angulata Rudolphi.
Ascaris clavata Rudolphi.
Ascaris (Agamonema) capsularis Diesing.
Ascaris (Agamonema) communis Diesing.
Ascaris aculeati von Linstow.
Cucullanus elegans Zeder.
Echinorhynchus proteus Westrumb.
Echinorhynchus pachysomus Creplin.
Echinorhynchus acus Rudolphi.
Echinorhynchus agilis Rudolphi.
Distomum varicum Zeder.
Distomum reflexum Creplin.
Distomum miescheri Zschokke.
Distomum appendiculatum Rudolphi.
Distomum ocreatum Rudolphi.
Distomum tereticolle Rudolphi.
Distomum sp. McIntosh.
Bothriocephalus infundibuliformis Rudolphi.
Bothriocephalus cordiceps Leidy.
Bothriocephalus osmeri (larva) von Linstow.
Bothriocephalus sp. I (larva) Zschokke.
Bothriocephalus sp. II (larva) Zschokke.
Bothriocephalus sp. III (larva) Zschokke.
Schistocephalus dimorphus Creplin.
Triænophorus nodulosus (larva) Rudolphi.
Leuckartia sp. Moniez.
Tetrabothrium minimum von Linstow.
Rhynchobothrium paleaceum Rudolphi.
Tetrarhynchus solidus.
Tetrarhynchus grossus Rudolphi.
Tetrarhynchus macrobothrius von Siebold (=Stenobothrium appendiculatum Diesing).
Tetrarhynchus sp. McIntosh.

The paper of Zschokke closes with a detailed discussion of the biology and relationships of the individual salmon parasites, including citations of the work of previous investigators on these forms.

In a later paper Zschokke (1896) lists the parasites of salmon caught in the Rhine at Basel, including the results of examinations extending over several years and embracing 16 species, as follows:

Bothriocephalus infundibuliformis Diesing.
Tetrarhynchus solidus Drummond.
Tetrarhynchus sp.
Schistocephalus dimorphus.
Distomum varicum Zeder.
Distomum appendiculatum Rudolphi.
Distomum ocreatum Rudolphi.
Distomum reflexum Creplin.
Distomum miescheri Zschokke.
Ascaris clavata Rudolphi.
Ascaris capsularia Diesing.
Ascaris sp.
Ascaris sp.
Echinorhynchus clavæceps Zeder.
Echinorhynchus acus Rudolphi.
Pisicola geometra Linnæus.

Unreported previously are *Echinorhynchus clavæceps* Zeder, *Pisicola geometra* Linnæus, and possibly also two undetermined species of *Ascaris*. Eliminating forms which do not properly belong to the Rhine at Basel and adding species recorded previously, the net result is 17 species of parasites in the salmon at Basel, or one-third of the total known parasitic fauna of that region. Of these 17, 13 are characteristic of the salmon and wanting in other fish there. The large majority of the list are of purely marine character and a further group is characteristic of migratory fish, leaving nothing of a limnetic type save *Pisicola geometra*, a leech which is merely a temporary ectoparasite.

This paper records also the results of the examination of additional salmon from the North Sea, the lower Rhine, and the middle and upper Rhine, making the grand total of 179 Rhine salmon examined by this author. The only new parasite recorded is *Scolex polymorphus* Rudolphi. Again, later, Zschokke (1902, p. 128–130) discusses the records of his earlier work without adding any new data.

In studies on the Rhine salmon Hoek (1899) records that he found in the young fish an ascarid, according to Fritsch *A. clavata*, and repeatedly specimens of a species of *Echinorhynchus* which Fritsch names *E. pachysomus* Creplin, though he did not observe it in the young salmon. In Hoek's opinion the forms obtained, though not fully grown, agree better with the description of *E. proteus* Westrumb, and indeed with the more limited concept of the name according to Hammann. Hoek observed not infrequently that young salmon were infested with a leech, *Cystobranchus* (*Pisicola*) *respirans* Troesch, which lived as an ectoparasite on the skin.

Concerning the Baltic salmon, other fragmentary data are also on record. Olsson (1867) reported *Bothriocephalus proboscideus* Rudolphi as frequent in *Salmo salar* both from fresh and from salt water during April and August. Later the same author (Olsson, 1876) listed *Distomum appendiculatum* Rudolphi as frequent in *Salmo salar* during August. Again (1893) he reported *Distoma appendiculatum* Rudolphi from the stomach as abundant in July. The material came from the Baltic Sea and the Gulf of Bothnia.

Hausmann (1897) lists from *Salmo salar Distomum appendiculatum, D. ocreatum, D. reflexum,* and *D. varicum.* Among 20 specimens examined 13 only were infested with trematodes.

Mühling (1898) records from *Salmo salar* in East Prussia six species of parasites, as follows: *Bothriotænia proboscidea, Apoblema appendiculatum, Echinorhynchus acus, Ech. fusiformis, Ech. proteus,* and *Ech. pachysomus.* The first two are very common, the others occasional. *Ech. fusiformis* is cited after Neumann.

G. Schneider (1902) reports the following data concerning salmon parasites in Finland: A salmon 1 m. long, caught November 6, 1900, in the mouth of the river, was infested with several hundred individuals of *Bothriotænia proboscidea* Batsch, which entirely filled the pylorus portion of the intestine and of the pyloric cœca. Otherwise the intestine contained no parasites and no food. A second salmon, investigated fresh July 2, 1902, had in the intestine the young and adult *Bothriotænia proboscidea* Batsch and one *Echinorhynchus* larva, which, however, evidently came from fish that had been eaten. In the stomach of this salmon he found *Clupea sprattus* Linnæus [p. 18 the name is given as *Clupea harengus membras* L.] and in the intestine remains of digested fishes, probably also herring. The synchronus presence of herring remains and of very young *Bothriotænia* in the intestine of this salmon confirms fully his formerly expressed opinion that the salmon infects itself with tapeworms through eating the herring.

According to Schneider (1902, p. 20), Kessler in a Russian paper reported the occurrence of adult *Bothriotænia proboscidea* in the intestine of *Salmo salar* from Lake Onega. This body of water is directly connected with the Baltic Sea, where, according to Mühling, as just noted, this species is a very common parasite of the salmon. Schneider has also found it abundant in salmon from the Gulf of Finland.

No doubt some observations have been made on the parasites of salmon in the Scandinavian peninsula, but they have thus far eluded my search.

Concerning the parasites in the British Isles many observations are on record. But they concern individual investigations at particular locations, and as a rule do not cover any continuous study of the problem. In consequence the lists are not as complete as those already cited for the Rhine and the Baltic,

and it is somewhat difficult to draw a precise comparison with the data for the latter regions. First may be placed such records as concern streams directly connected with the North Sea, and hence with the body of water from which the Rhine salmon come.

Concerning the parasites of salmon in the Tay, McIntosh (1863) has recorded certain data. More than 100 fish were examined, few were entirely free from parasites, many were richly infested. The parasitic species were both frequent and abundant, although only 10 species are definitely recorded, as against 14 in the Baltic and 20 in the Rhine salmon. The species from Tay salmon McIntosh lists as follows:

Ascaris (Agamonema) capsularia Diesing.
Echinorhynchus proteus Westrumb.
Echinorhynchus pachysomus Creplin.
Distomum varicum Creplin.
Distomum tereticolle Rudolphi.
Distomum sp.
Bothriocephalus infundibuliformis Rudolphi.
Tetrabothrium minimum von Linstow.
Tetrarhynchus macrobothrius von Siebold.
Tetrarhynchus sp.

The examination of this list shows clearly that the Scotch salmon combines elements from the parasitic fauna of both its relatives, the Rhine salmon and the Baltic salmon. The strong and continued infestation of the intestine below the pylorus goes to establish the fact that the taking of food is continuous.

No seasonal distribution of parasites could be noted, but the character of the parasitic species was striking. One pure marine species and two almost equally such, together with five characteristic salmonid parasites, show that the major portion of the parasitic fauna is of marine origin. On the other hand, the intestinal parasites were in large part not marine, but limnetic forms or such as are typical in the salmon. As in the Rhine salmon, so also in the Tay, the marine alimentary parasites are gradually lost without being renewed. They are replaced by such as are of evident limnetic character. Hence the conclusion of McIntosh, based on other evidence also, that the Tay salmon does from time to time take nourishment during its stay in fresh water. A comparison of the parasitic fauna of the three salmons gives, according to Zschokke, the following:

Fish.	Number of parasitic species.	Typical for the particular salmon.	Found also in other salmon and other localities.	In other migratory fish as well as the salmon.	Besides in migratory fish also in—		
					Marine fish.	Limnetic fish.	Both marine and limnetic.
Rhine salmon	20	2	2	2	8	1	5
Baltic salmon	14	1	2	1	2	2	6
Tay salmon	10	3	1	0	1	2	3

Much later than the work just outlined is a paper by Tosh (1905) in which he discusses his work on the internal parasites of the Tweed salmon. The material was collected in 1895 at a single place. The author notes the distinctly marine character of the parasitic fauna of this salmon, attributing it to the fact that "salmon do not feed in the fresh water of a short river like the Tweed, except under extraordinary conditions, when a prolonged stay is imposed upon them." In all he lists 15 species, as follows:

Ascaris capsularia Rudolphi.
Ascaris acuta Müller.
Ascaris obtusocaudata Zeder.
Distoma varicum Rudolphi.
Distoma ocreatum Rudolphi.
Distoma miescheri Zschokke.
Echinorhynchus acus Rudolphi.
Echinorhynchus proteus Westrumb.
Echinorhynchus angustatus Rudolphi.
Bothriocephalus infundibuliformis Rudolphi.
Tetrarhynchus grossus Rudolphi.
Tetrarhynchus macrobothrius Rudolphi.
Tetrabothrium minimum (larva).
Tetrabothrium sp. (larva).
Tænia sp. (larva).

Details are given concerning the frequence, appearance, and biology of each form. The most important is held to be *Bothriocephalus infundibuliformis*, which, according to an appended table, occurs in 26.4 per cent of the 892 fish examined. It does not seem, in the opinion of Tosh, to be seriously harmful to the host and is found in the largest and best-fed fish in numbers ranging from 1 to 6 per host. The tremendous infestations noted by Zschokke apparently do not occur in this region in the salmon, although observed in the sea trout.

The only notices from Ireland concerning salmon parasites are brief and also of long standing. Drummond (1838), writing in Belfast, described *Tetrarhynchus grossus* from the abdominal cavity of the salmon, which he found only once, and *Tetrarhynchus solidus*, new species, from the peritoneum and mesentery, which he took from three salmon in July, 1838.

Somewhat later Bellingham (1844) listed among the entozoa indigenous to Ireland the following taken from the salmon, namely:

Ascaris capsularia, on the peritoneum; also in 14 other species of fish, all marine.

Ascaris clavata, from intestine and peritoneum; also in 9 other species of fish, all marine.

Distoma varicum, from the stomach; common in some localities and seasons, rare in others.

Tetrarhynchus grossus, from the abdominal cavity; entered in this list on the authority of Drummond (1838).

Tetrarhynchus solidus, from the abdominal cavity; a single specimen loose in peritoneal cavity.

Bothriocephalus proboscideus, from intestine and pyloric cœca; exceedingly common and most so in largest and fattest salmon.

One should always recall the relative value of such comparisons as those in the preceding pages. The fact that from Irish salmon only 6 species of parasites are recorded, from the Scotch form 10 species, from the Baltic form 14 species, and from the Rhine salmon 20 species, is partly accounted for by the amount of attention directed to the various forms. Thus the first record concerning the Rhine salmon (Zschokke, 1889) listed 11 species of parasites obtained in the course of examining 45 specimens of the Rhine salmon. The second record by the same author (Zschokke, 1891) included 20 species of parasites from 129 hosts, and the third record (Zschokke, 1896) gave 23 species of parasites from a total of 179 hosts. Of these 136 came from the Rhine itself and 43 from the sea. More extended study of any host will increase the list of the parasites which it is known to support.

The same species of fish, *Salmo salar*, occurs in streams on the western or American coast of the Atlantic Ocean. Thus far no one appears to have devoted especial attention to the parasitic fauna of the American fish, but some scattered references to species found in our American salmon are recorded by different authors. No doubt the list can be extended considerably by longer search, but so far as I can ascertain the following brief references include all records of salmon parasites made on this continent and published up to the present time.

According to Zschokke (1891) Leidy reported *Bothriocephalus cordiceps* from the intestine of *Trutta salar* Linnæus. The reference, which is apparently cited from von Linstow (1878), is incorrect both in location and content. Leidy (1871) reported on the authority of Professor Hayden "the brook trout, *Salmo fontinalis*, of the headwaters of the Yellowstone River, to be much infested with a species of tapeworm * * * from the abdominal cavity, but not from the intestinal canal * * *. It belongs to the old genus *Bothriocephalus*, and to that section now named *Dibothrium*." This new species was named *Dibothrium cordiceps*. The species was subsequently studied in detail by Linton. I am unable to find any other reference to this parasite in the writings of Leidy or any record of its occurrence in any other than the original host, which was in reality *Salmo mykiss*, the Rocky Mountain trout; the adult parasite occurs in the intestine of the American white pelican, *Pelecanus erythrorhynchus*. This parasite accordingly seems to have no relation whatever to the salmon and should be eliminated from the list of its parasites.

In the catalogue of parasites from various collections in the United States by Stiles and Hassall (1894) there are listed from *Salmo salar Bothriocephalus*

proboscideus from Berlin in the Stiles collection and *Bothriocephalus* sp. from England in the Hassall collection; no specimens whatever are noted as having been taken from autochthonous fish.

In a list of trematodes from Canadian fishes Stafford (1904) records from *Salmo salar* Linnæus, *Derogenes varicus* O. F. Müller, found in mouth, œsophagus, and stomach; *Hemiurus appendiculatus* Rudolphi, found in œsophagus and stomach; *Lecithaster bothryophorus* Olsson (=*Apoblema mollissimum* Levinsen), and *Sinistroporus simplex* Rudolphi, from the intestine. The fish were apparently purchased in the markets in Montreal and represent conditions during the spring and autumn months of 1903.

I have found no further references to the parasitic fauna of *Salmo salar* on this continent. The list contains two species not previously recorded for this host, and yet it is insignificant in comparison with European records for the same host.

Appended hereto is a tabular list of all parasites hitherto reported from *Salmo salar*, arranged according to the place which the parasites hold in the present accepted system. The taxonomy of these groups is at present in such confusion that I have contented myself with entering the names employed by the author cited and in making a few inevitable corrections. Any attempt to adjust the nomenclature adequately would demand an amount of time beyond my present command and an amount of space out of keeping with the rest of this article. By the citation in the table of the authority, date, locality, and location, the reader is enabled to form at a glance a general opinion regarding the importance of any parasite yet reported from the salmon and to follow up its record with the minimum delay.

LIST OF PARASITES HITHERTO REPORTED FROM SALMO SALAR.

Name of parasite.	Condition.	Reported by—	Date.	Locality.	Location.	Frequency.	Notes.
(A) *Cestoda.*							
Abothrium crassum (Bloch)	Adult	Lühe	1899				Correction in name.
Bothriocephalus cordiceps Leidy	Larva	von Linstow	1878	After Leidy 1871	Intestine		Error in citation. True host is Salmo mykiss.
		Zschokke	1891				
Bothriocephalus infundibuliformis Rud	Adult	do	1889	Rhine	Append. pylor	Abundant	Almost regular. See Abothrium crassum.
		do	1891	Rhine and Baltic Sea.			
		do	1896	do			
		Tosh	1905	Tweed	Intestine	Abundant	From 1 to 6 per host.
Bothriocephalus osmeri von Linstow	Larva	Zschokke	1891	Rhine	Intestinal wall	Rare	
Bothriocephalus proboscideus Rud	Adult	Rudolphi	1810		Pylor. cœca	Exceedingly common.	See Abothrium crassum.
		Bellingham	1844	Ireland		Common	
		McIntosh	1863	Tay	Intestine		
		Olsson	1867	Baltic Sea	Append. pylor	Frequent	In hosts from both fresh and salt water.
		Stiles and Hassall.	1894	(Berlin?)			
Bothriocephalus solidus Rud	Larva	Rudolphi	1810				See Schistocephalus dimorphus.
		do	1819				Introduced by accident when its proper hosts chance to be eaten by the salmon.
Bothriocephalus sp. ? Zsch	Larva	Zschokke	1889	Rhine	Intestine	Rare	Later identified as B. osmeri (larva) q. v.
		von Linstow	1889				
Bothriocephalus sp. S. and H	Adult	Stiles and Hassall.	1894	England			
Bothriocephalus sp. I Zsch	Larva	Zschokke	1891	Rhine	Encysted on intestine.	Rare	
Bothriocephalus sp. II Zsch	do	do	1891	do	do	do	
Bothriocephalus sp. III Zsch	do	do	1891	Baltic Sea	do	do	
Bothriotænia proboscidea Batsch	Adult	Mühling	1898	East Prussia		Very common	See Abothrium crassum.
	Young and adult.	Schneider	1902	River and Gulf of Finland.	Append. pylor. and pylor. cœca.	Several hundred	
Dibothrium proboscideum	Adult	Diesing	1851				Do.
Leuckartia sp.? Moniez	do	Moniez	1881	Lille, France	Intestine		Probably Abothrium crassum.
		von Linstow	1889	After Moniez			
		Zschokke	1891	do			
Rhynchobothrium paleaceum Rud	Larva	do	1889	Rhine	Intestine, liver, peritoneum.	Abundant	
		do	1891	do			
Schistocephalus dimorphus Crepl	Larva	Diesing	1851		Ventric		Chance guest. Taken in when proper host is eaten.
		Zschokke	1891	Rhine		Rare	
		do	1896	do			
Scolex polymorphus Rud	Larva	do	1896	North Sea	Intestine		
Stenobothrium appendiculatum Dies	do	Diesing	1851		Intestine, liver		=Tetrarhynchus macrobothrium von Sieb.
		McIntosh	1863	Tay			Larva of Tetrarhynchobothrium bicolor Dies.
		von Linstow	1878				
		Zschokke	1891	Rhine	Ovary, body cav	Abundant	Almost regular.
Tænia solida O. F. Müller	Larva	Tosh	1905	Tweed			
		Müller	1777				Bothriocephalus solidus according to Rudolphi.
Tænia sp. Tosh	do	Tosh	1905	Tweed		Once	
Tetrabothrium minimum von Linstow	do	von Linstow	1889				
		Zschokke	1891				
		Tosh	1905	Tweed		Most	
Tetrabothrium sp. Tosh	Larva	do	1905	do		Once	
Tetrarhynchus appendiculatus		Rudolphi	1810				
Tetrarhynchus grossus Rud		Drummond	1838	Ireland	Abdom. cav	Only once	
		Bellingham	1844	do	do		Entered on the authority of Drummond, 1838.
		von Linstow	1878		Rectum, perit		
		Zschokke	1889	Rhine		Rare	
		do	1891	do			
		Tosh	1905	Tweed			
Tetrarhynchus macrobothrium von Sieb	Larva	Zschokke	1891	Rhine	Encysted on viscera		Larva of Tetrarhynchobothrium bicolor Dies.
Tetrarhynchus solidus Drummond		Drummond	1838	Ireland	Perit. and mesen	From 3 salmon	
		Bellingham	1844	do			
		von Linstow	1878		Rectum, perit., intestine.		
		Zschokke	1889	Rhine		Rare	
		do	1891	do			
		do	1896	do	Pylor. cœca		
		Tosh	1905	Tweed	Abdom. cav	A single specimen loose.	According to Tosh, degenerating stage of T. grossus.
Tetrarhynchus sp. McIntosh		McIntosh	1863	Tay	Cyst on rectum	Once	
		Zschokke	1891				
Triænophorus nodulosus Rud	Larva	do	1891	Baltic Sea	Cyst in liver	Once	
		do	1896				
(B) *Trematoda.*							
Apoblema appendiculatum Lev	Adult	Mühling	1898	East Prussia		Very common	Really Brachyphallus crenatus.
Azygia tereticollis	do	Looss	1899				Correction in name.
Brachyphallus crenatus (Rud.)	do	Odhner	1905	Baltic Sea			
		Looss	1907	Königsberg			
Derogenes varicus (O. F. M.)	Adult	Stafford	1904	Canada	Mouth, œsoph., and stomach.		
Distoma appendiculatum Rud. or Distomum appendiculatum.	do	Rudolphi	1819		Intestine, œsoph	Frequent	During August.
		Olsson	1876	Baltic Sea and Gulf of Bothnia.			
		Zschokke	1891	Baltic Sea			
		Olsson	1893	Baltic Sea and Gulf of Bothnia.	Stomach	Abundant	In July.
		Zschokke	1896	Baltic Sea			
		Hausmann	1897				
Distoma crenatum Rud	Adult	Rudolphi	1810		Ventric. et intest	Abundant	Not determinable, Lühe, 1901.
Distomum miescheri Zsch	do	Zschokke	1889	Rhine	Œsoph	Rare	
		von Linstow	1889				
		Zschokke	1891	Rhine			
		do	1896	do			
		Tosh	1905	Tweed			
Distomum ocreatum Rud	Adult	Olsson	1861	Baltic Sea	Ventric		Hemiurus crenatus (Rud.), according to Lühe, 1901, p. 399.
		von Linstow	1889				
		Zschokke	1891	Rhine			
		do	1896	do			
		Hausmann	1897				
		Tosh	1905	Tweed			

LIST OF PARASITES HITHERTO REPORTED FROM SALMO SALAR—Continued.

Name of parasite.	Condition.	Reported by—	Date.	Locality.	Location.	Frequency.	Notes.
(B) *Trematoda*—Continued.							
Distomum reflexum Crepl	Adult	von Linstow	1878		Ventric., œsoph		
		Zschokke	1889	Rhine			
		do	1891	do		Once	
		do	1896	do			
		Hausmann	1897			Rare	
Distomum sp. McIntosh	Young	McIntosh	1863	Tay	Duodenum	Once	
		Zschokke	1891				
Distomum tereticolle Rud	Adult	McIntosh	1863	Tay	Intestine	Once	See Azygia tereticollis.
		Zschokke	1891		do		
Distoma varicum Zed. or Distomum varicum.		Rudolphi	1810				See Derogenes varicus.
		Bellingham	1844	Ireland			
		Diesing	1851		Ventric., œsoph	Abundant	
		McIntosh	1863	Tay			
		Zschokke	1889	Rhine			
		do	1891	do			
		do	1896	do			
		Hausmann	1897				
Fasciola varica (O. F. M.)	Adult	Müller	1777				See Derogenes varicus.
Fasciola salmonis O. F. M		do	1780				Probably Hemiurus crenatus, Lühe, 1901.
Hemiurus appendiculatus (Rud.)	Adult	Stafford	1904	Canada	Œsoph., stomach		Probably incorrect determination.
Hemiurus crenatus (Rud.)	do	Lühe	1901	East Prussia		Very common	See Brachyphallus crenatus.
Hemiurus lühei Odhner	do	Looss	1907	Leipzig, fish market.	Œsophagus	Once	
Lecithaster bothryophorus (Olsson)	do	Stafford	1904	Canada	Intestine		=Apoblema mollissimum Levinsen.
Sinistroporus simplex (Rud.)	do	do	1904	do	do		
(C) *Nematoda.*							
Agamonema capsularia Dies	Larva	Diesing	1851		Periton		
		Zschokke	1889	Rhine		Very common	
		do	1896	do			
Agamonema commune Dies	Larva	von Linstow	1889				
		Zschokke	1896	Rhine		Rare	
Ascaris (Agamonema) capsularia Dies	Larva	do	1891	do	Intestinal perit		See Agamonema capsularia.
		do	1896	do	Body cav., liver, spleen, kidney, sex. organs.		
Ascaris (Agamonema) communis Dies	Larva	do	1891	do	Liver		See Agamonema commune.
Ascaris aculeati v. Linstow	do	do	1891	do	Œsoph., liver	Rare	
Ascaris acuta O. F. Müller		Tosh	1905	Tweed		Common	
Ascaris adunca Rud		Zschokke	1891	Rhine	Intest., stomach, œsoph.		
Ascaris angulata Rud		do	1891	do	Œsoph	Very rare	
Ascaris capsularia Dies	Larva	Rudolphi	1810				See Agamonema capsularia.
		Bellingham	1844	Ireland			
		Diesing	1851		Intest., abdom., perit.	Abundant	Almost regular.
		McIntosh	1863	Tay			
		Tosh	1905	Tweed			
Ascaris clavata Rud		Bellingham	1844	Ireland			
		Diesing	1851			Rare	
		Zschokke	1889	Rhine			
		do	1891	do	Encysted on peritoneum and intestinal wall.		
		do	1896	do			
		Hoek	1899	do			
Ascaris obtusocaudata Zed		Tosh	1905	Tweed		Once	
Ascaris spec		Zschokke	1896	Rhine		do	
Do		do	1896	do		do	
Cucullanus elegans Zed		Diesing	1851		Intestine, pylor		
		Zschokke	1891				
Cucullanus (dub.)	Larva	Goeze	1762				Ascaris capsularia acc. to Rudolphi.
		Rudolphi	1810				
(D) *Acanthocephala.*							
Echinorhynchus acus Rud		Zschokke	1891	Rhine	Œsoph., stomach, intestine.	Once	
		do	1896	do			
		Mühling	1898			Occasional	
		Tosh	1905	Tweed			
Echinorhynchus agilis Rud		Zschokke	1891	Rhine	Œsoph	Rare	
Echinorhynchus angustatus Rud		Tosh	1905	Tweed		Once	
Echinorhynchus clavaeceps		Zschokke	1896	Rhine	Intestine	do	
Echinorhynchus fusiformis		Rudolphi	1819				E. inflatus renamed—Rudolphi.
		Mühling	1898			Occasional	Cited after Neumann.
Echinorhynchus inflatus Rud		Rudolphi	1810				
		McIntosh	1863	Tay	Intestine		
Echinorhynchus lævis O. F. Müller		Müller	1777				E. nodulosus according to Rudolphi.
Echinorhynchus ? nodulosus		Rudolphi	1810				
Echinorhynchus pachysomus Crepl		Diesing	1851		Ventric., intestine		
		Zschokke	1891	Baltic Sea			
		Mühling	1898			Occasional	
Echinorhynchus proteus Westrumb		Diesing	1851		Intestine, perit		
		McIntosh	1863	Tay			
		Zschokke	1891	Rhine	Encysted on perit		
		Mühling	1898			Occasional	
		Hoek	1899	Rhine			
		Tosh	1905	Tweed		Common	
Echinorhynchus quadrirostris		Goeze	1762				See Cestoda. Tetrarhynchus appendiculatus acc. to Rudolphi.
Echinorhynchus salmonis O. F. Müller		Müller	1777				E. inflatus acc. to Rudolphi.
Echinorhynchus sublobatus Rud		Rudolphi	1810		Ventric		Host species uncertain.
Echinorhynchus sp		Zschokke	1889	Rhine			Afterwards referred to E. proteus.
(E) *Ectoparasites.*							
Lepeophtheirus strömii		McIntosh	1863	Tay	Base of fat fin, caudal rays, eye, and before hyoid.		
Cystobranchus (Pisicola) respirans		Hoek	1899	Rhine	Skin	Frequent	Infesting young salmon.
Pisicola geometra		Zschokke	1896	do	do	Temporary	

PARASITES OF PACIFIC SALMON.

The list of parasites for Atlantic salmon in America, though small, is much more extended than the records concerning the Pacific salmon. While tremendous numbers of the latter fish, which belong to several species of the genus *Oncorhynchus*, are taken every year for commercial purposes, apparently no one has studied the parasitic fauna or done more than to record casually a few data taken during a study of some other factor concerning the species. Even of such notes I have found only a very few.

In a report on the life history of the Alaska salmon, Bean (1890, and also 1893) noted a few items concerning parasites. He mentions the presence in 1889 of numerous intestinal worms in the red salmon and finds that all species of salmon [in fresh water?] are more or less covered with parasitic copepoda.

Much more extensive are the notes made by the brilliant young naturalist and student of the Pacific salmon, Cloudsley Rutter, who only a short time back met such an untimely death.

In the course of investigations on the natural history of the quinnat salmon in the Sacramento River, Rutter (1902) records some interesting items regarding their parasites. A common pest in the adult of this species in fresh water is a parasitic copepod which attaches itself to the gill filaments. Usually not numerous on a single fish, they yet sometimes destroy the gill filaments almost entirely. The intestine of the spawning salmon is frequently inhabited by tapeworms extending into the cœca and at times filling them completely. They do not occur in the stomach. In 1898 they were much more abundant than in 1900. Among 200 young salmon examined from fresh-water stations in the Sacramento basin in May, 1898, and April, 1899, parasites were found in the stomach contents of 31 fish. They were described as of two or three kinds, one elongated [cestode?], the others short and grain-like [trematodes?]. Rutter thinks that residence in fresh water is conducive to the growth of parasites in the stomachs of young salmon. He gives the following tables of their occurrence according to size of host and dates of capture.

OCCURRENCE OF PARASITES IN QUINNAT SALMON FROM SACRAMENTO RIVER.

According to dates of capture.

Month.	Number examined.	Number with parasites.	Percentage with parasites.
January	9	1	11
February	10	0	0
March	10	0	0
April	15	0	0
May	50	4	8
July	21	1	5
August	20	3	15
September	18	3	17
October	30	8	23
November	15	3	20
December	11	8	73
Total	209	31	15

OCCURRENCE OF PARASITES IN QUINNAT SALMON FROM SACRAMENTO RIVER—Continued.

According to size of fish.

Size.	Number examined.	Number with parasites.	Percentage with parasites.
1.4 to 2 inches	61	3	5
2.1 to 3 inches	57	3	5
3.1 to 4 inches	53	10	19
4.1 to 5 inches	30	12	40
5.1 to 6.3 inches	8	3	38
Total	209	31	15

It will be noted that the percentage of infestation increases rapidly with the size and age of the fish, but this would naturally be associated with the more extensive feeding of the older and larger fish, whether in fresh or salt water. In the absence of comparative data for salt water forms to contrast with these of summer residents in fresh water, it is not allowable to attribute this condition to the delayed migration of these fish, as Rutter does. From brackish-water stations 20 young salmon were examined and parasites found in 3 only. This number is too small to be available for comparison with those fresh-water forms noted above. Unfortunately no further data are available concerning the varieties of parasites found either in the adult or in the young specimens. It is probable that the adult parasites are the same as certain forms to be discussed later from the Alaska salmon.

OBSERVATIONS ON THE SEBAGO SALMON.

SPECIFIC RELATIONSHIPS

The Sebago salmon is regarded by some as merely a landlocked variety of the Atlantic salmon, *Salmo salar*, found both in European streams and in the rivers of Maine and northward. By others it is viewed as a separate species, *Salmo sebago*, but in any event closely related to the former. In their extensive catalogue of North American fishes, Jordan and Evermann (1896) include all these forms in the single species *Salmo salar* Linnæus, speaking of its range as follows:

North Atlantic, ascending all suitable rivers in northern Europe and the region north of Cape Cod to Hudson Bay; formerly abundant in the Hudson and occasional in the Delaware, its northern limit in the Churchill, Albany, and Moose rivers, flowing into Hudson Bay; sometimes perfectly landlocked in lakes in Maine and northward, where its habits and coloration (but no tangible specific characters) change somewhat, when it becomes (in America) vars. *sebago* and *ouananiche*. Similar landlocked varieties occur in Europe.

Of the Lake Sebago form which I had the opportunity of studying and which these authors regard as a subspecies, *Salmo salar sebago* (Girard), they write as follows:

Smaller in size, rather more plump in form, and nonmigratory; not otherwise evidently different. Sebago Pond and northward; introduced into lakes in various parts of the country; seldom entering streams; reaches a weight of 25 pounds.

It is important to notice that the same authors also recognize a second subspecies, and this may be the form from which were obtained the parasites reported by Stafford (1904) and already commented upon. Concerning this subspecies, Jordan and Evermann write that *Salmo salar* is—

> * * * represented in Lake St. John, Saguenay River, and neighboring waters of Quebec by the landlocked *Salmo salar ouananiche* McCarthy MS., new subspecies. Still smaller, rarely reaching a weight of 7½ pounds and averaging 3½. An extremely vigorous and active fish, smaller and more active than ordinary salmon, but so far as known not structurally different. Saguenay River, Canada (outlet of Lake St. John), and neighboring waters.

Were it possible to determine definitely whether the records of Stafford concern the oceanic form caught during its migration or the landlocked form, a more definite value could be placed upon his data. In the absence of such information one can not venture to use these records at all in the discussion of the biological problems concerned. What these problems are will be clearer after a more detailed consideration of the case.

SOURCE OF PARASITES.

In view of the close specific connection of the two forms, the European salmon just considered and the Sebago salmon, a comparative study of their parasitic fauna is of unusual interest, especially since the Atlantic salmon spends the greater part of its life in salt water, and after its entrance into fresh-water streams in the course of its migration does not in most cases partake of any food. Consequently whatever parasitic guests it harbors must, as already explained, be of marine origin. The exceptions to this statement are due to accidental infection, and are both small in numbers and insignificant in variety and relative importance. On the other hand, the landlocked Sebago salmon never enters salt water. Its period of active feeding and growth is passed in inland waters, those of Sebago Lake in the case of the specimens we secured and examined. Whatever parasites it harbors are hence obtained in that lake, and are either pure fresh-water organisms or such as have been introduced with the host and subsequently acclimatized to a fresh-water existence. In the case of such parasitic species as undergo direct development, like many nematodes, the introduction of a marine parasite into fresh water involves the habituation of the free living stage, either egg or larva, or both, to the limnetic environment, and this is the identical process involved in the transfer of any free living organism from a marine existence to one in fresh water. In the case of parasites which manifest indirect development with change of host the case is much more complicated. Such parasites usually have one or more brief stages of free existence in the open water as egg, embryo, or larva, like those just referred to. But they also employ one or more intermediate hosts, in which certain parts of the development are passed. Now, either the same marine animals which serve as intermediate hosts in the sea must be found in fresh water also, or must be successfully

introduced at the same time with the primary host and its parasites to which they are related, or, finally, there must be present in the fresh water other animals which can serve successfully as intermediate hosts. The interrelation is thus very complicated and the chance of achieving it so small that in most cases marine forms do not bring the majority of their parasites with them in the transfer to fresh-water existence. In other words, limnetic animals are less heavily parasitized than marine. For this reason the examination of so recent a migrant into fresh water as the Sebago salmon is of great biological interest.

At Lake Sebago only 7 specimens of the Sebago salmon were obtained and examined. These weighed, respectively, 2, 2, 2, 3, 5½, 8, and 16 pounds. While the number examined was from one standpoint small, yet in view of the scarcity of the species in the lake it was fortunately large. The series was also representative of different ages, ranging probably over several years in growth. It seems likely that if marked variations in food materials were found such a range of specimens would indicate the fact through differences in parasitic infestation. Yet there was a striking uniformity in the records in the series. Furthermore, the fish were all examined very soon after capture, and thus any post-mortem wanderings, which certainly do influence the location of parasites collected from market fish, were largely avoided. No doubt there are rare parasites of this species which are not represented in this collection, but, all things being considered, it may be asserted with some confidence that the records give a true picture of the number and location of the parasites infesting them.

The parasites found are recorded in the following table:

RECORD OF PARASITES FROM SALMO SEBAGO.

[x=many. xx=very many. §=more than in fish no. 14—not counted.]

Host.				Parasites, number and location.			
Serial No.	Length.	Weight.	Sex.	Œsophagus and stomach.	Pyloric cœca and adjacent part of intestine.	Intestine behind pyloric cœca.	Body cavity.
	In.	*Lbs.*					
14	16	2	♂	7 Azygia sebago (?) 2 Nematode A	45 Abothrium crassum.	1 Proteocephalus pusillus. 1 Azygia sebago	1 Nematode A. (?) See also stomach.
15	16	2	♂	13 Azygia sebago	§ Abothrium crassum.	1 Proteocephalus larva 1 Bothriocephalid larva	
16	27	8	♂	xx Azygia sebago [a]	70 Abothrium crassum.	Proteocephalus pusillus Proteocephalus pusillus 1 Bothriocephalid larva	1 large Bothriocephalid larva. 1 small larval cestode.
32	17	2	♂	1 Azygia sebago	30+Abothrium crassum.		
41	33	16	♂	18 Azygia sebago	80 Abothrium crassum.		33 Nematode B.[b] 1 Bothriocephalid larva encysted in spleen.
42	19	2¾	♂	xx Azygia sebago	x Abothrium crassum.		3 Nematode A.
106	22	5½	♂	19 Azygia sebago (?) 6 Nematode B	50 Abothrium crassum.		Not examined. (?) See also stomach.

[a] Also in swimming bladder (?). See text.

[b] Viscera a mass of adhesions; parasites difficult to pick out.

A NEW TREMATODE PARASITE.

Every one of the 7 fish examined contained specimens of a new trematode, which I have named *Azygia sebago*. It is relatively insignificant in size and difficult to detect amid the thick white mucus which lines the wall of stomach and œsophagus. Not a single host was without this parasite, and several salmon sheltered considerable numbers; yet in most cases they were not seen in life, but only appeared after the stomach and its contents had been agitated in a preserving fluid. Careful examination of the débris then never failed to disclose some specimens of this worm. Moreover, it was the only species of trematode that was found in the Sebago salmon. The description of the species may properly precede a discussion of its biological characteristics.

The genus *Azygia* was established by Looss (1899, p. 569) to include a well-known European species, *Distomum tereticolle* Rudolphi, which was made the type of the new genus. It was also the only species in the genus; for, as Looss remarks, he had not been successful in finding among the flukes that he knew any form which could be included naturally with the old species, *Distomum tereticolle*. There are at the disposal of the student several good descriptions and delineations of the old species, *Azygia tereticollis* Rudolphi, so that it is possible to determine with precision its structural features; the best of these descriptions is undoubtedly that by Looss (1894).

The new species, *Azygia sebago*,[a] is much smaller than the older form, measuring 10 mm. in maximum length and averaging 5 to 6, or less often 8 mm., in well-developed specimens. Fortunately, I have a large range of sizes, from such as are only barely over 1 mm. in length to the maximum noted, so that it was possible to follow the changes accompanying the assumption of the adult form. Specimens 2.85 mm. long have not yet produced ova.

The general form of the body is cylindrical, bluntly rounded at the anterior end, and tapering slightly toward the posterior end, which, however, is ultimately rounded off. The body is regularly divided into two regions by a shallow furrow at which the direction of the long axis changes more or less (fig. 1), giving the worm in lateral aspect much the appearance of a can-top tightener. While the relation of the regions is very variable, at times forming almost a single straight line and again standing at a considerable angle with each other, yet one can make out these conditions even in specimens which are poorly killed and badly distorted. The anterior region assumes the form of an ellipse surrounding the two suckers. This region changes relatively little in size with growth. In one of the smallest specimens measured (1.6 mm.) the distance between the

[a] During the spring of 1908 two of my students, Messrs. W. N. Anderson and H. B. Boyden, made a study of this form and prepared a partial report on its structure, to which I am indebted for some of the data in the following description, and also for two figures.

centers of the two suckers was 0.5 mm. In one 10 mm. long this distance measured 1 mm.

The posterior region is nearly a perfect cylinder until shortly before the tip, where it tapers somewhat. In some specimens the posterior end is considerably inflated and appears semitranslucent. This is undoubtedly due to the distended condition of the excretory reservoir, which inhibits contraction of the circular muscles in the portion of the skin adjacent to it.

The breadth of the body varies according to the degree of contraction, but may be estimated in general as from 0,7 to 1 mm. An immature specimen 2.85 mm. long measured 0.65 mm. in breadth between the suckers, 0.6 mm. behind the acetabulum, and 0.52 mm. behind the posterior testis. An immature specimen only 1.6 mm. in length measured 0.32, 0.28, and 0.21 mm. in breadth at the same points. In cross section the body is round or very slightly oval.

The oral sucker is subterminal and its opening looks almost directly ventrad. It is rather conspicuous, and in an average specimen measured 0.68 mm. in antero-posterior diameter and 0.67 mm. transversely. The depth in the same specimen was 0.6 mm. The orifice is nearly circular, though often appearing slightly flattened along the posterior margin. In an immature specimen 2.85 mm. long the oral sucker measured 0.35 mm. in antero-posterior diameter and 0.4 mm. laterally; the orifice measured 80 by 150 μ.

The ventral sucker or acetabulum is usually distinctly smaller than the oral. In the extreme case it appears about equal in size or, on the other hand, only about half as large. Ordinarily it is prominent, but in short, thick specimens it is almost hidden, whereas in elongated, slender specimens it projects so far as to appear almost pedunculate. It is also often slightly oval in a transverse plane. In an adult specimen it measured 0.57 mm. in antero-posterior diameter and 0.69 mm. laterally. In a specimen 2.65 mm. long the corresponding measurements were 0.3 and 0.33 mm., and the orifice measured 52 by 80 μ.

The alimentary canal opens in the oral sucker, close behind which lies the pharynx without any prepharynx between the two. The pharynx measures 0.21 by 0.13 mm. It is often seen in the vertical position represented in the figure of Messrs. Anderson and Boyden, which I have taken the liberty of copying here. The œsophagus is very short and it often proceeds anteriad from the upright pharynx, as shown in the drawing (fig. 3, pl. CXXI). At its tip start the two branches of the intestine, which also usually extend forward a short distance and then turning posteriad continue almost to the extreme posterior tip of the body. These crura being longer than the body in the usual specimen are thrown into folds, which often appear as if the canal possessed irregular outpocketings, such as one finds in *Paragonimus*. Observations both on the living material and

on serial sections show positively that such is not the case, but that the crura are simple tubes. The number of folds, twists, and turns depends upon the degree of contraction and usually appears greatest between the acetabulum and the ovary.

The excretory system is very characteristic of the genus *Azygia*. An elongate carrot-shaped collecting reservoir or bladder extends from the excretory pore, which is located at the posterior tip, through the center of the body anteriad to the posterior testis. The wall is heavy and is thrown into folds which appear at intervals projecting slightly into the cavity. From the anterior end of this reservoir two tubes pass off, right and left, which are at the start dorsal to the posterior testis; they soon pass toward the ventral surface, but cross the acetabulum on its dorsal aspect and dorsal to the oral sucker and are reflected posteriad. During their entire course they lie within the intestinal crura and usually ventrad to it. Their heavier walls indicate clearly that these conspicuous tubes are more nearly analogous to the collecting reservoirs of other flukes than to the delicate excretory vessels which here also are seen connecting with the tubes and the reservoir at various points.

The three germ glands, the ovary and two testes, lie close together in a longitudinal row distant from the anterior end about two-thirds the length of the worm. The ovary is most anterior and smallest of the group. An unusual morphological feature is the inclusion of the shell gland, a small yolk reservoir, the ends of the yolk ducts, and the first coils of the uterus within the same capsule that incloses the gland proper (fig. 6, pl. CXXI). The relation of the ducts as worked out by reconstruction is represented in figure 5 after the studies of Messrs. Anderson and Boyden. This resembles closely conditions as shown by Looss (1894) for *A. tereticollis*, although I do not find that he has noted the massing of organs within a common capsule. The uterus extends forward in numerous short coils which all lie within the intestinal crura until at the acetabulum it merges into a short, heavy-walled metraterm. The latter passes dorsal to the acetabulum and ventral to the cirrus pouch into the genital cloaca, with an inconspicuous genital pore located just anteriad to the acetabulum.

The vitelline glands lie along either side of the worm exterior to the intestinal crura. They begin a little behind the level of the acetabulum and extend to a point about halfway from the posterior testis to the end of the body. This constitutes perhaps the most striking morphological difference between this species and *Azygia tereticollis*, in which the vitellaria do not pass posteriad of the posterior testis. This conspicuous difference in the extent of the vitellaria enables the student to differentiate the two forms at a glance.

Attention should be called to the fact that on account of this structural feature a correction must be made in the generic description of *Azygia*, in which

stress was originally laid on the extent of the vitellaria. The condition of the vitellaria in the older species has also been employed by Pratt (1902) as a characteristic of the genus in elaborating his key for the determination of the flukes. Although typically a member of the genus *Azygia*, the present form would fall in another genus according to the terms of that synopsis. No one who sees a specimen or reviews the structure of this form can doubt its relationship; the precise extent of the vitellaria is evidently a subordinate feature, and as such of specific rank only.

The follicles of the vitellaria are distinct, regularly oval bodies, lying in two longitudinal rows on each side with a more or less conspicuous break opposite the ovary between the anterior and posterior series. The follicles measure from 0.06 to 0.07 by 0.03 to 0.04 mm. The symmetry of the rows is in places interrupted by extra follicles, making at such points three rows of follicles instead of two as usual. The ducts from the anterior and posterior series unite opposite the ovary to form a common transverse duct which at the center of the body joins its fellow from the opposite side. At the point of union there is a small yolk reservoir. As already noted, this is included within the common capsule which surrounds the ovary and is ordinarily not visible except in sections. Laurer's canal is present and opens on the dorsal surface just posterior to the ovary. It does not have the enlargement ordinarily called a seminal receptacle, but is usually somewhat coiled and lies on the left side of the ovary. This may be an adaptation to the extreme variations in length so characteristic of this worm.

The eggs are small; an average of 50 measurements places their size at 48 by 27 μ, which is slightly larger and broader than those of *A. tereticollis*, according to the measurements given by Looss (1894).

The testes are oval bodies lying one directly behind the other and that behind the ovary. The three organs are separated only very slightly from each other. The outline of the testes is smooth and measures 0.42 to 0.46 by 0.59 to 0.6 mm. with the major axis transverse. One can usually distinguish that the two are not equal in size. The coiled seminal vesicle and a poorly developed cirrus with prostate lie in a common connective tissue capsule, the cirrus pouch, which stands immediately anterior to the acetabulum. The pouch measures about 0.23 by 0.17 mm. in diameter. It opens anterior to the metraterm into the genital sinus already mentioned.

One histological feature deserves consideration here because of its conspicuous character. In sections of *Azygia sebago* one notices certain muscle elements which are so prominent and regular as to deserve almost the name of a layer; they occur within the parenchyma, far removed from the usually recognized dermal layers and at a point where ordinarily one finds only scattered

dorso-ventral or oblique fibers which are not subject to any regularity in arrangement. These are longitudinal fibers extending from the oral sucker throughout the entire length of the distome, as is clearly seen in a frontal section (fig. 4, pl. CXXI). In position they lie one-fourth to one-fifth the radius of the section distant from the external surface. The cross sections of these fibers show them to be much heavier than the other muscle elements and to occupy an oval zone parallel to the outer surface of the body. They divide the body accordingly into a cortical and a medullary portion. The vitellaria are the only conspicuous organs which lie in the cortical layer. This muscle layer is undoubtedly related to the marked contractions of the fluke which have already been commented upon. Unfortunately I have no material available from which to determine whether similar fibers also exist in *A. tereticollis*. Looss (1904) does not mention them.

The relations of oral sucker, pharynx, and crura, the convolutions of the intestinal branches, the coils of Laurer's canal and of various ducts and the sinuous course of the collecting tubes in the excretory system all point toward the variable extensibility of the worm. Differences in caliber and in the distance between organs also indicate the same. Observations on the living parasite serve to show that it is constantly extending and contracting the body to such an extent as to double or halve the length within a few seconds of time. In fact, I have never before observed a form which indulged in such energetic twisting and contracting. This habit renders any observations on the living worm very difficult.

Looss (1894, p. 7) comments on the active migration of *A. tereticollis* after the death of the host, a feature previously recorded for *D. cylindraceum* by Braun (1890, p. 568). *A. sebago* manifests the same tendency in the most marked degree. The normal seat of this parasite I feel sure is the stomach, and perhaps the œsophagus also, but even a slight delay in the examination of the host resulted in finding single specimens well down the intestine as well as up in the pharynx and even among the gill filaments. In one case a salmon caught late in the day was kept overnight to be photographed, as it was a peculiarly fine specimen. When the viscera were examined, about twenty hours after the capture of the fish, my field notes record that there were 36 distomes in the air bladder and that they were seen coming in through the ostium with mucus from the œsophagus. Other specimens were found in the pharynx and gill cavity and one even in the body cavity. The last can be attributed no doubt to some tear in the alimentary lining which permitted the fluke to make its way unhindered into what is ordinarily a closed cavity. In still another salmon which had gorged itself on smelts my field notes contain com-

ments on the activity manifested by these distomes, which climbed about on the smelts and in them as they lay half digested in the stomach of the salmon.

This was so noticeable that I turned my attention at once to the smelt [a] to ascertain if perchance it played any part in the life history of the distome. In all, I have records of 52 smelts examined, and in 46 of these were found specimens of *Azygia sebago*. The parasite occurred in the stomach only and the infestation was small, from 1 to 14 distomes being found in each host, with an average of only 4 to a fish. In most cases the parasites which were taken from the stomach of the smelt were immature, not having yet reached that size at which the production of ova begins; they were on the average 3 to 4 mm. long, or in some cases even smaller, running from 1.5 to 2.5 mm. in length. Single specimens reached a length of 6, 7, and even 10 mm. In one case, indeed, there were none shorter than 6 mm., and the specimens varied from that to 10 mm., so that one can not fairly maintain that they never reach the size attained in the salmon. Nevertheless, after the account is cast up the average shows distinctly that the distomes do not reach their full size in the smelt and, so far as collections made during July and August can indicate, those taken from this host are usually small in size and sexually immature. I did not obtain any information as to the source from which the smelt acquires its infection, but in view of the universality with which smelt form the food of the salmon in Sebago Lake the latter undoubtedly owe to them the major portion of their infestation with this parasite.

The host record of *Azygia sebago* is even yet unfinished. In the course of my work numerous other fish from these same waters were examined. In young specimens of *Esox reticulatus* 6 to 16 inches long I found this same parasite reasonably abundant. To be sure, they seemed to average somewhat longer, being 10 to 12 mm. in length in material from one host and 10 to 14 or even 18

[a] This fish I am compelled to designate under the name *Osmerus mordax* (Mitchill), as Jordan and Evermann (1896) do not recognize the Sebago smelt as a separate form, saying of the species "Atlantic coast of the United States from Virginia northward to Gulf of St. Lawrence, entering streams and often landlocked." I am inclined to think that even in Sebago Lake there are two smelts. My attention was first directed to this possibility by Dr. W. C. Kendall, who, recalling our previous discussion, writes as follows in a recent letter:

"You may recall that there seem to be two forms in the lake differing somewhat in size and habits. The large form, which is the one that we caught with hook and line, is nearer to the marine smelt. The small form is the one that we found in the salmons' stomachs. You will doubtless recall that the principal food, when any at all was found in their stomachs, of the large form was small fish, generally young smelts. Our examinations of the stomach contents of the small form show Entomostraca almost exclusively. This difference is indicated also by the gillrakers, which are more numerous in the small form."

These distomes occurred equally in both sorts of smelt and those from the smaller smelts were larger than those from the larger fish. This is, of course, a mere accident, but it serves to show that the two types of smelt conduct themselves alike toward the parasite.

mm. long in that from another host. In the latter it was noticeable that the suckers protruded very conspicuously and the body was much smaller in caliber than in the specimens from the salmon and the smelt. Yet in the absence of any structural differences I am forced to conclude that this contrast in size and general external appearance is due to some slight difference in the technique employed or in the condition of the parasites when they were preserved. This is all the more probable when one considers that in one case the specimens from *Esox* were identical in appearance with those from the salmon. This parasite was found in all but one of the dozen specimens of *Esox reticulatus* examined, being present in the stomach in numbers of 1 to 80 in each host. In two cases a single specimen was found in the intestine, perhaps due to some post-mortem wandering on the part of the parasites. In 4 specimens of *Anguilla chrysypa* out of 9 examined I also found *Azygia sebago* in the stomach, but in small numbers only, averaging 3 to each host. Finally 2 of these distomes were found in a single *Perca flavescens*, here also in the stomach.

In order to give a ready comparison, I append hereto a table of similar measurements from a series of this distome taken from the various hosts mentioned. The difference in length indicates in part age and in part method of preservation. In fact, it is difficult to achieve any uniformity among specimens so exceedingly active as this species.

MEASUREMENTS OF AZYGIA SEBAGO.

Serial No.	Host.	Length.	Anterior tip to center of oral sucker.	Diameter of oral sucker.	Distance between centers of suckers.	Diameter of acetabulum.	Anterior tip to center of ovary.	Distance between center of ovary and anterior testis.	Distance between centers of testes.	Distance from posterior testis to posterior tip.	Breadth between suckers.	Breadth behind acetabulum.	Breadth behind posterior testis.
		Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
16	From Salmo	8.75	0.31	0.74	1.38	0.65	4.76	0.31	0.62	3.07	1.29	1.38	1.23
74–79	From Osmerus	2.85	.16	.4	.62	.33	1.6	.12	.12	1	.65	.6	.53
60	do	1.64	.1	.25	.4	.2	.89	.1	.1	.55	.32	.28	.21
96	do.[a]	7.85	------	.56	------	.37	------	------	------	------	.28	.31	.25
7–8	From Esox	12.6	.38	.72	1.84	.55	7.88	.9	.91	3.25	.75	.77	.74
46	From Perca	4.08	.29	.51 by .57	.78	.35 by .4	2.69	.15	.19	1.16	.71	.77	.55

[a] Much elongated; poor technique; preserved by helper.

The question naturally presents itself, Has this form been seen by others previous to the present date? The records on the subject are scanty, but they throw some light on the question.

Leidy has described (1851, p. 206) a form as *Distomum terreticolle*[a] Rudolphi, which Pratt (1902, p. 957) lists as *Azygia tereticollis* (R.) Leidy. The original description is as follows (Leidy, 1851, p. 206):

Distomum terreticolle, Rud. Entoz. Syn., p. 102; Dujardin, Hist. Nat. des Helm.; Diesing, Syst. Helm., p. 358.

Body subcylindric, light flesh color, posteriorly rounded. Ventral acetabulum (¾ line) 1.6 mm. behind the oral (⅓ line) 0.7 mm. in diameter. Oral acetabulum (¼ line) 0.5 mm.

Length (8 lines) 16.8 mm.; breadth posteriorly (½ line) 1 mm., anteriorly (⅓ line) 0.7 mm.

Habitation.—Stomach of *Esox reticulatus* Lesueur.

Remark.—The generative aperture is placed immediately in advance of the ventral acetabulum. When the animal contracts, the two acetabula are nearly brought into contact.

The description is scanty, and yet one can say with some assurance that the form before Leidy was not the European species named by Rudolphi and discussed by a long series of authors, of whom Looss (1894) has given the most complete description with truly admirable figures. Leidy's specimen is much too small for average adults of *Azygia tereticollis*, which is, moreover, cylindrical instead of broader posteriorly, as was Leidy's worm. Again, *Azygia tereticollis* has the oral sucker larger than the acetabulum, whereas in Leidy's form the reverse is true. Finally the suckers in Leidy's form do not agree at all in size with the suckers in *Azygia tereticollis*, as described by Dujardin and others.

It is somewhat more difficult to say whether the form before Leidy was the same as that I collected in the Sebago salmon. In size the two are not very different, although Leidy's was larger. Other measurements do not agree at all well. The sizes given for the suckers are just about reversed. The final determination of this point, however, must await a reexamination of Leidy's original material.

The only other reference to the occurrence of *Azygia* on this continent, so far as I know, is the brief note of Stafford (1904, p. 488), in which he records *Azygia*[b] *tereticollis* Rudolphi from mouth, pharynx, œsophagus, and stomach of *Esox lucius* Linnæus, *Lota maculosa* Le Sueur, and *Ameiurus nigricans* Le Sueur. Absolutely the only data concerning the worm which Stafford records is the size, 12 by 1 mm. Now, this does not agree with adults of *A. tereticollis*, for Looss (1894, p. 18) says of that species that the first eggs are not set free into the uterus until the worm is 8 to 10 mm. or more in length, and these are uniformly abnormal and defective. In another place he remarks (1894, p. 7) that in most cases eggs are found in worms 12 mm. long, although in scanty numbers. I am of the opinion that Stafford did not have before him the true *A. tereticollis*

[a] The text by error contains *terreticolle* for the specific name instead of *tereticolle*.

[b] Unfortunately, Stafford spells the genus *Azigia* and the species *tereticolle*.

and incline to the belief that the form which he observed may have been the species under discussion.

The European species, *Azygia tereticollis*, has been reported from *Esox lucius*, *Lucioperca sandra*, *Lota vulgaris*, *Trutta variabilis*, *Salmo trutta*, *Salmo fario*, *Salmo hucho*, *Salmo alpinus*, and *Salmo salar*. All of these save *Salmo salar* are fresh-water fish, and the parasite may be regarded as a characteristic of fresh-water species. The American species, *Azygia sebago*, I found in *Salmo sebago*, *Esox reticulatus*, *Osmerus mordax*, *Anguilla chrysypa*, and *Perca flavescens*. Stafford recorded what may have been the same from *Esox lucius*, *Lota maculosa*, and *Ameiurus nigricans*. These include strictly fresh-water forms, landlocked species, and one migratory fish, but inasmuch as the records have been taken in fresh water even the last host does not constitute any evidence against the fresh-water habitat of *Azygia sebago*. Its congener, *Azygia tereticollis*, found by McIntosh in the salmon of the Tay, formed part of the evidence that this host feeds during its fresh-water residence. Equally here we may regard *A. sebago* as a fresh-water element acquired by its host since the latter became landlocked in Lake Sebago. The presence of the parasite in several other characteristic fish of the same water basin is clear evidence of the sources from which it might have come.

CESTODES.

Cestodes constituted the most conspicuous element of the parasitic fauna. Every salmon opened contained a mass of large worms in the pyloric region. They lay with the head and anterior portion of the body in a pyloric cœcum usually at or near its tip. The worms were large and the body was thrown into loops which occupied the initial cœcum and folded through the intestinal canal into other cœca, often crowding them full apparently to bursting. Viewed from the body cavity, even before the viscera were opened, one could distinguish the cœca which contained the parasites by their opaque, chalky appearance in distinct contrast with the translucent character of those cœca in which there were no tapeworms. When the intestine was opened it appeared full of the cestodes, which protruded in loops hanging from the cœca into the cavity or crossing into other cœca in a tangled mass, in several cases large enough to distend the wall conspicuously. The anterior cœca were those primarily or chiefly occupied by the worms and although often the entire cavity of the intestinal canal was crowded full of parasites, it was noteworthy that they rarely if ever entered any of the posterior cœca. When few worms were found they lay with the scolices at least in the cœca of the most anterior region.

The species to which I have referred in the preceding paragraph is the well-known *Bothriocephalus infundibuliformis*, according to Lühe (1899) more correctly designated *Abothrium crassum*, which is so common in the Atlantic salmon

from various parts of Europe. Of its occurrence in the Rhine salmon, where it is found in 42 per cent of the specimens examined, in 91 per cent of the Baltic salmon, in 26 per cent of the Tweed salmon, in most of the Tay salmon and of the Irish salmon, enough has been said in the historical survey. It is a typical salmonid parasite, and is found even in eight species of that family which inhabit fresh water. Its presence in the landlocked *Salmo sebago*, which confines its life cycle to fresh water, is hence not surprising. Evidently the life cycle of the species permits of easy adaptation to a fresh-water existence, for I have to report its occurrence not only in the host under discussion, but also in another prominent American salmonid, the Great Lakes trout, *Cristivomer namaycush* (Walbaum). It was found abundantly in specimens of this host which I examined in July and August, 1894, at Charlevoix, Mich. From 30 to 80 tapeworms of this species were present in each Sebago salmon, and neither size nor age played any evident part in determining the degree of infestation. Absolutely every one of the salmon taken was infested. In considering the possible life history, I naturally turned to the Sebago smelt as the host of the larval form, probably a plerocercoid, and examined a number of these fish with great care, but was unable to detect the larva, if indeed it was present. Nothing was discovered which throws any light on the life cycle. It is worthy of note that all of these parasites were full grown; not a single specimen was found which was not discharging ripe proglottids. Consequently the infestation must have taken place somewhat earlier in the year. It would take observations at other months to determine when; and the food at that time would evidently be the source of the parasite.

In addition to this dominant species some other cestodes were also recorded. A few fragments of a small species of *Proteocephalus* were found in each of four hosts, and a larval form, which probably belongs to the same *Proteocephalus*, was obtained in each of two hosts. Two different bothriocephalid larvæ of small size also occurred each in a single salmon. The four forms just mentioned were all found in the intestine.

The insignificant size of a new species of *Proteocephalus* found and the small number of individuals present in any one host resulted in its being overlooked at first, and it may easily have been present in more hosts than shown by the records. It was found in four out of the seven salmon examined, but in one case only a few loose proglottids were discovered by accident among material from the intestine. A careful examination in comparison with the descriptions of known species leads me to the view that this is a new species to which the name *Proteocephalus pusillus* may be given. The salient points in the description of this new species are as follows:

Proteocephalus pusillus nov. spec.—Adult cestode with short strobila, measuring only 30 to 50 mm. in length. Proglottids scanty, segmentation

distinct. Head much contracted. Neck 1 to 1.5 mm. long by 0.21 mm. broad. First proglottids 0.09 mm. broad, changing gradually until in mature proglottids the length greatly exceeds the breadth. Ripe proglottids measure 0.84 to 1.4 mm. long by 0.18 to 0.35 mm. broad. Terminal proglottids present and fertile. Sexual organs typical for *Proteocephalus;* uterus median, with 10 to 14 lateral outpocketings on either side. Testes numerous, within vitellaria. Genital pore lateral, one-third to two-fifths of length of proglottid from anterior margin of same. Ovaries bilobed, median isthmus indistinct, anteroposterior diameter nearly equal to breadth of both lobes. Only a few specimens obtained from a single host species, *Salmo sebago.*

This species approaches most nearly to *P. ocellata* and *P. percæ* among known species. Unlike the new species, however, both of these older forms have a fifth sucker, fewer lateral uterine outpocketings, a longer neck, differently shaped ovaries, and markedly different proglottids.

In specimens with developed proglottids the head was so much contracted or distorted that any special description would be of little value. One could easily observe the general features characteristic of the genus. There was no well developed terminal or fifth sucker, and the end organ, which is known to replace it in many forms of this genus, was inconspicuously developed, if present. Personally, I incline to the view that on more careful examination this structure will be found in all species, even those in which its absence has been made a matter of record. Accordingly, not much weight can be put in its presence or absence in any individual case.[a]

Three plerocercoid larvæ or young cestodes were found in company with *Proteocephalus pusillus*, which I regard as young forms of this species. The largest came from the salmon which was most heavily infected with this cestode parasite. It was 3.15 mm. long and had begun to assume clearly the appearance of an immature cestode. The head measured 0.3 mm. wide by 0.26 mm. long, and the suckers 0.14 mm. in length by 0.11 mm. in width. The neck was slightly narrower than the head, but was not clearly set off from the body, which was very uniform in diameter and measured 0.25 mm. in average width. The posterior end of the body was swollen into a rounded knob about 0.35 mm. broad and of approximately the same length. This feature was evidently produced by a powerful contraction of the terminal region of the body. In and near it one could see very indistinct indications of proglottid formation. In form, size, and general aspect this young cestode was in full agreement with the anterior regions of the mature cestodes of this species with which it was

[a] For a more definite discussion of this peculiar structure so variable in development in the cestodes of this genus, I would refer to a paper now in press by my student, Mr. George R. La Rue, to whom I am indebted for a comparison of this material from *Salmo sebago* with preparations of other species of *Proteocephalus*

associated. The head, which was not contracted, showed on careful study the delicate outline of a rudimentary end organ. While such a structure was not demonstrated in the mature individuals described above, one can say positively that if present it could not have been seen owing to the greatly contracted condition of the adult scolices. I believe that its presence will be demonstrated in more favorable specimens. The complete agreement of this largest larva with the mature specimens in all other features compels me to regard both as different stages in the development of the same species.

The other larvæ were still in early stages of development, and probably had been ingested by the salmon at a very recent date. Their relationship is not so clear in all respects, and yet I do not hesitate to associate with the new species of *Proteocephalus* a plerocercoid or young cestode obtained from the same host as the adult worms and the older larva just described. The head is broadly conical, without furrows, and measures 0.3 mm. in breadth. The suckers measure 60 to 75μ in diameter. There is no rostellum or fifth sucker to be found, while the end organ is so poorly developed as to be visible with difficulty and only under the most favorable circumstances. The neck is nearly as broad as the head. In general appearance this larva resembles the adult cestode and the older larva previously described. With some reserve one may also assign to this species a single plerocercus taken from another specimen of *Salmo sebago*. The head, which measures only 150μ in breadth, is shaped like that of the young cestode and like it is without rostellum or fifth sucker, while the end organ is difficult to demonstrate. Neither furrows nor ridges are seen on the larva, which has a total length of 1.14 mm. The sucker measures only 30 to 45μ in diameter. The neck is slightly narrower than the head. This form certainly belongs to the genus *Proteocephalus* and probably to the species already described.

From the scantiness of the material obtained one might infer that the Sebago salmon is only a casual host of the species. Yet I did not secure this parasite from any other fish in Lake Sebago and adjacent waters, and I have not met it in fish examined in other places. The presence of larvæ in different stages of development with only a few adult specimens in any one host, although some were found in the majority of the salmon examined, would rather favor the view that the cestode was a regular though infrequent parasite of this host.

Sparganum sebago, nov. spec.—In addition to the cestodes already mentioned, there are to be noted two specimens of bothriocephalid larvæ which deserve more extended mention.

The first was taken from the spleen of one salmon. It measured 25 mm. in length and 1.8 mm. in maximum diameter. There is no neck, but the body

increases slightly in breadth for about one-quarter of the entire length and then tapers gradually to the posterior end, which is rounded off. The body is elliptical in cross section without any segmentation, but with numerous rather prominent annular wrinkles. It seemed as if the margins of the body were thicker than the center. The head was retracted. (Fig. 7 and 8, pl. CXXI.)

The second specimen (fig. 9 and 10, pl. CXXI) was found free in the body cavity of another salmon. It was 36 mm. long and 0.86 mm. in breadth. The body was somewhat thicker than in the other specimen, but less deeply wrinkled, and the center was certainly thicker than the margins. In this, as in the color and texture, it appeared different from the first specimen. There was no neck. The head measured 0.31 mm. in transverse diameter and 0.43 mm. from the apex to the base of the grooves, which were keyhole shaped. The groove measured 0.25 mm. in transverse diameter at the anterior end and 0.09 near its posterior end. In spite of the differences in appearance noted above it is easily possible that the two specimens belong to the same species and I have preferred to list them for the present under a single heading, naming the form *Sparganum sebago*.

A word should be said with regard to other hosts for these cestodes. *Abothrium crassum* was not found in any other fish examined at Sebago Lake. Larvæ of *Proteocephalus* and of some bothriocephalid were found in a very few cases in other fish taken from these waters. There were none, however, of which it could be said with reasonable certainty that they were the same as the forms collected from the Sebago salmon and mentioned above. The question of the occurrence of such salmon parasites in other hosts of this region must be left entirely open for the present at least.

NEMATODES.

Nematodes were not common. They occurred only in half of the specimens of salmon examined and were not abundant. In one salmon 33 of these worms were obtained, but in the other three only a dozen all told. Accordingly they seem to play only a minor part in the parasitic fauna of the Sebago salmon. They belong to two or three separate species, which are radically distinct. Thus far I have not been able to make a satisfactory determination for any of them, owing to the scantiness of the material and to its unsatisfactory condition. This much can be said: They do not belong to any of the species, or even to the genera, heretofore recorded for the Atlantic salmon. A few notes may be added here concerning these forms.

A small nematode was found in the stomach and in the body cavity of two salmon. In all there were only six individuals of this species. I have not been able to satisfy myself that the individuals recorded as from the stomach really belong there, but incline to think that they were adherent to the external

surface of the stomach and passed unnoticed when that organ was opened and shaken in a preserving fluid in order to collect the small specimens of *Azygia sebago* concealed in the gastric mucus. Subsequently they were found in the material obtained in this process. They are probably true parasites of the body cavity. Since an approximate determination may easily be misleading I forego all attempt to name this form and designate it for the present simply as "Nematode A."

The group of 33 nematodes obtained from the body cavity was a source of great surprise. These worms are identical with a form found in very large numbers in the Alaska salmon. Since, however, this species is to be discussed at length in the section of my report which deals with that host, it seems wise to omit here any details and refer to the worm simply as "Nematode B." It is a large form belonging to the Filariadæ, but so delicate that it is almost impossible to obtain perfect specimens, and it has thus far proved beyond my skill to preserve any in a complete condition. It has been an exceedingly interesting object of study and will receive at an early date, in connection with the records of the Alaska salmon and its parasites, that detailed consideration which its frequence and its interest warrant. The six nematodes recorded from the stomach were collected and preserved by an assistant. They are in very poor condition, so that any determination can hardly be more than an impression, but the only real reason why I hesitate to refer them to the same species is that in all the thousands of specimens from nearly 200 hosts which I handled in the course of my investigations on the Alaska salmon I never once found the species anywhere save in the body cavity. It is not impossible that these specimens were reported from the stomach through some error. As repeated examination is bringing me more and more firmly to accept the identity of this lot with those which I collected personally from the body cavity of the Sebago salmon and of the Alaska salmon, I am being forced to assume the existence of some error in recording them as from the stomach.

In any event, it may be said that not more than three species of nematodes are present in the Sebago salmon and that these species are only infrequently and scantily represented in this host. None of the nematodes were found in any other fish examined at Sebago Lake, nor are they known to me from fish of any fresh-water locality in this country. Thus far also I have failed to find any reference in the literature which could be construed as indicating either of these forms.

RÉSUMÉ AND CONCLUSIONS.

The first general conclusion to be drawn from this study of the parasitic fauna of the Sebago salmon is that the total number of parasites recorded from this host is small. In all, there have been listed only 1 trematode, 2 cestodes, 4 (?) cestode larvæ, and 2 nematodes, or a total at most of 9 species

of parasites. To be sure, the number of hosts examined was small, and this may account for the low total record. Two of these parasites, *Azygia sebago* and *Abothrium crassum*, were found in every fish examined, and each of six other parasites was found in two hosts. This may be compared with Zschokke (1896, p. 824), who records the parasitic census of 10 salmon from the North Sea. In these 10 fish were found 10 species of parasites. A trematode and a cestode occurred each in 9 of the fish examined. The cestode was *Abothrium crassum*, the same species as that found in every Sebago salmon; the trematode was *Distomum ocreatum*, a purely marine form, and hence in sharp contrast with the abundant trematode in the Sebago salmon, which is a member of a characteristic fresh-water genus. This contrast, as well as several other details commented on in the previous pages, seem to indicate the fresh-water aspect of the parasitic fauna in the Sebago salmon.

The conditions in the Sebago salmon are all the more striking when one considers the forms which are not found among its parasites. Reverting first to the trematodes, one notices that the only genus represented here, *Azygia*, has been recorded from the Atlantic salmon in Europe only in a single case, while here its representatives were found in every host examined. On the other hand, *Derogenes varicus*, recorded from a good percentage of European salmon in all localities, was not seen even once. The other distomes recorded by European observers in various regions, and often as fairly frequent parasites of the salmon, are entirely wanting in Sebago salmon. *Azygia* is the only purely fresh-water distome found in European salmon; it is the only distome found in the Sebago salmon. The other distomes recorded in European salmon are purely marine species, or very largely so, but none of them occur in the Sebago salmon.

Among the cestodes conditions are identical. The common form, *Abothrium crassum*, is confined to salmonids, without reference to their habitat, and is as common in fresh-water species as in marine. On the other hand, those cestodes which are typically marine, like *Rhynchobothrium paleaceum*, *Scolex polymorphus*, and the several species of *Tetrarhynchus*, are absolutely wanting in the Sebago salmon. The various cestode larvæ are too little known to justify their consideration in this connection. They are not referable, even indefinitely, to either habitat. To this statement one must make two exceptions. *Scolex polymorphus*, recorded from the salmon in Europe, is typically marine, occurring in many sea fish, even though several species may be indicated under the single name. On the other hand, the larva of *Proteocephalus* is equally typically limnetic and it is recorded from the Sebago salmon only unless the single record of *Tænia* sp. for a larva from the salmon in the Tweed should be referred to this form. In this group again it appears clear that the marine parasites of the European salmon are wanting in the Sebago species, that the only cestodes

identical in the two forms are such as are clearly fresh-water species, and that the Sebago salmon contain at least one clearly fresh-water genus which is not reported from the corresponding European host.

Among the nematodes the evidence is less conclusive, since the amount of material is smaller; indeed, hardly enough to form a basis for any conclusions. At the same time, all the species which give to the parasitic fauna of the European salmon its marine aspect are entirely wanting here. Not a single specimen of *Agamonema* was discovered, although two species are found in the European salmon, and one of them, *Agamonema capsularia*, is very common. Both *Ascaris* and *Echinorhynchus* are unrepresented in the parasitic fauna of the Sebago salmon. Among the numerous species of each already recorded as parasitic in the European salmon three out of four are purely marine. Here again one notes that the marine elements in the parasitic fauna of the European salmon are wanting in the Sebago salmon. Possibly the large filariad found abundantly in the Alaska salmon, and reported also from one or two salmon taken in Sebago Lake, forms an exception to the general rule. As I have already noted, it appears to be marine in origin. This may be, however, a false argument, and the species may actually be one limited to this host or to the salmonid family, regardless of habitat. In this connection one naturally recalls at once the case of *Abothrium crassum*, which, from the observations on salmon in the North Sea and then in the Rhine, might be said to be a marine form, since it gradually disappears on the journey up the Rhine. But it occurs in hosts of purely fresh-water habitat, such as *Salmo hucho* in Europe and *Cristivomer namaycush* in the Great Lakes of North America. Evidently further information is needed before one can safely assign this nematode to a definite habitat.

Summing up all the evidence concerning the parasites of the Sebago salmon, one finds that four species are unknown in character, one only is possibly marine, one is a pure salmon parasite, and three are clearly fresh-water forms. The latter are also its most frequent and numerous guests. Furthermore, the Sebago salmon lacks every one of those parasites found in the European salmon which must be regarded as purely or largely marine, and possesses in common with its European congener only one characteristic salmon parasite and possibly also two fresh-water forms, which, though abundant in its own parasitic fauna, are very rare in that of its relative.

The parasitic fauna of the Sebago salmon manifests a striking fresh-water aspect, all the more unexpected in view of the marine character of that in the European salmon as demonstrated by Zschokke. One could hardly find a more convincing demonstration of the fundamental biological relation between parasite and host.

The parasitic fauna of any animal is primarily a function of its habitat.

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1891. Die Parasitenfauna von *Trutta salar*. Ibid., bd. 10, p. 694–699, 738–745, 792–801, 829–838, 8 tab.

1896. Zur Faunistik der parasitischen Würmer von Süsswasserfischen. Ibid., bd. 19, p. 772–784, 815–825.

1902. Marine Schmarotzer in Süsswasserfischen. Verhandlungen der Naturforschenden Gesellschaft in Basel, bd. 16, p. 118–157.

EXPLANATION OF PLATE.

FIG. 1. *Azygia sebago*. Group of individuals from *Salmo sebago*, after preservation in corrosive sublimate and then alcohol. ×2.

2. *Azygia sebago*. Specimen from salmon, stained and mounted in balsam. Dorsal view. ×12½.

3. *Azygia sebago*. Anterior region of alimentary canal in lateral aspect. Reconstruction by Messrs. W. M. Anderson and H. B. Boyden. *in*, intestine; *œ*, œsophagus; *os*, oral sucker; *ph*, pharynx. Highly magnified.

4. *Azygia sebago*. Longisection showing relations of principal organs. *exc*, main excretory vessels; *lpm*, longitudinal parenchym muscles, for explanation of which compare text; *vit*, follicles of vitellarium. Camera drawing. ×358.

5. *Azygia sebago*. Female reproductive system in dorsal aspect. Semidiagrammatic to show relation of organs in ovarial complex. *lc*, Laurer's canal; *od*, germ duct; *ov*, germarium; *sg*, shell gland; *ut*, first coils of uterus; *yd*, transverse vitelline duct; *yr*, yolk reservoir. After reconstruction by Messrs. Anderson and Boyden. Highly magnified.

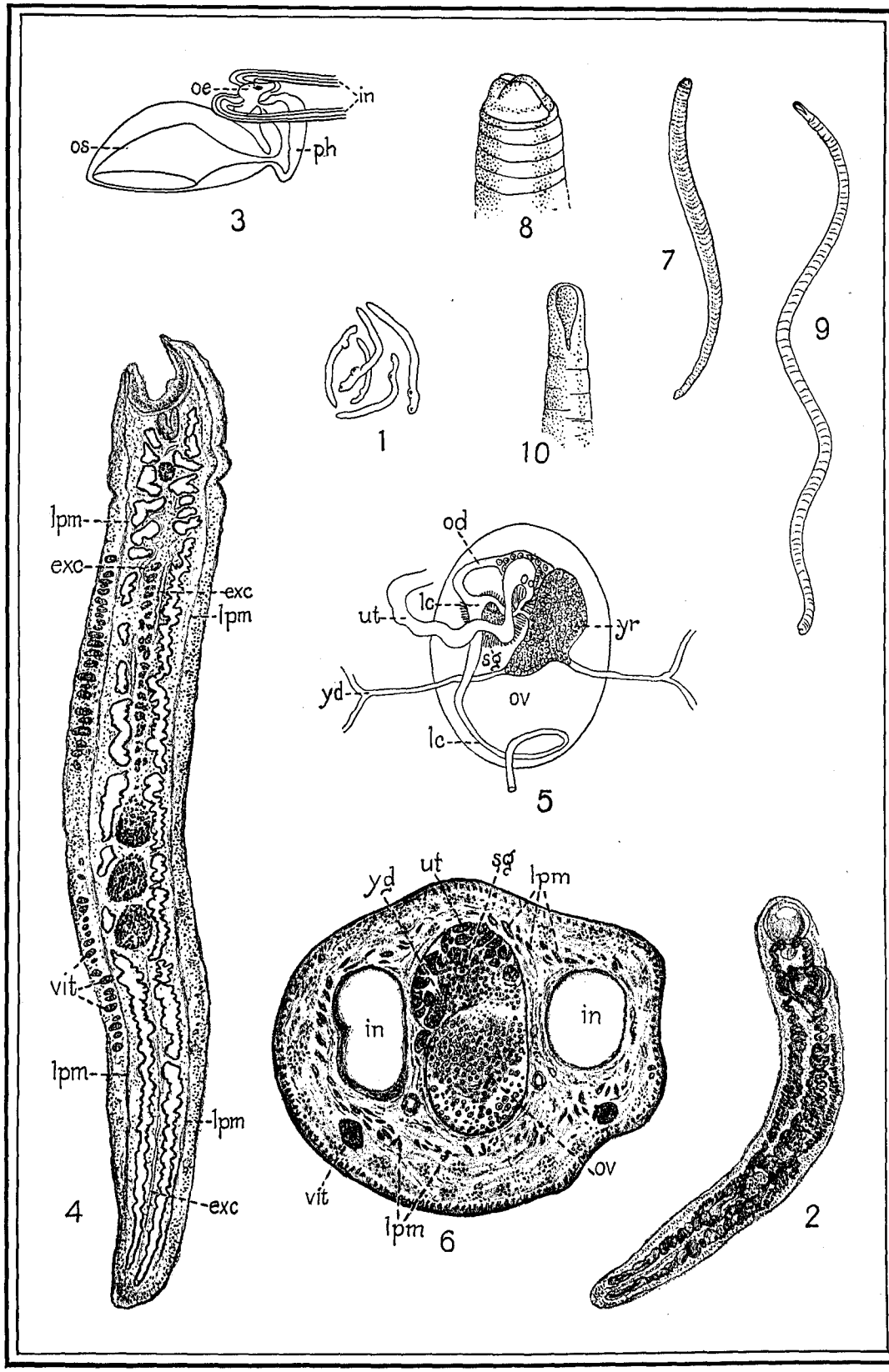
6. *Azygia sebago*. Transsection through ovarial complex, showing relations of organs to common capsule (see text). *in*, intestinal crura; *lpm*, longitudinal parenchym muscles; *ov*, germ gland; *sg*, shell gland; *ut*, first coil of uterus; *vit*, follicle of vitellarium; *yd*, common yolk duct and part of yolk reservoir. Camera drawing ×60.

7. *Sparganum sebago*, nov. sp. Bothriocephalid larva from spleen of *Salmo sebago*. Drawn from alcoholic specimen. ×2.

8. Head of larva, shown in fig. 7 ×25.

9. *Sparganum sebago*, nov. sp. Bothriocephalid larva from body cavity of *Salmo sebago*. Drawn from alcoholic specimen. ×2.

10. Head of larva, shown in fig. 9. ×25.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NOTES ON THE FLESH PARASITES OF MARINE FOOD FISHES

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INTRODUCTION.

In beginning the study of fish parasites it was soon realized that by far the most likely place to find entozoa is within the body cavity of the host. Often, therefore, on account of the abundance of material and the limited time at my disposal, I confined my collecting almost wholly to what could be secured from the alimentary tract and the body cavity. An occasional search for parasites in the flesh of marine fishes met with so few finds that it came to be in large measure neglected. In 1904, however, I discovered that the parasitism which I had already noted in the case of the butterfish (*Poronotus triacanthus*), instead of being of occasional and accidental occurrence, is really of almost universal prevalence in all localities where I have studied this fish.

The results of my investigations on the butterfish parasite naturally suggested inquiry as to the condition in this particular of other food fishes, and it is the purpose of this paper to set forth some of the results of my investigations of this subject. In the summer which has just passed (1908) I spent three weeks at the laboratory of the Carnegie Institution at the Dry Tortugas, and the remainder of the time at the laboratory of the Bureau of Fisheries, Woods Hole, Mass. Most of the fishes that I examined were examined for flesh parasites, and, with one or two exceptions, this paper is confined to results obtained in the present season. This applies more especially to the tabulated results.

The results of this study are as yet very uneven; at the same time they afford certain conclusions which are of importance, as will appear in the progress of the paper. It may be stated properly in this connection that while very few, or even in some cases only one, example of a species of fish was examined, the general results of this past summer's investigation are in agreement with those of previous years—namely, that the marine food fishes, with the exception of the butterfish, are singularly free from parasites in the flesh. Indeed, with the exception of the butterfish, I have not yet found any one of our food fishes which is more than an accidental intermediate host for any parasite. At least, if there are any such they are confined to those cases in which the walls of the alimentary tract furnish a lodgment for various cestode cysts.

The method employed in the examination of the flesh for parasites was the same I have used in examining butterfish in previous years. The fish were split open longitudinally and the flesh separated from the backbone and vertebral spines. Occasionally the flesh was further divided. This method exposes the usual location of flesh parasites.

PRINCIPLES OF DISTRIBUTION OF ENTOZOA.

In order that the subject-matter of this paper be perfectly clear, it is necessary to give a brief résumé of the principles which determine the distribution of the entozoa. The term "entozoan" is a convenient general designation for any animal which lives within another animal. The adult egg-producing animal lives in the alimentary tract, or some part in direct connection with the alimentary tract, as the bile duct, or, in the case of air-breathing animals, also in the air passages. As a rule the eggs, or in the case of the cestode or tapeworm the ripe joints, which separate from the parent chain, are thrown off with the natural discharges of the animal in which they are living. The animal which harbors the adult tapeworm is called the final host. In order to develop, the eggs, as a rule, must enter the alimentary tract of another animal. In this animal the eggshell is digested off and the minute embryo thus liberated penetrates the mucous membrane of this second or intermediate host and sooner or later comes to rest. A cyst of connective tissue is formed around it by the tissues of its host. In this cyst the parasite remains quiescent, and ordinarily this is the end of the individual unless it is swallowed by the animal in whose alimentary canal it can become sexually mature. In this case another generation of eggs is produced and the round of life from egg to egg again is completed.

In the majority of instances a cestode egg gives rise to but one adult chain. In a few instances a large number may develop from one egg, on account of the multiplication of larvæ by a kind of budding in the encysted stage. So far as I have observed, there are no examples of this latter method of reproduction among the cestodes that infest fishes.

ZOOLOGICAL ORDERS REPRESENTED BY FLESH PARASITES OF FISHES.

The following groups are represented in the parasites which I have found in the flesh of our marine food fish:

SPOROZOA.

These protozoan parasites occur in small white cysts, usually along the backbone of small fishes. They seem to be of rather common occurrence in young alewives and herring.[a] I have not examined many full-grown herring

[a] Linton, E.: Parasites of fishes of the Woods Hole region. Bulletin U. S. Fish Commission, vol. XIX, 1899, p. 438, 439.

and alewives, but, so far as my researches have gone, the flesh parasites appear to be confined to the young fish. It seems probable that the badly infected young do not reach maturity. Our knowledge of the life cycle of the sporozoa is very fragmentary, and it is perhaps better to expend our energies in the accumulation of knowledge, even if it must consist largely of apparently unconnected facts, than to attempt to explain what further investigation may show in a clear light.

NEMATODA.

While immature roundworms are very common on the viscera of fish, they are, fortunately from our point of view, of exceedingly rare occurrence in the flesh of marine fish. I have not found them in the flesh of any of the fishes which are strictly food fish at Woods Hole, Beaufort, or Tortugas. In Bermuda I found numerous roundworms (*Ichthyonema globiceps*) in the flesh of a gar (*Tylosurus acus*). These were colored blood-red and lay in tangled clusters in the flesh, most abundant near the backbone. They bore a close resemblance to blood vessels. I have occasionally found this species, or a species near it, in the ovaries of some of our food fishes. If these were of common occurrence the fact would be somewhat disturbing. The worms are long and thread-like, often growing to the length of several inches. They are, moreover, crowded either with ova or, in most cases, with the young. The latter are very minute, but very active, and are in vast numbers. What would be the result if eaten in insufficiently cooked food is not known. If, like the dread *Trichina*, they can resist the digestive juices of the human stomach, they might easily penetrate the mucous membrane and, carried by the blood, finally lodge in congenial tissues of the body, to become encysted, provided the body is able to stand the inflammation produced by the invasion.

Nematodes are very resistant to digestive fluids and are much more to be feared than either trematodes or cestodes. In addition, they are nearer the popular conception of the word worm than representatives of other orders of the helminths. It is, therefore, a satisfaction to state that the probability of consuming nematodes along with our fish food is very slight, indeed, and in no way to be compared with the like probability in the eating of pork.

TREMATODA.

While this order of flat worms has a very large representation among the species of entozoa inhabiting fish, their occurrence in the flesh of marine fish is extremely rare, so much so that the few cases which I have recorded must be regarded as accidental. The only cases where members of this order are at all likely to enter our alimentary canals along with our fish food will be as skin parasites. Many fish, especially tautog, cunner, and, to a lesser degree, flounders,

tomcod, and fish of similar habits, have small distomes encysted in the skin and in the fins. As these are almost always all removed in preparing the fish for cooking, they need cause no more thought, even to the ultra fastidious, than other accidental débris that may be caught by the slimy epidermis of the fish. On fishes inhabiting small fresh-water lakes this form of parasitism is common. The bearer of the adult stage of these skin parasites is commonly some fish-eating bird.

CESTODA.

This order is represented by many genera and species among the entozoa of marine fishes. The sharks and skates harbor a long list of adult cestodes in their alimentary canals, especially in the intestine or spiral valve. The mature joints of these cestodes, each filled with hundreds, even thousands of eggs, are cast into the water in vast numbers along with the fæces of the host. It is a peculiarity of these free segments that they may continue living for some time, even many hours, in sea water. In the water they are likely to be eaten by such fish as feed on small worms, crustacea, and the like. The adult stage of any of these cestodes of the sharks and skates is limited to a few closely related species, or, in some cases, apparently to a single species. They are, on the other hand, capable of living on a large number of intermediate hosts. A little reflection on the contrasted conditions to which the adult and the larval stages, respectively, of a cestode are subjected will serve to explain this difference.

In the adult stage the cestode passes its whole existence in the alimentary canal of its host. It has become adapted to a highly specialized set of conditions. Hosts differ specifically not only in respect to their morphological characteristics but in their physiological characters as well. Thus a given cestode may find the juices of the alimentary canal of a tiger shark kindly while it finds the juices of the alimentary canal of any other shark fatal to its development. There is also some difference in the character of the food. The latter might seem to account for the difference between the parasites of a shark whose diet consists mainly of crustaceans, and one which has a strictly fish diet. On the other hand, sharks which feed on practically the same food, if they are not closely related morphologically, may be found to harbor a different set of cestode parasites. For example, the entozoa of the dusky shark (*Carcharhinus obscurus*) and those of the blue shark (*C. milberti*) comprise practically the same species. When the list from either of these sharks is compared with the list from the sand shark (*Carcharias littoralis*), some constant differences at once appear. There is one species of cestode (*Crossobothrium laciniatum*) which is almost invariably present in the sand shark and usually in considerable numbers. It has not been found in any other species of shark or skate. Furthermore, very few of the long list of cestodes from the dusky shark have been found in the sand shark.

When we turn to the intermediate hosts of these cestodes we find no such limitations. For example, there is a cestode (*Tetrarhynchus bisulcatus*) which is of common occurrence in the dusky shark in the Woods Hole region. I found the same or a closely related species in a shark, which was rather doubtfully identified as a blue shark, at Beaufort, and two specimens, not yet mature, in a sharp-nosed shark (*Scoliodon terræ-novæ*) at that place. This cestode may be said to be practically limited to the dusky shark as its final host. I have found it encysted in at least 18 species of fish at Woods Hole, in 22 at Beaufort, and in 2 in Bermuda. The intermediate hosts of this parasite include a great range of species. They are not even confined to the teleosts, but include some of the sharks and skates as well. The occurrence of encysted cestodes in sharks and skates is not as rare as it was thought to be by Beneden, who coined the word xenosite, or stranger, for such cases.

It does not come within the plan of this paper to give details of distribution. The following typical examples, therefore, will probably be sufficient to illustrate this matter of the limitation in the number of final hosts and the wide range of intermediate hosts.

DISTRIBUTION OF TYPICAL CESTODES IN FINAL AND INTERMEDIATE HOSTS.

Cestode.	Usual or only known final host.	Intermediate host.
Tetrarhynchus bisulcatus	Carcharhinus obscurus	18 species of Woods Hole fishes. 22 species of Beaufort fishes. 2 species of Bermuda fishes.
Rhynchobothrium bulbifer	Mustelus canis	22 species of Woods Hole fishes.
Rhynchobothrium speciosum	Carcharhinus obscurus	12 species of Woods Hole fishes. 3 species of Beaufort fishes. 5 species of Bermuda fishes. 4 species of Tortugas fishes.
Rhynchobothrium imparispine	Raja ocellata	28 species of Woods Hole fishes.
Otobothrium crenacolle	Sphyrna zygæna	In a large number of Woods Hole and Beaufort fishes, and in 3 Bermuda fishes; especially abundant in flesh of butterfish.

In view of the frequency of occurrence of cestode parasites in body cavities of marine fishes their comparative rarity as flesh parasites is striking. While larval cestodes have been found in the great majority of the species of fish I have examined, in those cases where a considerable number of individuals were examined the number of species of fish in which I have found parasites in the flesh is surprisingly small. A glance at the appended tables will show the small number of fishes found to harbor parasites in the flesh among those examined in the summer of 1908. When it is remembered that with no more than three exceptions entozoan parasites have been collected from all the species of fish named in the tables, that flesh parasites are recorded from only 12 species out of a total of 76, and that in only 2 of the 12 species were flesh parasites found in many individual fish or in large numbers in any, the comparative scarcity of flesh parasites in the marine fishes becomes a still more noteworthy fact.

Aside from the butterfishes, which will be considered later, the only instances in which I have found cestodes in the flesh of marine fishes under conditions which led me to regard their occurrence as other than accidental are the following:

1. Two species of gars, *Tylosurus acus* in Bermuda and *T. rapidoma* at Beaufort. Two fish of the former species and one of the latter were examined. In each of them there were many cestodes in the flesh. This cestode was described[a] under the name *Otobothrium* sp. The examples from the Bermuda gars proved to be the same species and have been given a specific name, *O. penetrans*.[b]

2. The sand launce (*Ammodytes americanus*). I have found a species of cestode (*Rhynchobothrium bulbifer*) in the flesh of a considerable number of these fishes in previous years, although none were found in the lot which was examined this season.

3. Two sticklebacks (*Gasterosteus bispinosus*) which were examined this season had each many cestodes encysted in the flesh.

Two of the three cases cited above are based on too small a number of individuals to be of much value, at the same time the manner of infection in each case was such as to lead me to more than suspect that they are common carriers of cestode parasites in the flesh.

THE CASE OF THE BUTTERFISH.

A reference to the appended table III, wherein details of the examination of the butterfish are given, and to tables I and II, where a summary is given in which the parasitism of the butterfish may be compared with that of other food fishes examined during the summer of 1908, will show that in respect to the matter of flesh parasites the butterfish occupies a unique position. All the other food fish, as a rule, show either none or only an occasional individual with parasites in the flesh, and even in cases where any were found in the flesh, there were at most few, often but one. The butterfish, on the other hand, proves to be so generally infected that the infected condition really seems to be the normal. An examination in the season of 1908 of 720 butterfish, ranging in length from 6 to 23 centimeters, resulted in finding cestode cysts in the flesh of all but 21.

As this case of parasitism has already been reported it is not necessary to devote much time to it here.[c] Inasmuch as the case is a most remarkable and exceptional one, however, there are certain phases of the subject which should be considered.

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[a] Linton, E.: Parasites of fishes of Beaufort, N. C. Bulletin, Bureau of Fisheries, vol. XXIV, 1904, p. 357.

[b] Linton, E.: Notes on parasites of Bermuda fishes. Proceedings U. S. National Museum, vol. XXXIII, 1908, p. 100

[c] Linton E.: A cestode parasite in the flesh of the butterfish. Bulletin Bureau of Fisheries, vol. XXVI, p. 1–48, pl. 1 and 2.

This parasite is a cestode, described first from adult forms found in the spiral valve of the hammerhead shark (*Sphyrna zygæna*).[a] In the butterfish it is found, sometimes in enormous numbers, in the flesh. The favorite resting place of these cysts is between the vertebral spines on the ventral side of the backbone, but they are often almost equally abundant between the vertebral spines on the dorsal side of the backbone, and scattered generally through the muscles of the body, for the most part in a dorsoventral median plane. The cysts are small, usually 1 millimeter or less in greatest diameter, oval in shape, and present the appearance of small fish-roe. In the young fish they are translucent white, which becomes tinged with yellow in the larger fish. Each cyst, when crushed, liberates a characteristic cestode nurse (plerocercus or blastocyst) in which is the scolex or head of the tapeworm. In all the cysts that I have studied this season, even those from the smallest fish, I have not failed to find a well-formed scolex bearing the characteristic marks by which the species may be recognized. In former years the smaller fish were found to be much less infected than the older fish and many were found in which no cysts were seen. Also in former years cysts were found in some of the smaller fish which contained scoleces in which the characteristic hooks on the proboscides and the pits on the bothria were not yet developed. In the season of 1908 even the smaller fishes were found to be largely infected. As they are recorded in the tables, the grouping into "cysts in enormous numbers," "very numerous," "numerous," etc., is more or less arbitrary. It is to be hoped, however, that it will convey a fairly correct picture of the actual condition. Of course the terms are to be understood as of only relative significance. A small fish, for example, recorded as having numerous cysts would contain a smaller actual number than would a large fish similarly characterized.

This case of parasitism of the individuals of a species which inhabits the open sea is most exceptional. In a confined area, as in a small lake, or in exceptional conditions, such as obtain in as large a body of water as Yellowstone Lake, a general prevalence of parasites can be accounted for.[b] But why should the butterfish and its near relative, the harvestfish, be so excessively and universally parasitized while other species of fish, though they inhabit the same waters and feed on practically the same food, escape? That an occasional butterfish should be found with these cysts in the flesh would not of itself be a thing remarkable. That these cysts should even be present in very large numbers, even thousands, as is often the case, is not inexplicable. That such an enormous percentage should be affected, as is proved by the facts exhibited in the tabular statements in this paper, is the really difficult matter to explain.

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[a] Linton, E.: Notes on entozoa of marine fishes of New England, with descriptions of several new species. Report U. S. Fish Commission, 1887, p. 850–853, pl. XIII, fig. 9–15; pl. XIV, fig. 1–4. 1891.

[b] Linton, E.: On two species of larval Dibothria from the Yellowstone National Park. Bulletin U. S. Fish Commission, vol. IX, p. 65–79, pl. XXIII–XXV; p. 337–358, pl. CXVII–CXIX. 1891.

1. As to the fact that these parasites have the habit of gaining lodgment in the flesh of the butterfish, it may be said that evidently here is a case of mutually favoring conditions. A careful study of the anatomy of the butterfish, especially of the vascular system, may throw some light on the problem. At any rate the fact that the larvæ of *Otobothrium crenacolle* penetrate to the muscles of the butterfish and harvestfish, instead of lodging in the submucous coat of the stomach and intestine, as is their habit in other fishes in which this cestode has been found, is probably a purely physiological question. The other species of *Otobothrium* mentioned above presents a somewhat similar case. In the case of the gars, however, a large number of small gars have been examined for flesh parasites without any being found. Either the infected gars were exceptional cases, or it is only in certain regions that the conditions favor the ingestion of cestode eggs.

It would appear that certain species of the Tetrarhynchidæ, and notably of the genus *Otobothrium*, are enabled to penetrate to the muscles of certain intermediate hosts, possibly on account of being of suitable size and structure so that they are carried by the blood away from the immediate vicinity of the viscera. Or, more probably, there is here a case of accidentally mutual adjustment on the part of the anatomical structure, and possibly the physiological habit of the butterfish on the one part, to the structural features, and possibly the physiological requirements of the parasite on the other.

2. That these cysts should be present in very large numbers in a single fish is not difficult to understand once given the possibility of their being in the flesh at all. A free, ripe segment of the cestode *Otobothrium crenacolle* will remain living for hours after it has been placed in sea water. Moreover, it may contain an enormous number of eggs. There is no necessity, therefore, in postulating some method of reproduction of cysts by budding, for which there is not the slightest evidence, to account for the presence of a large number of cysts in a single butterfish. The ingestion of a single joint, in which there is a large number of eggs, will be sufficient to give rise to several hundred, possibly a few thousands of cysts, each with its living scolex. Indeed it is rather easier to explain the cases in which there are hundreds of cysts than it is to explain those in which there are less than a dozen. Cases of slight infection are probably due to the accidental swallowing of a few eggs instead of an entire joint. This might happen if a fish swallowed a bit of fecal matter which might well have one or more eggs intermingled with it.

3. How is the apparently almost universal parasitism of the butterfish to be explained? Before attempting to answer this question it may be well to consider whether the case, aside from the fact that the cysts are in the muscles, is unique. Unfortunately, I have not my notes arranged in such a way as

will enable me to tabulate readily or completely the data which it is desirable to marshal for this particular purpose. The following statements, however, are abundantly warranted from many observations made during previous years, and have some bearing on the immediate question.

The stomach wall of most squeteagues (*Cynoscion regalis*) contains a greater or less number of cysts of a definite species of cestode (*Tetrarhynchus bisulcatus*) which is found in the adult stage in the stomach and intestine of the dusky shark. Furthermore there is found in the cystic duct of the same fish a larval cestode (*Scolex polymorphus*), almost always in considerable number. The same parasite is also quite common in the cystic duct of the summer flounder (*Paralichthys dentatus*). For example, during the past summer I examined a flounder from Menemsha Bight which appeared to be suffering from a case of jaundice. The whole surface was yellow, the unpigmented under side being a decidedly bright lemon yellow. The flesh and the viscera were also yellow. The cystic duct was occluded by a mass which looked something like a soft tumor. When this mass was cut open it was found to consist of a cluster of these cestodes. Their heads were buried in the mucous membrane while their bodies effectually stopped the lumen of the duct. Other cases of prevalent parasitism in intermediate hosts could be cited.

In like manner cases of prevalent parasitism of final hosts are not lacking. Thus every specimen of tiger shark (*Galeocerdo tigrinus*) which I have examined, about 15 in all, at intervals during many years, has been found to harbor large numbers of a singular cestode (*Thysanocephalum crispum*), a species which has not been found as yet in any other host. Again, nearly every sand shark in the Woods Hole region harbors a species of cestode (*Crossobothrium laciniatum*), often in large numbers.

Plainly, then, all that is necessary to make parasitism, by means of a given species of parasite, affect the majority of the individuals of the host, is to have the source of infection sufficiently widespread, abundant, and pervading in the natural habitat of the infected species. Not only must the final and the intermediate hosts, in the case of the cestodes, be related to each other as eater and eaten, but their association together must be otherwise close, else the intermediate host will not become largely infected. At present I can see no other explanation of the almost universal prevalence of this parasite in the flesh of the butterfish than that which I gave in the paper cited above. The butterfish must have formed the habit of following sharks, attracted by the bits of food which float off in the water while the shark is feeding. The voracious, fish-eating sharks tear and shake their prey as they eat it, so that there must often be in the vicinity of a shark a cloud of bits and shreds of meat which are greedily sought by smaller fish. This zone of sure, even if it be intermittent, food supply

can not fail to be attractive to small fish. These small fish, especially when traveling in schools, must themselves often pay tribute to the shark. There is thus established by the common bond of mutual advantage an association which must be extremely favorable to the parasite which can thrive well in both the intermediate and the final host which are the principals in this association. From time to time the ripe joints of the cestode will be discharged into the water along with the fæces from the intestine of the shark. These joints look, behave, and doubtless feel to a small fish much as other small swimming forms, entomostracans, annelids, and the like do, and consequently are picked up by them. In some such manner do the eggs of the cestode gain lodgment in the intermediate host. What is difficult to picture is the actual situation which not only makes possible but actually brings to pass the infection of practically all the butterfish. A study of the appended tables will make it quite clear that among the half grown and fully grown butterfish an individual which is free from these cysts in the flesh is exceptional.

Butterfish are not fish of rare occurrence traveling singly or even in very small schools. They are taken in considerable numbers in the fish pounds, and evidently move in fairly large schools. How far they migrate along the coast is not known. I have found the adult cestode, though not abundant, in the sharp-nosed shark at Beaufort. This shark is abundant. The other known final host is the hammerhead shark, which is not an abundant species, though it is one which has a wide distribution. I hope to be able to gather more data on this interesting problem of distribution.

GENERAL CONSIDERATIONS AS TO FLESH PARASITES OF FISHES.

To what extent is the food value of fishes impaired by the presence of parasites in the flesh?

With the exception of the common butterfish (*Poronotus triacanthus*), and its rarer relative the harvestfish (*Peprilus alepidotus*), I find that the marine food fish I have thus far examined are so free from parasites in the flesh that the question has, at present, little more than an academic or rather a purely zoological interest. To take the case of the butterfish, it may be remarked:

1. Since the cysts might be easily mistaken for ova by one whose knowledge of the natural position of the ovary is indefinite, and since the nutritive value of the cysts is doubtless little different from that of so much fish-roe, it is likely that the food value of the parasitized fish is not much different from that of the nonparasitized or but slightly parasitized fish of the same weight. There is no evidence of any inflammatory or pathological condition of the tissues of the fish brought about by the presence of the cysts. From another point of view the cysts are a decided detriment. A number of badly parasitized fish was selected

and an equal number, corresponding in length and depth, of nonparasitized, or but slightly parasitized fish. The two sets were weighed and the weights compared. This was repeated a number of times. In each instance the parasitized fish weighed less than the others.

2. It can be quite confidently asserted, although no feeding experiments have been attempted, that these cysts, even if they were to be swallowed uncooked, would fail to develop in man, or indeed in any warm-blooded animal. Even among fishes they are restricted to a few closely related sharks for their final hosts.

3. The greatest impairment which is wrought on the value of the butterfish as food by this parasite is the subjective effect which the knowledge of its presence in the flesh of the fish has on the mind or imagination of the consumer. This is probably in large part due to the fact that the parasite is a parasite, and especially a worm parasite. The conjunction of such appetite-destroying ideas as are embraced in the mere words worm and parasite is bad enough, but when one substitutes the word cestode for worm, and then is obliged to confess that the word cestode means tapeworm the situation is not made better in the least.

Touching the matter of the discovery of this parasite in the flesh of the butterfish, I may be permitted to say that I am very sorry to be the bearer of this painful news. Possibly some compensation will be afforded by the further intelligence which I feel warranted in bringing that the plight of the butterfish is a most exceptional one, and that so far as my investigations have gone, it can be stated with entire confidence that the flesh of the marine food fishes is, to a very high degree, free from parasites. Certainly the examination of such excellent food fishes as the scup, bonito, squeteague, flounders, etc., as shown in the appended tables, is sufficient to warrant the conclusion that so far at least as the investigation has progressed, the presence of parasites in the flesh of our marine food fish, excepting always from this guaranty the butterfish, is very exceptional.

TABLE I.—SHOWING SUMMARY OF RESULTS OF THE EXAMINATION OF FOOD FISHES FOR PARASITES IN THE FLESH, WOODS HOLE, MASS., JULY TO SEPTEMBER, 1908.

Name of fish.	Number of fish examined.	Parasites found in the flesh.	Name of fish.	Number of fish examined.	Parasites found in the flesh.
Eel (Anguilla chrysipa)	4	None.	Butterfish (Poronotus triacanthus).	720	Cysts in 699; large numbers in most cases.
Round herring (Etrumeus sadina).	243	None.	White perch (Morone americana).	2	None.
Herring (Clupea harengus).	1	Sporozoa.	Scup (Stenotomus chrysops).	73	None.
Alewife (Pomolobus pseudoharengus).	73	Sporozoa in 21.	Squeteague (Cynoscion regalis).	39	Four cysts in 3 fish.
Glut herring (Pomolobus aestivalis).	1	None.	Kingfish (Menticirrhus saxatilis).	19	None.
Smelt (Osmerus mordax)	21	None.	Cunner (Tautogolabrus adspersus).	59	None.
Silverside (Menidia notata).	28	One cyst.	Tautog (Tautoga onitis)	37	None.
Mullet (Mugil cephalus)	23	None.	Triggerfish (Balistes carolinensis).	2	None.
Barracuda (Sphyræna borealis).	5	None.	Whiting (Merluccius bilinearis).	24	None.
Mackerel (Scomber scombrus).	2	None.	Pollock (Pollachius virens).	3	None.
Chub mackerel (Scomber colias).	10	One cyst.	Tomcod (Microgadus tomcod).	5	None.
Bonito (Sarda sarda)	57	None.	Hake (Phycis tenuis)	4	None.
Pilotfish (Seriola zonata).	4	None.	Hake (Phycis chuss)	5	None.
Mackerel scad (Decapterus macarellus).	9	None.	Summer flounder (Paralichthys dentatus).	9	None.
Yellow crevalle (Caranx chrysos).	1	None.	Sand dab (Lophopsetta maculata).	16	None.
Round pompano (Trachinotus falcatus).	5	None.	Winter flounder (Pseudopleuronectes americanus).	40	One cyst.
Bluefish (Pomatomus saltatrix).	58	None.			
Harvestfish (Peprilus alepidotus).	12	Numerous cysts in all.			

TABLE II.—SHOWING SUMMARIZED RESULTS OF EXAMINATION OF FISHES FOR PARASITES IN THE FLESH, DRY TORTUGAS, FLA., JUNE TO JULY, 1908.

Name of fish.	Number of fish examined.	Parasites found in the flesh.	Name of fish.	Number of fish examined.	Parasites found in the flesh.
Green moray (Lycodontis funebris).	1	None.	Bermuda chub (Kyphosus sectatrix).	2	None.
Great barracuda (Sphyræna barracuda).	3	None.	Cock-eye pilot (Eupomacentrus leucostictus).	3	None.
Blue runner (Caranx ruber).	4	None.	Cow pilot (Abudefduf saxatilis).	6	None.
Red grouper (Epinephelus morio).	5	None.	Chlorichthys bifasciatus	1	None.
Rockfish (Mycteroperca venenosa).	4	A few degenerate cysts in flesh of one and under the peritoneum of another.	Blue parrotfish (Scarus cœruleus).	6	None.
			Parrotfish (Scarus croicensis).	5	None.
			Scarus sp	2	None.
Big eye (Priacanthus cruentatus).	1	None.	Black angelfish (Pomacanthus arcuatus).	10	None.
Gray snapper (Neomænis griseus).	14	None.	Angelfish (Angelichthys isabelita).	2	None.
Schoolmaster (Neomænis apodus).	1	None.	Blue tang (Teuthis cœruleus).	8	None.
Muttonfish (Neomænis analis).	1	None.	Surgeonfish (Teuthis hepatus).	12	None.
Yellowtail (Ocyurus chrysurus).	11	None.	Shellfish (Lactophrys triqueter).	1	None.
Yellow grunt (Hæmulon sciurus).	3	None.	Shellfish (Lactophrys trigonus).	4	None.
White grunt (Hæmulon plumieri).	54	None.	Cowfish (Lactophrys tricornis).	2	None.
Porgy (Calamus calamus)	12	Two cysts in one, one cyst in another.	Shark sucker (Echeneis naucrates).	2	None.

TABLE III.—SHOWING OCCURRENCE OF CESTODE CYSTS IN FLESH OF BUTTERFISH, AND RELATION TO SIZE OF HOST.

Length in centimeters.	Number of fish examined.	Number of fish with—				
		Very numerous cysts in flesh.	Numerous cysts in flesh.	Many cysts in flesh.	Few cysts in flesh.	No cysts in flesh.
1904.						
20 centimeters and over	100	21	63	5	11	0
15 to 20 centimeters	42	8	7	13	13	1
10 to 15 centimeters	56	4	4	19	25	4
Less than 10 centimeters	4	0	0	0	1	3
Total for 1904	202	33	74	37	50	8
1905.						
20 centimeters and over	242	69	54	32	80	7
15 to 20 centimeters	75	21	5	11	26	12
10 to 15 centimeters	26	2	1	1	8	14
Less than 10 centimeters	4	0	0	0	0	4
Total for 1905	347	92	60	44	114	37
1906.						
20 centimeters and over	32	17	6	3	5	1
15 to 20 centimeters	24	7	1	4	7	5
10 to 15 centimeters	7	0	0	0	0	7
Total for 1906	63	24	7	7	12	13
1907.						
20 centimeters and over	12	1	2	4	4	1
1908.						
20 centimeters and over	180	75	38	38	26	3
15 to 20 centimeters	129	61	32	22	14	0
10 to 15 centimeters	207	63	67	42	29	6
Less than 10 centimeters	204	3	30	75	84	12
Total for 1908	720	202	167	177	153	21
Total for 1904–1908	1,344	352	310	269	333	80

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STRUCTURE AND FUNCTIONS OF THE EAR OF THE SQUETEAGUE

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Professor of Zoology, Harvard University

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STRUCTURE AND FUNCTIONS OF THE EAR OF THE SQUETEAGUE.

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INTRODUCTION.

Although fishes have no external ears, they have long been known to possess internal ears which in complexity of structure often approach even those of the higher vertebrates. It is therefore natural to expect that the functions ascribed to the internal ears of birds, mammals, etc., would be found in one form or another among the fishes. These functions are chiefly three—first, hearing, which is historically the earliest function to be ascribed to the internal ear; second, an influence on bodily equilibrium both when the body is at rest and when it is in motion, a view founded upon the experimental investigations of Flourens (1828); and, third, an influence on tonus or strength of contraction of the skeletal muscles, as demonstrated first by Ewald (1892).

The ear of the squeteague (*Cynoscion regalis*) is a well-developed organ and shows in a striking way all the essential parts of the ears in fishes. The male squeteague, moreover, is well known to produce sounds through a special mechanism not possessed by the female (Tower, 1908). Because of these structural conditions and of the highly specialized habit of sound production in these fishes, I was led to make an investigation of their ears. The only objection to this species for such study is its lack of vitality. It can not be kept many days in confinement, even in large fish boxes in the open sea, and it is not resistant to the effects of operations. Nevertheless, the exceptionally favorable conditions at the Woods Hole Laboratory of the Bureau of Fisheries made it possible to overcome these obstacles sufficiently to carry out the proposed work.

ANATOMY OF THE EAR.

The internal ears of the squeteague are relatively large organs and are lodged in the lateral walls of the posterior part of the skull. In a dry preparation of the skull their position is indicated on the ventral side by two smooth elongated bony capsules (fig. 4, pl. CXXII), whose posterior ends lie close together near

the occipital condyle and whose anterior ends diverge as they approximate the regions of the orbits. These capsules form a part of the bony roof of the mouth and are separated from this cavity by only a thin covering of mucous membrane. In an adult fish the capsules are nearly an inch and a half (3.5 cm.) in length and their longitudinal axes diverge from each other anteriorly at an angle of a little over 40°. The internal ears lie partly in these capsules and partly in the bony wall of the skull dorsal to the capsule (fig. 2). Each ear consists of a sacculus with its appended lagena, and a utriculus and its semicircular canals.

The sacculus is an elongated, thin-walled structure which lies in the cavity of the bony capsule. It has the shape of a long flattened bean, and measures in an adult fish a little over 1¼ inches (3.5 cm.) in length by almost ½ inch (1.1 cm.) in width. The walls of the sacculus are very thin and conform closely to the shape of the inner surface of the bony capsule, to which they seem to be molded. Much of the median wall of the sacculus is occupied by a large sensory patch, the macula acustica sacculi, which receives the most considerable branch of the eighth nerve. This patch is in the form of an elongated band of moderate width extending lengthwise of the sacculus; its anterior end spreads out into a very considerable oval area; its posterior end is marked by a smaller expansion. The lateral wall of the sacculus is smooth and without special nerve terminals.

Each sacculus contains a large ear stone or otolith, the sagitta (1, 2, 3, pl. CXXII), to use the term employed by Webb (1905), which almost completely fills its cavity. In full-grown squeteagues these otoliths are conspicuous structures; they may measure 1¼ inches (3.2 cm.) in length by ⅜ inch (1 cm.) in width. Their dry weight may exceed 25 grains (1.7 gm.). They are white and hard and, excepting for a small organic residue, dissolve completely with effervescence in dilute acetic acid. They are chiefly carbonate of lime, and their specific gravity, 2.84, is between those of the minerals calcite and aragonite. Their concentric structure favors the belief that they are secretions from the sacculus. Their lateral faces are irregularly concave (fig. 1, C–F, pl. CXXII) with a dorsal blade-like edge and a ventral blunt one. Posteriorly they are roughly pointed; anteriorly they are flattened out into an almost spatula-like ending. Their median faces (fig. 1, A–B) are relatively smooth with a slightly depressed figure on them corresponding to the form of the macula acustica sacculi, against which they are well adapted for resting lightly.

At the posterior end of the sacculus is a small triangular pocket, the lagena, which contains a flattened otolith, the asteriscus, and a single sensory patch, the papilla acustica lagenæ, to which a branch of the eighth nerve is distributed.

Although the sacculus communicates freely with the lagena, it does not connect with the utriculus. A careful search in fresh and in well-preserved material for a communication between these two parts failed to reveal the least

trace of such a structure. This condition has been reported already by Retzius (1881, p. 215) for 20 of the 33 species of teleosts that he studied. Among these there were 15 that belonged to the same order as the squeteague, the Acanthopteri, and in only 1 of these 15, *Gasterosteus*, was the sacculus found to communicate with the utriculus. In this respect, then, the squeteague is like the great majority of the acanthopterous fishes thus far examined.

The utriculus is a slender sac which lies dorsal to the sacculus and is of about half the length of that structure. From near its middle a large duct, the sinus superior, extends dorsally, and from the upper end of this sinus pass off the anterior and the posterior semicircular canals. Each canal bends ventrally and after enlarging into an ampulla, connects with an end of the utriculus. Close to the region at which the ampulla of the posterior canal unites with the utriculus, the horizontal canal arises and, after a semicircular course, it enlarges to form an ampulla and then unites with the utriculus near the place where the ampulla of the anterior canal joins that organ. In the utriculus close to its anterior end is a sensory patch, the macula acustica recessus utriculi, over which a small otolith, the lapillus, is found. Each of the three ampullæ of the semicircular canals contains a sensory patch, the crista acustica, but these are unprovided with otoliths. No macula neglecta could be found. Unlike the sacculus and the lagena, which are mostly surrounded by bone, the utriculus and the semicircular canals lie for the most part in the loose tissue between the brain and the wall of the skull. The horizontal canal and the posterior vertical canal are in part surrounded by bone, but the anterior vertical canal merely rests against the bone that forms the inner surface of the skull.

It is thus clear that the ear of the squeteague is not a single sense organ, but two organs structurally distinct—what may be called the saccular organ including the sacculus with its outgrowth, the lagena, and its two sensory patches and two otoliths, and the utricular organ including the utriculus and its three semicircular canals, with four sensory patches and one otolith.

FUNCTIONS OF THE EAR.

As was stated at the outset, three chief functions have been ascribed to the vertebrate ear. The sense of hearing has long been associated with the cochlea and adjacent parts of the internal ear, and recent discoveries confirm this view. The bodily equilibrium of vertebrates was shown by Flourens (1828) to be seriously interfered with on cutting the semicircular canals, and though there has been opposition to this view, the work of Mach (1874a, 1874b), Breuer (1874), and many recent investigators has added much in support of it. Finally, Ewald (1892) has pointed out, in a most elaborate study, that the internal ear exerts an influence on the tonus of skeletal muscles—i. e., the vigor of an animal's movements is largely dependent upon the integrity of this sense organ.

Since the ear of the squeteague is really double, in that the saccular and utricular organs are anatomically separate, and since these organs are large and fairly accessible, it seemed reasonable to expect that experiments upon them might be devised which would lead to a more definite knowledge as to the localization of function in these parts.

UTRICULAR ORGAN.

After some practice on the heads of dead squeteagues it was found possible to destroy the utriculus and semicircular canals of live fishes by cutting them with a long, narrow knife blade inserted through a small incision on each side of the head, and yet to leave the sacculus and its appended parts uninjured. This operation could be performed without serious bleeding and without injury to the brain. The slight opening thus made through the skin and subcutaneous parts closed of itself, and even after the death of the fish it showed no tendency to gap open. It was expected that these operations would be followed by a loss of equilibrium, but it was soon clear that the squeteague could still keep its upright position. Since this fish, like many others, is in unstable equilibrium (Monoyer, 1866) when in its so-called resting posture, I suspected that the retention of its upright position after the loss of the utricular organ was dependent upon the eyes, and to eliminate the action of these sense organs a set of blinders was devised. These were attached to the head of the squeteague by means of a cord harness. A single loop of cord was tied snugly round the body of the fish just posterior to the pelvic fins, and from the point at which this loop crossed the dorsal line a cord was run over the median dorsal line of the head to the large premaxillary teeth, where it was made fast. To this median dorsal cord were attached two cloth flaps that could be turned down over the eyes and held there by a cord, passed from one flap to the other under the jaws. In this way the eyes could be covered without interfering with the freedom of movement of the mouth and gills, for unless these parts are entirely free the animal is extremely restive and may even lose its balance.

Five sets of four fishes each were tested for the effects of destroying the utriculus and the semicircular canals. Before operating upon the fishes each was tried to see that it responded to sound vibrations and that it swam normally with the eyes covered. In testing the reactions to sound, the fish was placed in a large wooden tank of sea water, and after it had become quiet the side of the tank was tapped once or twice with a mallet in such a way that the fish could not see the movements. At each tap the fish almost invariably made a slight spring forward. To test the relation of the eyes to equilibrium, the harness was put on the fish and the eyes covered by the blinders. The majority of fishes immediately swam away slowly, though in normal equilibrium, but a few

lost orientation and would even rest on their sides on the bottom of the aquarium. In only such fishes as responded to the tapping and swam upright after the blinders had been put on them were the utriculus and the semicircular canals destroyed. The following records from one of the five sets of fishes tested will give a fair idea of the results of these experiments:

Fish No. 1 was operated upon for the destruction of the right and left utriculi and the semicircular canals. After the operation the fish swam irregularly, often revolving on its long axis. It died about three hours after the operation. Dissection showed extensive hemorrhages within the cranium.

Fish No. 2 was subjected to the same operation as No. 1. After the operation the fish swam irregularly for about half an hour. It then reassumed normal equilibrium both in resting and in swimming. Five hours after the operation it still swam normally. The blinders were then put on it and it lost equilibrium and swam in irregular spirals, but it regained its equilibrium as soon as the blinders were removed. This test was repeated several times during the next few hours and always with the same results. During this period the fish was also placed several times in the wooden aquarium; it always responded normally to the taps of the mallet on the aquarium wall. At all times after the operation the locomotor movements of the fish were weaker than they had been before the utriculus was destroyed, a condition that made it much easier to catch the fish in a hand net after the operation than before it. The fish retained its power of orientation till about the time of its death, thirty-two hours after the operation. On dissection the utriculi and semicircular canals were found to be cut through in many places, but the sacculi and brain were intact.

Fish No. 3 was subjected to the same operation as No. 1. The fish swam irregularly and rested in unusual positions; it never regained its equilibrium. It died in about twenty hours after the operation. A post-mortem examination showed that the medulla had been partly cut.

Fish No. 4 was subjected to the same operation as No. 1. The fish at first swam irregularly, but twenty minutes after the operation it had regained its equilibrium. In its response to tapping, its method of swimming when blinded, and in its muscular weakness it resembled No. 2. It lived for about two days after the operation. On examination, its utriculi and semicircular canals were found much cut to pieces, but the sacculi and brain had not been injured.

Of the total of twenty fishes in which the utriculi and semicircular canals had been destroyed, 11 through early death or other unfavorable conditions proved to be useless for experimentation. The remaining 9 reacted much the same as No. 2 and No. 4 in the set just described. In all 9, so far as I could judge, the animals were as sensitive after the operation as before it to the noise produced by tapping on the side of the aquarium. Immediately after the operation all swam with disturbed equilibrium, but within an hour, and often in even less time,

they reassumed their equilibrium. This was persistently retained up to about the time of death, except when their eyes were temporarily covered. With the blinders on, they invariably swam irregularly. All 9 fishes after the operation were noticeably weaker in their responses than before it. Most of these fishes lived only a few days and only one lived for as long as five days after the operation.

These observations show that the utriculus and the semicircular canals of the squeteague are not essential for the responses of these animals to sounds. They show also that though these organs are concerned with equilibrium, they share this function with the eye, for it is only after both sets of sense organs have been rendered ineffective that permanent disturbances in equilibrium occur.

There is, however, no reason to assume that in this relation the utriculus and its canals stand second to the eye. They are certainly of prime importance as sense organs in which impulses originate for the reflexes of equilibrium. In this respect my results fully confirm those of Loeb (1891a, 1891b), Ewald (1891, 1907), Kreidl (1892), Lee (1892, 1893, 1894, 1898), Bethe (1894, 1899), Gaglio (1902), Quix (1903), and Fröhlich (1904b) on various fishes. They also agree with those of Tomaszewicz (1877), Kiesselbach (1882), Sewell (1884), and Steiner (1886, 1888) in that they make evident that the destruction of the utriculus and the semicircular canals is not necessarily followed by permanent disturbances in equilibrium. Had these investigators, however, taken steps to eliminate the influence of the eyes of the fishes on which they worked, it is probable that they would have found these animals incapable of retaining their equilibrium. I therefore can not agree with their conclusion, briefly put by Ayers (1892), that the ear has nothing to do with equilibrium. The utriculus and the semicircular canals of the squeteague are one or both certainly concerned with this function, and this conclusion probably holds good for other fishes, but whether the sense organs involved are the cristæ acusticæ of the semcircular canals or the macula acustica recessus utriculi with its otolith, or both, I can not say. These parts are also concerned with muscular tonus, as is seen by the weakness of the fish after their destruction, a condition already observed by Ewald (1891, p. 5; 1907, p. 191) for *Anguilla* and by Bethe (1894, p. 575) for *Perca* and *Sardinius*.

SACCULAR ORGAN.

The sacculus and lagena each contain sensory patches, i. e., on the median face of the sacculus is the very large macula acustica sacculi, and on the corresponding side of the lagena the much smaller papilla acustica lagenæ. The sacculus, as already mentioned, contains a very large otolith, the sagitta, which rests on the macula acustica sacculi, and the lagena contains a much smaller one, the asteriscus, which covers the papilla acustica lagenæ. For

experimental purposes the sacculus is scarcely accessible from the dorsal or lateral aspects of the head, but it is so near the roof of the mouth that I determined to approach it from that side. As already stated, it is separated from the mouth by only a thin layer of bone and mucous membrane. It was not difficult to hold the mouth of a squeteague open and, by means of long bone forceps, to cut through this thin wall and thus gain access to the sacculus, but this operation was attended with so much loss of blood that it was finally abandoned.

Since the lateral wall of the sacculus is essentially nonnervous, it occurred to me that I might force the sagitta off the sensory patch on which it rested and against the nonnervous lateral wall by driving a pin in an appropriate direction through the thin roof of the mouth. A little practice on the heads of dead fishes showed that this could be accomplished with comparative ease. The pins used were long steel hat pins about 8 inches (20 cm.) in length. These could be easily manipulated in the open mouth of the fish, and after they had been forced into place against the sagittæ they could be cut off short next the roof of the mouth. Apparently they offered no obstacle to the breathing and other mouth movements of the fish. Squeteagues that had thus been operated upon lived about as long as normal squeteagues do in confinement. Of 10 fishes in which it was attempted to pin off the otoliths in this manner, 7 survived for nearly a week and were used in the following experiments. The 3 others died during the experiments, and hence their records were omitted as incomplete. In all 10 cases, final dissection showed that the otoliths had been pinned against the nonnervous side of the sacculus as was intended. The tests carried out on the 7 vigorous fishes gave very uniform results.

Before the otoliths were pinned down, each squeteague was tested with the blinders for equilibrium and in the wooden aquarium for responses to sound. After pinning down the otoliths the fishes swam at first irregularly, but in ten minutes at most they regained their equilibrium, and they retained this even when the blinders were put on them. After the immediate effects of the operation of pinning down the otoliths had disappeared, the equilibrium of these fishes was indistinguishable from that of normal fishes. The vigor of their movements was likewise unimpaired by this operation. After it they were about as difficult to catch with a hand net as before it. On testing them with sound stimuli they were found to be only slightly responsive as compared with their former condition. Thus a fish that before the pinning of the sagittæ had responded to every tap of the mallet on the wooden wall of the aquarium, reacted to only 3 in 30 taps after the sagittæ were anchored laterally. This considerable reduction in reactiveness was also noticed in the other 6 fishes. When, moreover, a squeteague with the otoliths pinned down was placed in the aquarium with a normal fish and the wall of the aquarium was tapped, it was quite easy to determine from the movements of the 2 fishes which was the

normal one, for the normal fish almost invariably responded by a slight leap forward to every tap, while the other fish only very rarely reacted. The same was true when normal *Fundulus heteroclitus* were put in the aquarium and compared with squeteagues whose ear-stones had been pinned. I therefore believe that the larger otolith of the sacculus, the sagitta, is concerned with the squeteague's sensitiveness to sound, and further, for reasons already given, that it has nothing to do with equilibrium or with muscle tonus.

These conclusions are in accord with the observations of several other investigators. Thus, so far as hearing is concerned, Smith (1905) has pointed out that in all sciænid fishes which drum, as the squeteague does, the sagittæ are very large, but in *Menticirrhus*, which does not drum, these otoliths are relatively small. Hence, the size of the otolith seems to be related to the drumming habit, as might be expected if the otoliths are concerned with hearing. Further, Piper (1906a) has demonstrated that a negative variation is observable in the eighth nerve of *Esox* when that portion of the ear of *Esox* which contains the otoliths is subjected to sound vibrations. From the standpoint of equilibrium Laudenbach (1899) has already shown that the removal of the otoliths from the ears of *Siredon* and the frog has no effect on the subsequent success of these animals in keeping themselves upright, a state of affairs in agreement with my experience in pinning down the otoliths in the squeteague. These observations therefore confirm me in the belief that the sagitta of the fish's ear is in some essential way concerned with the responses of these animals to sounds, as surmised by Scott (1906), and has nothing to do with equilibrium or muscle tonus. So far as equilibrium is concerned this conclusion is rather the reverse of what would be anticipated, for in the invertebrates, at least, the otoliths have been clearly shown to be concerned with equilibrium, and this function has been definitely ascribed by Breuer (1891), Sherrington (1906), and others to these bodies in the vertebrates; but this opinion is not supported by my observations.

The sagittæ in the ears of vertebrates are certainly not merely tolerated foreign bodies, as Ayers (1892, p. 309) has maintained, but, as has just been pointed out, they are of real functional significance. How they act in the reception of sound is not known with certainty; but since in the squeteague they have a specific gravity of 2.84 and that of the whole head is about 1.8, it is quite probable that when sound vibrations influence the normal fish they induce the relatively lighter parts of the head, including the macula acustica sacculi, to vibrate against the relatively heavier otolith; in other words, the otolith is a relatively stable body against which the auditory hairs of the macula acustica sacculi may strike. In my opinion sound stimulates the auditory hairs in some such mechanical way as this.

That the sagitta and its underlying sensory patch is not the only sound-receptive mechanism in the squeteague may be inferred from the fact that after

both sagittæ are pinned down the squeteague will still respond occasionally to sound, but whether this response is through the sensory patch in the lagena or even in the utriculus, or through the skin, can not be stated. That it is from an organ far inferior to that in the sacculus is plain from its character, and hence, though there may be other parts of the body of the squeteague than the macula acustica sacculi that are sensitive to sound, this structure is certainly the chief organ in this respect.

It also seems fair to me to class the reactions of the squeteague to sound, when these reactions are mediated by the ear, under the head of hearing. While no sharp line can be drawn between touch and hearing, it seems to me that when any vertebrate can be shown to possess an ear which is stimulated by the vibrations of material particles it is fair to ascribe hearing to such an animal, and, for reasons already given, I believe this to be the case in the squeteague. I therefore reaffirm my former statement that certain fishes can hear, a statement that was based originally upon the conditions found by me in *Fundulus heteroclitus* (Parker, 1903a, 1903b) and confirmed in certain respects in other fishes by Zenneck (1903) and in the goldfish by Bigelow (1904). It does not seem to me that the very inadequate tests by Körner (1905) on some 25 fishes, with negative results so far as hearing was concerned, as well as the similar results of Lafite-Dupont (1907) can have great weight against positive results such as have already been obtained by other investigators, for it is comparatively easy in certain tests to find animals irresponsive to sounds by which they are certainly stimulated as shown by other methods (Yerkes, 1905). From the observations given in this section, I conclude that in the squeteague the sacculus with its contained sagitta is the chief organ of hearing and that these parts have nothing to do with equilibrium or muscle tonus. Although I agree with Hensen (1904) in ascribing hearing to fishes, I believe, for reasons already given, that the ears of these animals are also directly concerned with equilibrium.

SUMMARY.

1. The ear of the squeteague (*Cynoscion regalis*) is anatomically double in that it consists of (1) a utricular organ with its semicircular canals and (2) a saccular organ with its lagena. There is no utriculo-saccular canal.

2. The utriculus possesses a macula acustica recessus utriculi covered by an otolith, the lapillus, but no macula neglecta. Each of the three semicircular canals has a crista acustica without an otolith.

3. The sacculus possesses a macula acustica sacculi covered by a large otolith, the sagitta, and the lagena has a papilla acustica lagenæ covered by a small otolith, the asteriscus.

4. Squeteagues whose eyes have been covered with blinders usually swim with normal equilibrium. Squeteagues whose utriculi and semicircular canals

have been destroyed soon recover normal equilibrium. When the utriculi and semicircular canals are destroyed and the eyes are covered, the squeteagues swim with great irregularity and have all the appearances of having lost their equilibrium completely. Such fishes show marked muscular weakness, but respond to sounds as do normal individuals.

5. Squeteagues whose sagittæ have been pinned down against the non-nervous sides of their sacculi retain normal equilibrium and show no diminution of muscular strength, but they respond to sound to a slight degree only.

6. The utricular organ has to do with equilibrium and muscular tonus, and possibly, but not probably, with hearing.

7. The saccular organ has nothing to do with equilibrium or muscle tonus, but is the chief organ of hearing, a function in which the sagitta plays an essential part.

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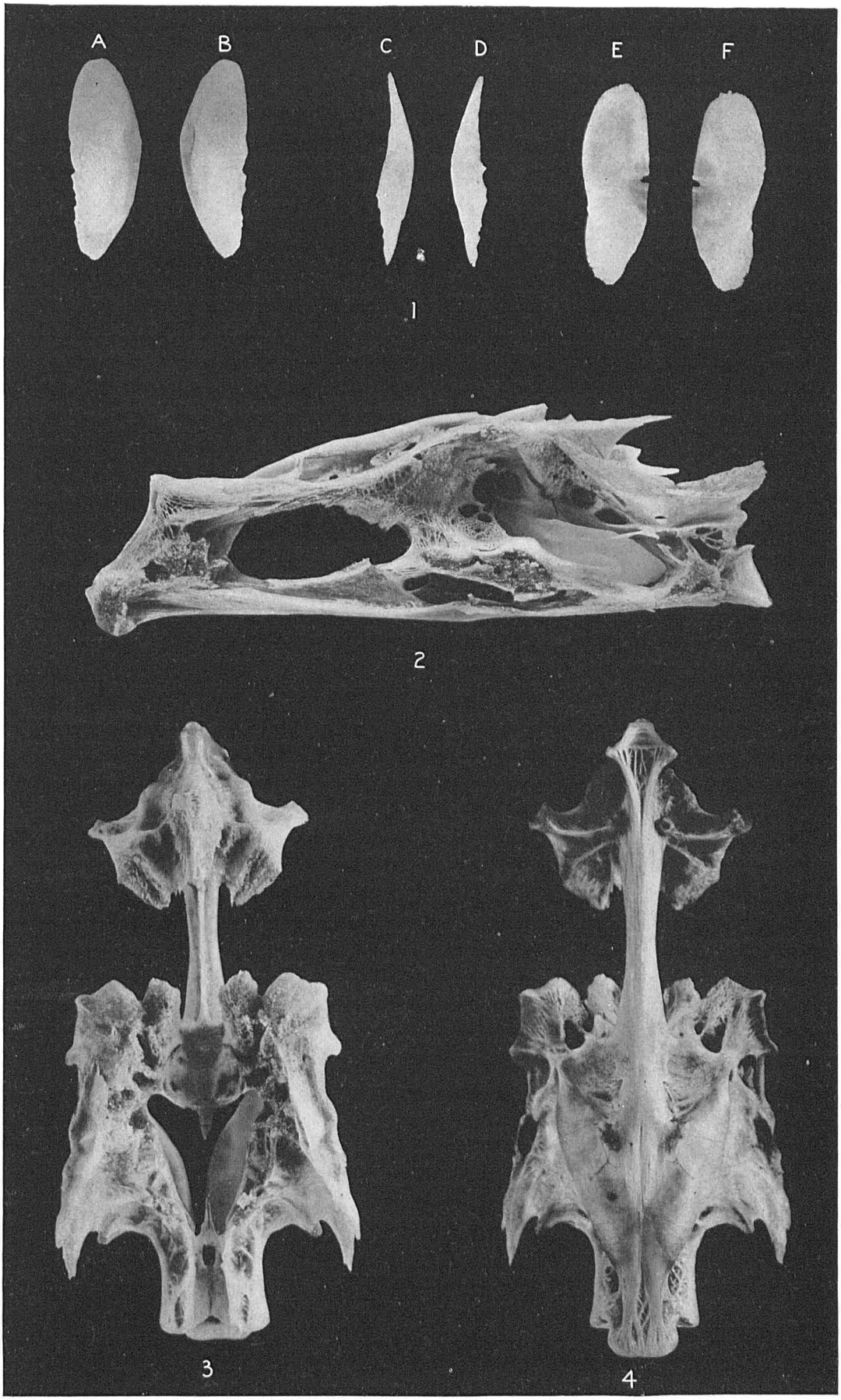
EXPLANATION OF PLATE.

FIG. 1.—Saccular otoliths (sagittæ) from the squeteague. All figures are placed with the anterior ends uppermost. *A*, *B*, median faces of a right (*A*) and of a left (*B*) otolith. *C*, *D*, dorsal edges of a left (*C*) and of a right (*D*) otolith. *E*, *F*, lateral faces of a left (*E*) and of a right (*F*) otolith.

FIG. 2.—Right half of the cranium of a squeteague viewed from the median face. The sagitta is shown in the bony capsule that partly surrounds the sacculus.

FIG. 3.—Dorsal view of the cranium of a squeteague. Much of the dorsal wall has been cut away to show the two bony capsules in which the sagittæ lie; the right sagitta is in normal position; the left one is turned out against what would be the nonnervous lateral wall of the sacculus.

FIG. 4.—Ventral view of the cranium of a squeteague, to show the bony capsules in which the sacculi are lodged.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AN INTENSIVE STUDY OF THE FAUNA AND FLORA OF A RESTRICTED AREA OF SEA BOTTOM

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AN INTENSIVE STUDY OF THE FAUNA AND FLORA OF A RESTRICTED AREA OF SEA BOTTOM.

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Director U. S. Fisheries Laboratory, Woods Hole, Mass.

The preparation of detailed lists of the animals and plants occupying regions of greater or less extent has long been the favorite occupation of a certain class of naturalists. Such lists abound in the annals of botany and zoology. And it is only thus, indeed, that we have learned how our planet is populated. The cumulative labors, first of individuals, then of scientific organizations and of governments, have given us the data from which to formulate the laws of geographical distribution. In the beginning we have the bare facts of occurrence; then correlations are established between given conditions of environment and the presence of given species or varieties; finally, we are brought within striking distance of the great central problem of the origin of species. So much for the scientific aspect of the case. On the practical side, faunistic studies need offer no apology for their existence. They have, indeed, formed a part of the established policy of our government for many years. The Department of Agriculture has long maintained a biological survey of the land animals and plants of this continent, while our Bureau of Fisheries has slowly but steadily been conducting a census of the inhabitants of our seas and lakes. Truly, these creatures are not all fit for food, nor indeed for any commercial purpose whatever—though we must add that there are probably many more animals and plants of economic value than we now realize. But the life of the sea is an interrelated whole. One species stands in relation to another as its enemy, prey, food, parasite, host, messmate, or the like, and intimate chemical relations may exist, as we find between the animal kingdom and the plant kingdom as a whole.

Moreover, as we now view the case, all these multitudinous living creatures are, so to speak, related by "blood." What we learn of one is commonly applicable to its nearer relatives and frequently to a long series of other forms.

Hence the futility of endeavoring, even on economic grounds, to restrict our investigations to food fishes or other animals of obvious commercial importance. What we discover from the study of a "minnow" is, in the great majority of cases, quite as applicable to a mackerel or a cod. But the minnow is easier to obtain and easier to manipulate. A few years ago an expert in the employ of the Bureau of Fisheries investigated the hearing of fishes. His experiments were concerned chiefly with a little fish of no seeming importance whatever. He cut its nerves and, worse yet, played musical notes at the helpless creature! Could anything seem less practical or less worthy of the attention of serious-minded persons? Recently the fishermen of certain sections of our coast have been stirred up by the alleged effects of naval target practice and of the noise produced by motor boats in driving away fishes from their customary haunts. To whom does the Bureau appeal to settle this problem? Naturally to the man who knows most about the hearing of fishes. The matter is tested, and the problem—or one phase of it, at least—is settled very briefly. The motor boats are found to be innocuous—at any rate to the fishes. Regarding the cannon, a decisive answer is likewise hoped for soon. But this is taking us a long way from the biological survey of the Woods Hole region.

Years ago Woods Hole was selected by Professor Baird as the most promising spot upon our coast for the commencement of a scientific study of fisheries problems. From the very outset he gathered about him a staff of naturalists of the type that was dominant in that generation—men eager to seek out every living thing concealed beneath the waves, to describe and figure and name. Accordingly, the first volume published by Baird as Commissioner of Fish and Fisheries contains not only a catalogue of the fishes of the east coast of North America, but an extended report upon the invertebrate animals of Vineyard Sound and adjacent waters and a list of the marine algæ found in this same region. In spite of the previous labors of Desor and Adams and Gould and Leidy and Stimpson and Perkins and the two Agassiz, who had already made essays into the waters of southern New England, Verrill and Smith found in Vineyard Sound and Buzzards Bay a practically virgin field. We begin to realize the pioneer nature of much of their work when we recall that even some of our most abundant and familiar species—e. g., the sponge *Chalina arbuscula*, the tube-worm *Hydroides dianthus*, the shrimp *Virbius zostericola*, and the beach flea *Orchestia agilis*—were first described in the Report upon the Invertebrate Animals of Vineyard Sound. And, indeed, this report, hasty and ill-digested as it was, remains to this time our chief single reference work upon the fauna of this section of our coast. That first inclusive list of local species has been much extended, it is true, partly by the original authors, partly by a more recent group of naturalists, who have prepared for the Bureau of Fisheries a series of monographic reports upon certain phyla or classes of animals.

The undertaking of which it is my privilege to speak to you was commenced in the summer of 1903.[a] The project was twofold: First to make as complete a census as possible of the marine fauna and flora of an arbitrarily limited region within the vicinity of Woods Hole, Mass. (fig. 1);[b] and secondly, to carry on systematic dredging operations throughout that portion of this region comprising Vineyard Sound and Buzzards Bay. For the former division of the work we have resorted for data to all previous published reports, to copious manuscript notes which have been furnished us by various investigators, to the wealth of information accumulated during many years past by the veteran collector of the Bureau of Fisheries, Mr. Vinal N. Edwards, as well as to original records from our own operations. The final product, a much elaborated check list, is nearly ready for press. But it is the second part of this project to which I shall invite your attention. The method of procedure here employed was to dredge at rather frequent intervals throughout the entire extent of Vineyard Sound and Buzzards Bay. Each of these dredging stations was numbered, and was definitely located upon our charts, and the total "array" of animals and plants from each point was determined. From such records it was of course possible to plot out the distribution of every animal and plant encountered, granting, of course, the thoroughness and reliability of our methods and the accuracy of our determinations of species. It will be impossible here to enter into a discussion of the methods employed or of the trustworthiness of our data. It is sufficient to state that a full report upon this entire undertaking is nearly ready for press, and that due allowance has been made for all possible sources of error. It is my present purpose merely to give a brief statement of a few of the more interesting results.

To begin with, the waters which have been explored are exclusively shallow ones, at no point exceeding 25 fathoms in depth. Accordingly, none of the characteristic deep-sea deposits and none of the abyssal types of animals have been encountered. Within the limits stated, however, we have dealt with a wide diversity of conditions. Among these are to be mentioned differences in the character of the bottom, in the temperature, salinity, depth, and purity of the water, and in the tidal currents. Foremost among the conditions determining the distribution of the bottom-dwelling organisms we have found to be the character of the bottom, considered chiefly in relation to its physical texture. It is a mere platitude to state that fixed animals require a solid basis for attachment, and burrowing ones a suitable medium for excavation. Drifting sand is of course unfavorable to the growth of many forms, and soft mud

[a] This work has been conducted for the Bureau of Fisheries by the present author in cooperation with R. C. Osburn and L. J. Cole (zoology), and B. M. Davis (botany). A large number of specialists have likewise rendered assistance in identifying specimens, revising terminology, etc.

[b] Roughly, from Newport to Monomoy, and from the mainland of Massachusetts to the 20-fathom line.

doubtless interferes with the respiratory currents of many others. Since Vineyard Sound and Buzzards Bay are rather sharply distinguished from one another by the presence or absence of mud on the one hand and of clean sand and gravel on the other (pl. CXXIV), it is natural that the most obvious distinction in distribution should be that between the predominantly sound-dwelling species and the predominantly bay-dwelling ones. The former, it must be added, greatly preponderate over the latter numerically. Within each of these large bodies of water the local distribution of many forms is very obviously determined by the occurrence of one or another variety of bottom. Thus it happens that many species whose occurrence in Vineyard Sound is general are found in Buzzards Bay only in the adlittoral zone, particularly along the Elizabeth Islands (fig. 6). Here the mud is less prevalent, and bottoms of clear sand and gravel are frequently met with.

A type of distribution which is almost the converse of the last is encountered in the case of certain mud-dwelling species which are of general occurrence throughout the bottom of Buzzards Bay, but which in Vineyard Sound are confined to a few definite areas where mud is known to be present (e. g., the annelid *Clymenella torquata* and the bivalve mollusk *Yoldia limatula*, figure 7 and 8). Furthermore, Vineyard Sound is roughly divisible into an eastern half, in which the bottom is predominantly stony and gravelly, and a western half, in which the bottom is mainly of sand. Accordingly, many species, particularly attached forms (fig. 9), are scarce or absent in the western half of the Sound, except in the littoral and sublittoral zones, while certain sand-dwelling forms, among which we may name the rays and the flounders among the fishes (fig. 10, 11), and the lady-crab (*Ovalipes ocellatus*), are especially common in that very region. The lower end of Buzzards Bay is comparatively free from deposits of mud, and accordingly we often meet with species here which are generally distributed in the sound, but which are scarce or absent from the more central parts of the bay. The scarcity or apparent total absence in Buzzards Bay of many local species of animals representing every phylum, is, we believe, due chiefly, if not entirely, to the character of the bottom.

The temperature factor, with little doubt, is a controlling one in determining the distribution of many species within the limits of our chosen region. We encounter a large number of animals, belonging to practically all the subkingdoms, and likewise certain plants, whose distribution in local waters is confined to the western end of Vineyard Sound and the mouth of Buzzards Bay (fig. 13, 14, 15, 17, 27). Here the water temperature at the bottom averages during the summer months about 10° F. (5.6° C.) lower than at Woods Hole and in the less exposed waters of the region. (Fig. 2.) The mean bottom temperature at 14 stations in the western third of Vineyard Sound and just without the latter, at a time when it was probably near its maximum, was found by us to be 60.2° F. (15.7° C.).

This temperature is exceeded at Woods Hole during that portion of the year between June 3 and October 12 (diag., pl. CXXIII). It thus appears that the summer conditions of temperature, such as obtain in the vicinity of Woods Hole during the months of June, July, August, and September, do not directly affect the western half of Vineyard Sound, and in only a limited degree the lower end of Buzzards Bay.

A few words are necessary here regarding the hydrography of this section of the New England coast. As is well known, the Gulf Stream courses in an approximately northeasterly direction, at a distance of about 100 miles south of Long Island, Marthas Vineyard, and Nantucket (fig. 1). That this great body of warm water must affect the temperature of the surface strata, at least in Vineyard Sound and Buzzards Bay, is rendered probable by the fact that large masses of the floating *Sargassum*, or "gulf weed," with their attendant animal life, are driven thither nearly every season by prolonged southerly gales. It is likewise generally believed that between the Gulf Stream and the southern coast of New England there passes another more or less well-defined current, having its origin in the far north. That the water of this colder current is diffused by the tides along its coastward margin and affects the temperature of the outlying waters of our region, especially at the bottom, can hardly be doubted.[a]

With few exceptions, those species whose occurrence locally is confined to these colder waters are known to be primarily northward-ranging types, which are here near the southern limit of their distribution, so far, at least, as such shallow waters are concerned. Many of these same species have likewise been encountered by us at Crab Ledge, off the southeastern bend of Cape Cod, and some of them likewise on the shoals to the eastward of Nantucket. Certain other forms (fig. 18, 26), though elsewhere of general distribution, are absent from just those waters to which these northern types are restricted. Such appear to be, for the most part, southward-ranging types, which find their northern limit in Cape Cod. The numerous species (fig. 5 and many of the others) which are of general distribution throughout the waters of the region, or which, at least, do not appear to be restricted as regards the temperature of their medium, are more commonly either species with an extended range in both directions up and down the coast or with a southward range only. The truly northern types are less likely to show such a general distribution in Vineyard Sound and Buzzards Bay. It is impossible to state at present how the temperature factor is effective in limiting the distribution of species locally. Our thermometric determinations seem to show that the temperature of those waters which immediately join the ocean is lower than elsewhere for probably not much more than half of the year, the difference being greatest during the summer

[a] See report by Libby in Bulletin of the U. S. Fish Commission, vol. IX, 1889 (1891) p. 391–459; also address before the Fourth International Geographical Congress, London, 1895. It must be added, however, that the existence of such a cold current off the New England coast is now questioned by some authorities.

months. It is likely that all the waters of the region approach very nearly to the freezing point of salt water for a longer or shorter period nearly every winter. It may be that the rule which has been formulated by Verrill[a] and Allen for birds, and by Merriam[b] for terrestial animals and plants in general, applies here—namely, that the limits of distribution are determined by the temperature at the breeding season only. If this be true it would follow that adult animals and plants might survive temperatures in which propagation could not occur.

It is certain, however, that an actual destruction of adult organisms may occur as the result of a too high or too low temperature. The case of the common sea urchin (*Arbacia punctulata*), which, as our records show, was almost exterminated in Vineyard Sound during the particularly cold winter of 1903–4[c] is a good illustration of this point; and it is a matter of common observation among fishermen that great numbers of dead fishes of certain species are frequently found during the thaw following a particularly hard spell of cold weather.[d] Conversely, certain members of our local fauna (e. g. the noncolonial hydroid *Tubularia couthouyi*) are known to be able to grow and maintain an active existence only at a low temperature. It is manifestly impossible, therefore, to make any single, all inclusive statement as to mode of operation of temperature in restricting the distribution of species in the Woods Hole region.

As regards the depth factor, we can find little evidence of actual bathymetric distribution in the waters under consideration. It is true that certain species, according to our dredging records, seem to be restricted to the sublittoral zone (e. g. *Crepidula convexa*, fig. 23), but these are probably also littoral in their habitat, and it is possible that proximity to shore rather than depth proper may be the determining factor in such cases.

Salinity, likewise, though undoubtedly a potent factor in determining the distribution of species in or near the mouths of streams, seems to play a negligible part in the explanation of our dredging records. The only point in the region covered where the dilution of the sea water is at all considerable is near the head of Buzzards Bay (fig. 4); but we have recorded hardly a single species which was dredged here exclusively or even predominantly.

One question which will naturally present itself to the student of geographical distribution is this: What is the position of the Woods Hole fauna in the fauna of our American coast? To which of the larger zoogeographical regions does it belong? And is it situated in the middle of that region or close to one of its

[a] American Journal of Science, March, 1866, p. 249.

[b] North American Fauna, no. 3, p. 26; Proceedings of the Biological Society of Washington, April, 1892, p. 45.

[c] The mean water temperature at the Woods Hole station for January and February, 1904, was 29.3° F., that for the same months during the other four years of the period 1902 to 1906 being 32.3°.

[d] Gould cites a case of the wholesale destruction of oysters by "ground frost" (see Boston Journal of Science, 1840, p. 492).

limits? In other words, do the majority of species have a range which extends mainly to the northward along this coast, or do the majority have, on the whole, a southward range; or is there no appreciable preponderance of one sort over the other? Simple as these questions may seem, it is difficult to give an answer that is at all satisfactory. The known range, as distinguished from the actual range, of a species, is very frequently determined by historical accident. Thus the Bay of Fundy, Massachusetts Bay, Woods Hole, New Haven, Charleston, etc., frequently figure in our literature as limits of distribution, and this for obvious reasons. Similarly, Cape Cod has taken a conspicuous place as a limit of distribution in all the accounts of our Atlantic Coast fauna and flora. In fact, it has been pretty generally assumed that Cape Cod forms a rather definite boundary between the fauna and flora inhabiting the regions above and below it. This was urged by Gould[a] as early as 1840, and has been maintained by Dana, Verrill, S. I. Smith, and others for the animal kingdom, and by Harvey and Farlow for plants. The faunal region extending to the southward of this barrier has been termed the Virginian, that to the northward the Acadian,[b] Woods Hole and the adjacent waters being assigned to the former. While it would be vain to dispute the importance of the barrier formed by Cape Cod and the outlying islands and shoals, together with the temperature conditions associated with them, it seems probable that its significance has often been exaggerated, owing to the historical prominence of this region of the coast in the annals of American zoology and botany. Some facts are herewith offered in support of this opinion.

Of the 202 species of animals which have been taken at 10 or more of our dredging stations, and which, therefore, may be regarded as representative of our local marine fauna, 100, or almost exactly 50 per cent, are reputed to have a range on our coast which is predominantly southward. By this it is meant that the extent of their known range to the southward is at least twice that of their known range to the northward. On the other hand, 48 of the species (24 per cent) have a range which is predominantly northward, while 29 of them (14 per cent) have a range of approximately equal extent (so far as known) in both directions. The remaining 25 species have been relegated to the doubtful column, owing to the unsatisfactory nature of the data at our disposal; some of these forms having been found only in the vicinity of Woods Hole. The fact to be emphasized is that the ratio of southward-ranging species (as thus defined) to northward-ranging species is approximately two to one, while about 14 per cent of them do not seem to be thus restricted in latitude.

Viewing these 202 species in another way, it is to be noted that 129, or about 63 per cent of them, are known to have a range extending north of Cape Cod,

[a] Boston Journal of Natural History, vol. III.

[b] See particularly Verrill, in Proceedings of the Boston Society of Natural History, vol. x, 1866, p. 333–357.

leaving only 37 per cent which, so far as reported, have not transcended this barrier. Doubtless more complete information will reduce the latter figure. As has already been pointed out, any locality where extensive collecting has been done is sure to figure as the reputed limit of distribution—whether northern or southern—for many species. It is significant, therefore, that only 40 of the species under consideration (20 per cent) have not yet been recorded from points south of Woods Hole.[a] Comparing this figure with the 37 per cent which are not known to occur north of Cape Cod, it may be that we have some measure of the real effectiveness of the last as a barrier to distribution.

It must be conceded at once that it is impossible to form a just estimate of the geographical range of a species from any mere statement, however correct in itself, of the extreme limits of its distribution. The bathymetric range and other factors of its habitat at various latitudes must be taken into consideration. It is obvious, likewise, that the same importance must not be attributed to the isolated and occasional occurrence of a given species as to its occurrence at points where it is widespread and abundant. But in most of the published tables which are available for consultation no distinction is made between the two.

Crude in the extreme, therefore, as any such computations must be, the conclusions seem to be fairly well grounded (1) that Cape Cod does have an appreciable influence as a barrier to distribution, and (2) that the southern types preponderate considerably over the northern ones in our Woods Hole fauna, or at least such of it as is accessible to the dredge. These generalizations may not be true of each individual group (e. g., coelenterates and amphipods); and in general it must be remembered that a considerable minority of northern forms are included in our local fauna, while more than 60 per cent of our species are known to occur north of Cape Cod. On the other hand, it is well to add that our local fish fauna, which is but sparingly represented in our dredging records, and consequently plays little part in the foregoing tabulation, is overwhelmingly southern, 75 per cent being southward-ranging in the foregoing sense of the term, while nearly 50 per cent of the total number of recorded species are such as are reputed to find in Cape Cod their northern limit of distribution. And, lastly, we must bear in mind that we are here dealing only with the *benthos* of the region, the plankton, as well as the littoral fauna, being left out of consideration.[b]

Turning now to another phase of our results, the comparative distributions of different species of the same genus are presented by us in a large number of cases (e. g., *Pecten*, *Asterias*, *Crepidula*, *Pagurus*, fig. 16, 17, 20–27). In some cases, two such species have a practically coincident distribution, as regards both

[a] More strictly, south of Vineyard Sound and Buzzards Bay.

[b] Of the total number of 1,600 (±) species of animals recorded for this region, only 500 (+) have been taken during our dredging, and of these less than half have been employed in the above computations.

extent and frequency; in other cases, one is of much greater abundance than the other, though their range of distribution is practically the same; in others still, one has a much more restricted range than the other. As instances of the last condition we may mention the two common starfishes, *Asterias forbesi* and *A. vulgaris* (fig. 20, 21), or the two chestnut shells, *Astarte castanea* and *A. undata*. In each of these examples the two related species overlap throughout a part of their range, but the range of one is more restricted than that of the other.

Whether or not the specific differentiation preceded or followed such a change of habitat is not even suggested by any of the facts which we have encountered. Who can say, for example, whether the tendency to restrict itself to muddy bottoms preceded or followed the differentiation of the amphipod crustacean *Ampelisca macrocephala* as a species distinct from *A. spinipes?* Yet this is the kind of data with which we have to deal. Nevertheless, the bare fact that various closely related species do show decidedly different distribution patterns is one of great interest, for it shows that the slight morphological differences by which the species are distinguished from one another are oftentimes correlated with marked physiological differences, sufficient to adapt the two to differing habitats. Thus the assertion so often made that the slight structural differences by which we distinguish one species from another are commonly of no conceivable utility, and therefore can never have arisen through the action of natural selection, loses much of its force. While it may be true that these slight structural differences in themselves can play no significant rôle in the life of the organisms concerned, it is likewise evident that there are certain correlative physiological changes sufficient to adapt the organisms to somewhat different modes of life. That natural selection has been the controlling factor in the origination and perpetuation of such specific differences, whether morphological or physiological, is far from certain. But that the characters concerned are in most cases too insignificant to be of selective value is also far from certain.

To the reader who would demand an exact economic equivalent for the labor and money here expended our answer must be a more general one. Science and industry move together. Industry is helpless without the aid of science, and the greatest industrial progress is at present being made by those countries which realize this fact most fully. But science can never prosper if forced to play the rôle of a servant. She must be free to pursue her own ends without being halted at every step by the challenge: *cui bono?* The attempt to restrict our scientific experts to problems of obvious economic importance would be equivalent to depriving ourselves of their services altogether. It is to-day accepted as a commonplace that all the great discoveries of practical value have rested ultimately upon principles first brought to light by the student

of nature. The enlightened manufacturer of Germany looks upon a well-paid scientific investigator as a good investment. As a result of this policy the rest of the world is looking on uneasily while its own industries pass into the hands of this far-sighted competitor. Great Britain and the Scandinavian countries, the great fishing nations of Europe, have long been leaders in the scientific investigation of the sea. And in recent years we have witnessed the formation of an international council, representing all of those nations having an immediate interest in the fisheries of the North Sea, and organized for the study of hydrographic and biological problems as well as of purely economic ones. To Americans there should be no novelty in all this. Let us keep in mind the oft-quoted words of the distinguished founder of our Fish Commission in outlining the policy adopted by him:

> As the history of the fishes themselves would not be complete without a thorough knowledge of their associaties in the sea, especially such as prey upon them or in turn constitute their food, it was considered necessary to prosecute searching inquiries on these points, especially as one supposed cause of the diminution of the fishes was the alleged decrease or displacement of the objects upon which they subsist.
>
> Furthermore, it was thought likely that peculiarities in the temperature of the water at different depths, its chemical constitution, the percentage of carbonic-acid gas and of ordinary air, its currents, etc., might all bear an important part in the general sum of influences upon the fisheries; and the inquiry, therefore, ultimately resolved itself into an investigation of the chemical and physical character of the water and of the natural history of its inhabitants, whether animal or vegetable. It was considered expedient to omit nothing, however trivial or obscure, that might tend to throw light upon the subject of inquiry, especially as without such exhaustive investigation it would be impossible to determine what were the agencies which exercised the predominant influences upon the economy of the fisheries.

So that if we can not, from our present labors, offer any suggestions of direct value to the practical fisherman, we trust that we have at least added to the intelligent understanding of the marine life of our coast. And we likewise trust that the ultimate benefit to the practical fisherman will be as great as that to the man of science.

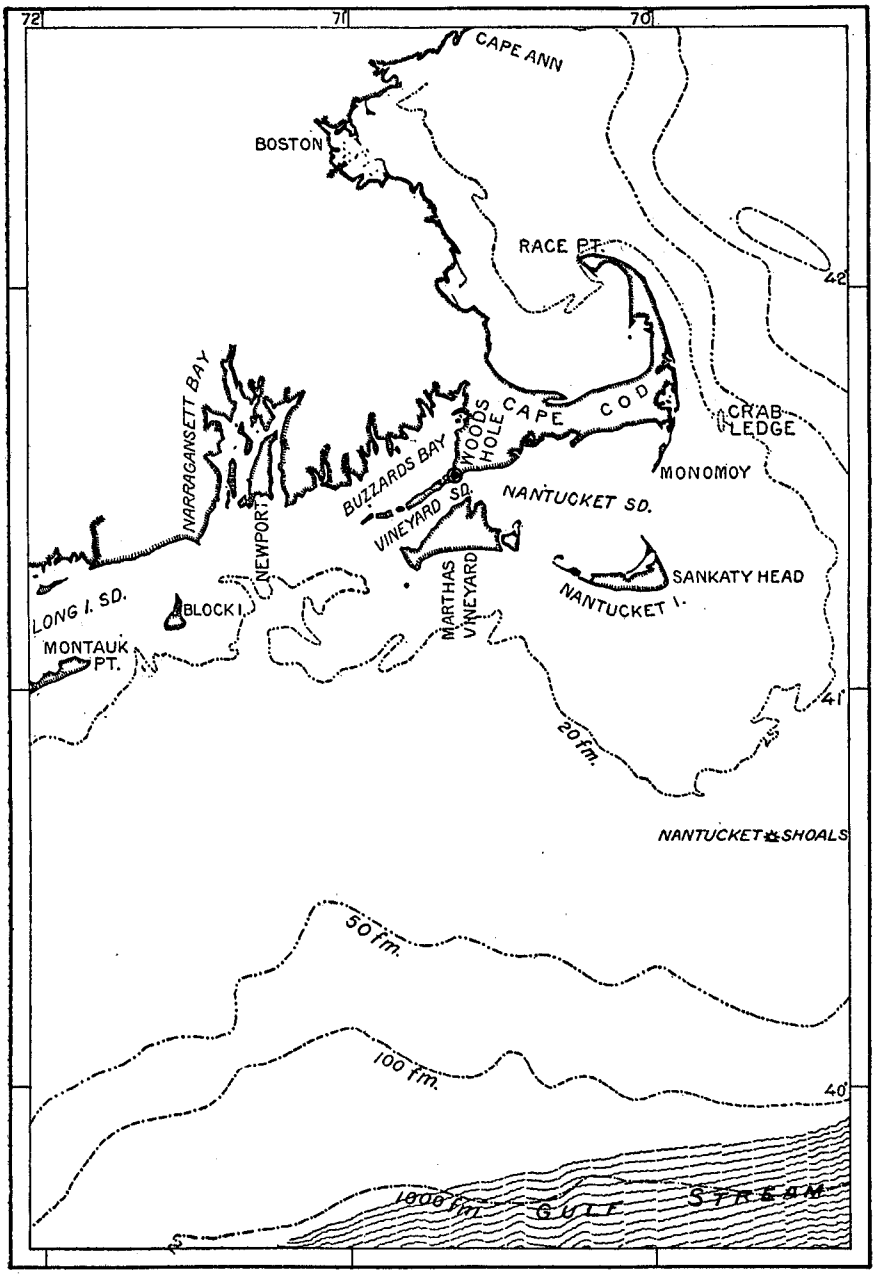

FIG. 1.—Map showing Woods Hole region and adjacent portions of the New England coast.

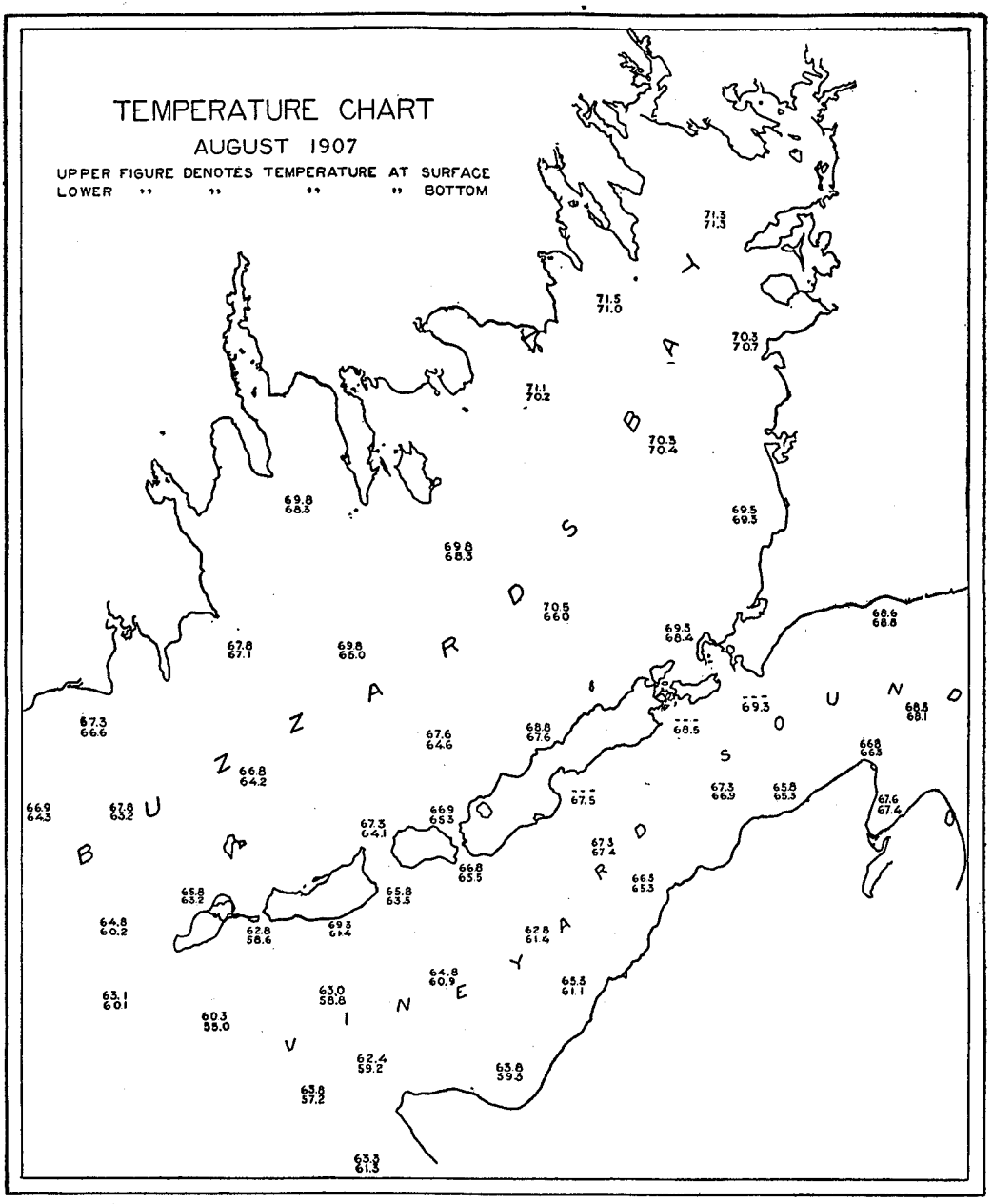

FIG. 2.—Chart showing temperature throughout Buzzards Bay and Vineyard Sound in August.

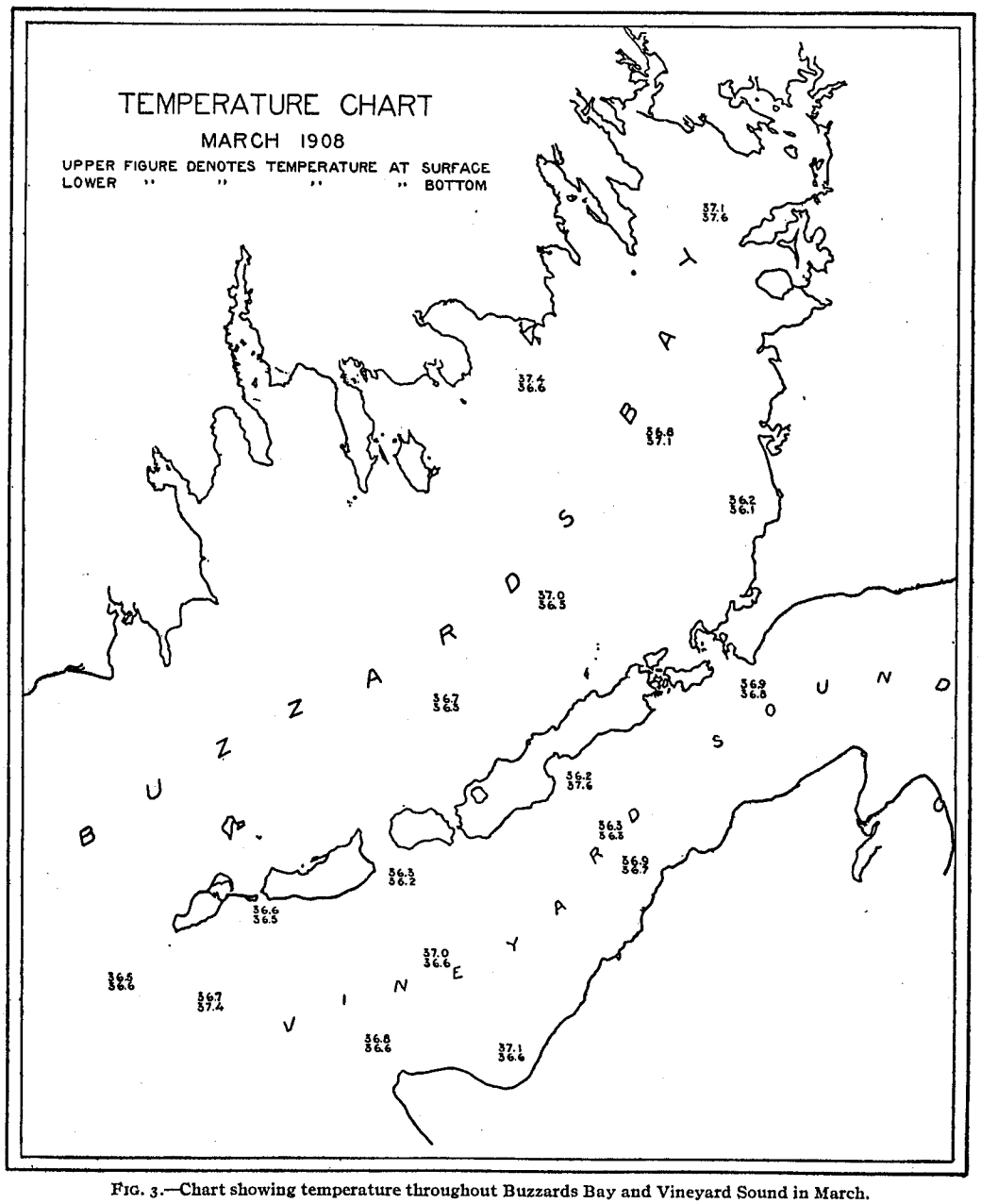

FIG. 3.—Chart showing temperature throughout Buzzards Bay and Vineyard Sound in March.

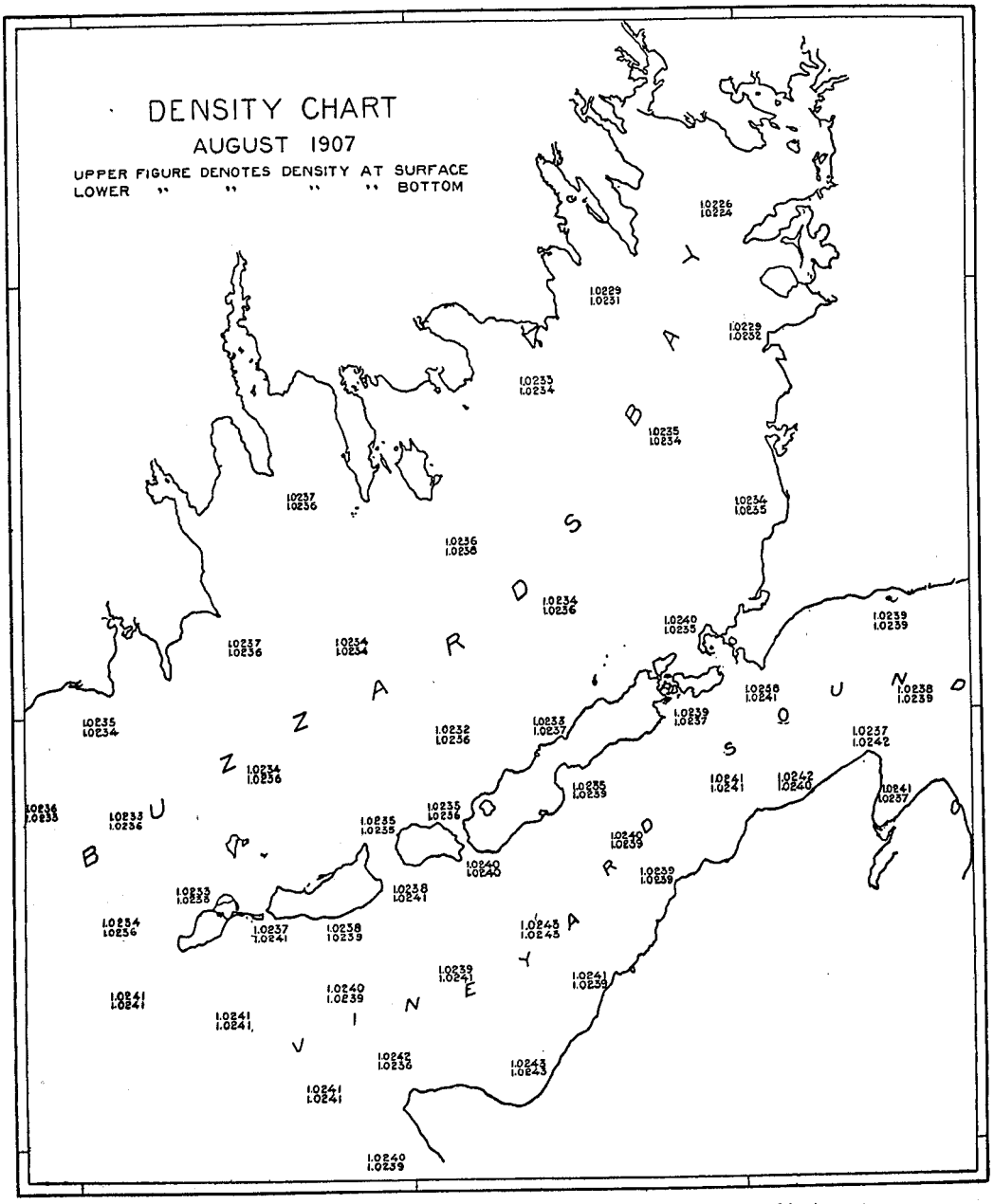

FIG. 4.—Chart showing density throughout Buzzards Bay and Vineyard Sound in August.

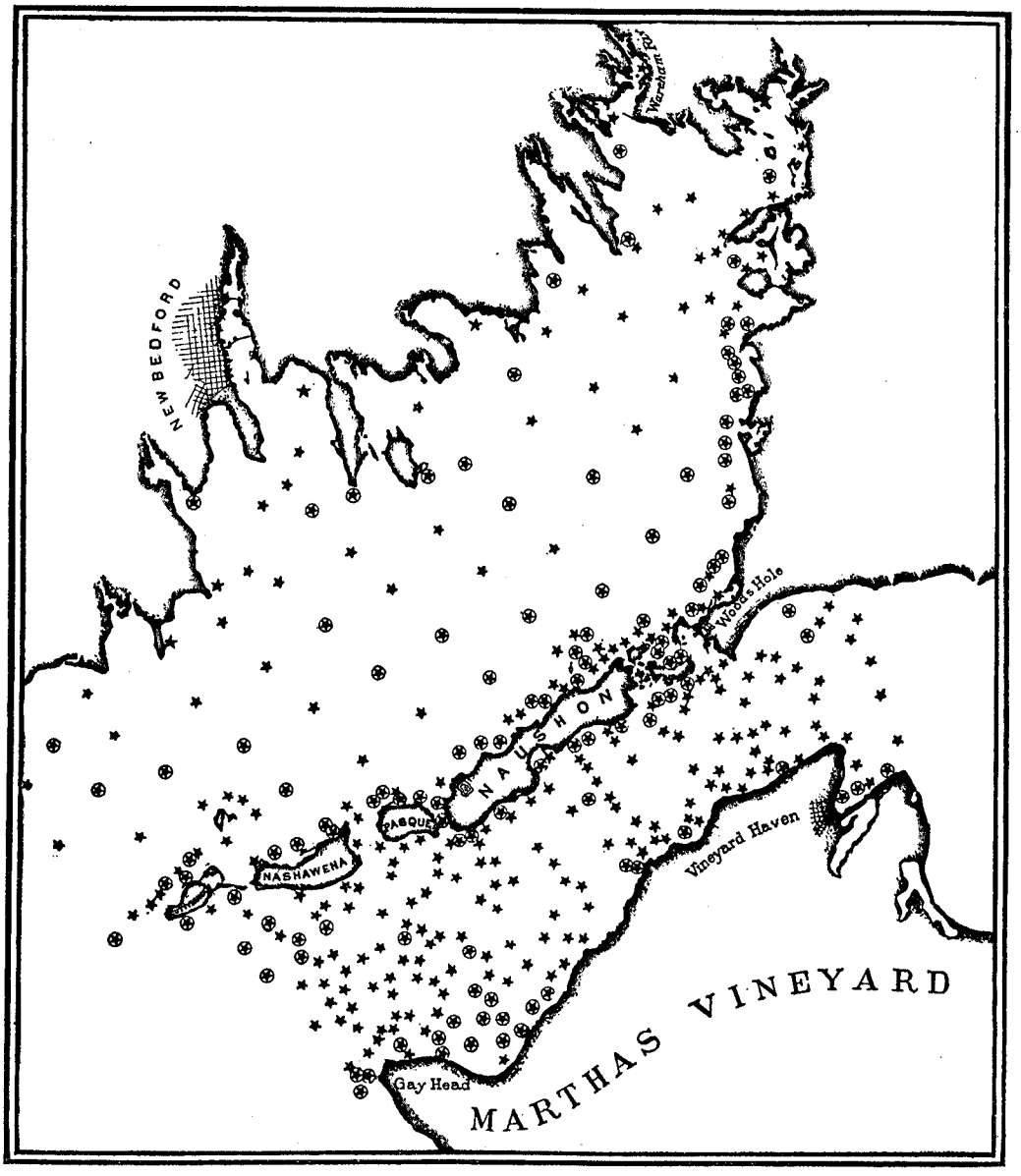

FIG. 5[a].—Local distribution of the gastropod mollusk *Tritia trivittata*. This species was recorded from 353 stations out of the total of 417 comprised within the limits of the map. It has thus the most general distribution of any species of animal dredged within these waters.

[a] The circle around the star, here and elsewhere among the mollusks, denotes the known occurrence of *living* specimens. Where the circle is wanting, either dead shells only were present or the point is not indicated in the records. This symbol has, however, been employed only in the case of shell-bearing animals.

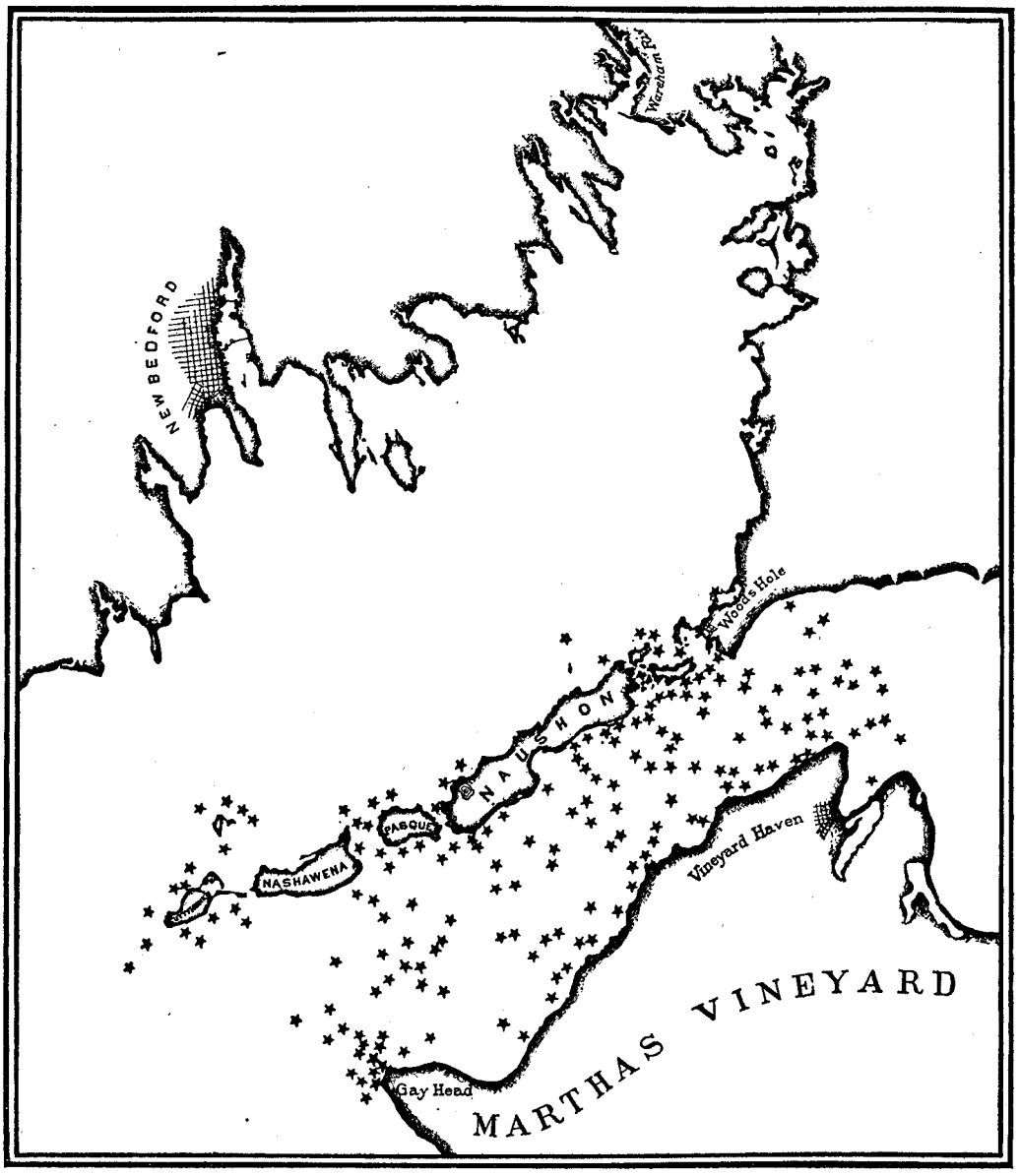

FIG. 6.—Local distribution of the polychaetous worm *Nereis pelagica*. Of general occurrence in Vineyard Sound; in Buzzards Bay mainly restricted to adlittoral zone, along the Elizabeth Islands. An example of distribution determined by the character of the bottom.

FIG. 7.—Local distribution of the polychaetous worm *Clymenella torquata*. This is likewise determined by the character of the bottom, but is almost the converse of that of *Nereis pelagica*, the present species being in a large degree restricted to a muddy habitat.

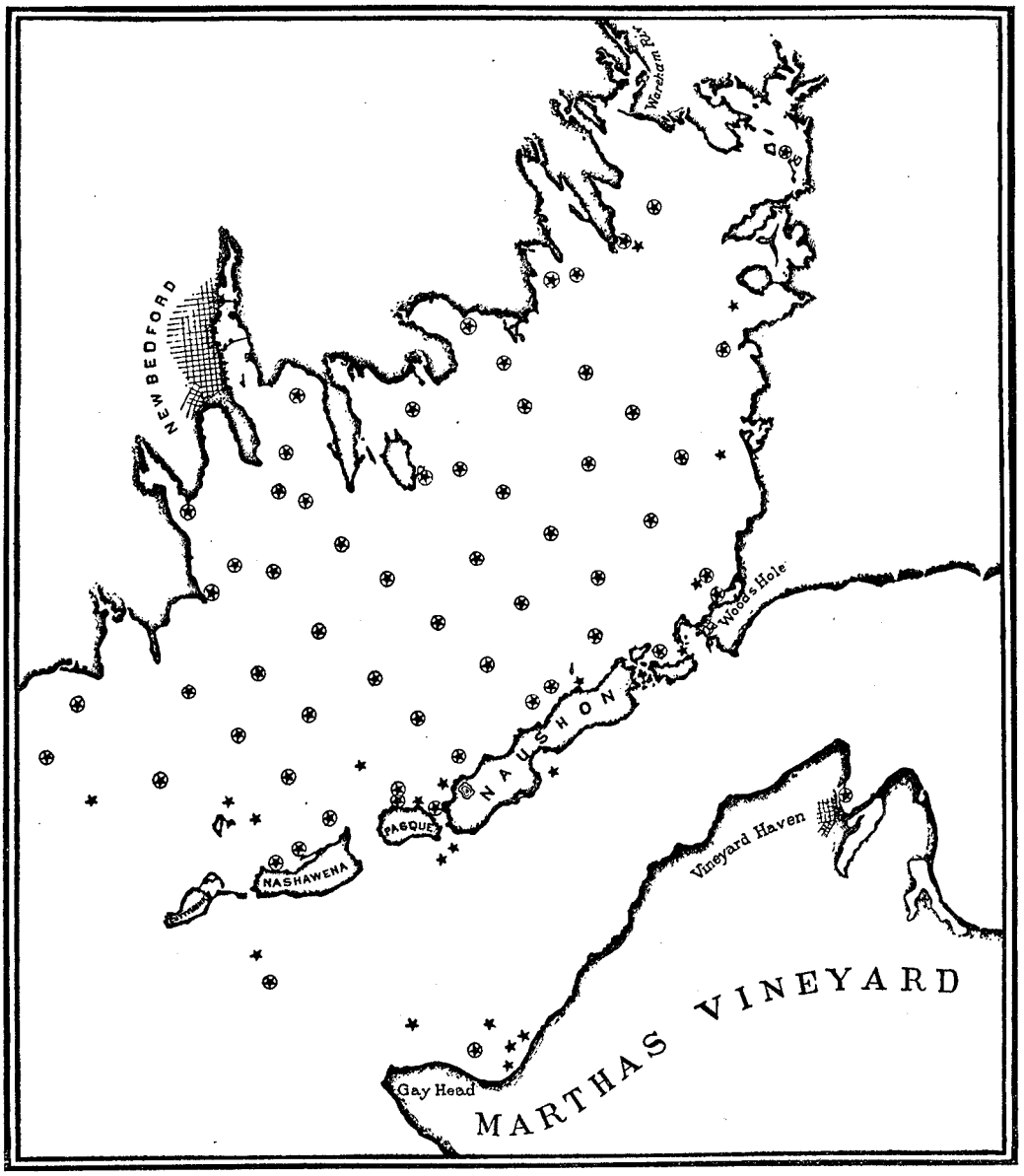

FIG. 8.—Local distribution of the bivalve mollusk *Yoldia limatula*, another mud-dwelling species, chiefly restricted to Buzzards Bay.

FIG. 9.—Local distribution of the sertularian hydroid *Thuiaria argentea*. The colonies of this species are almost invariably attached to stones and shells; hence the distribution is determined by the character of the bottom.

FIG. 10.—Local distribution of the common skate, *Raja erinacea*, a fish adapted to life upon sandy bottoms.

FIG. 11.—Local distribution of the "window-pane" flounder, *Lophopsetta maculata*. This is likewise a bottom-dwelling fish restricted to sandy places.

FIG. 12.—Showing localities at which the oyster, *Ostrea virginica*, or its shells, were taken. This is a good example of a spurious distribution pattern, since the shells in the main channel of Vineyard Sound were doubtless thrown overboard from passing vessels.

FIG. 13.—Local distribution of the bivalve mollusk *Venericardia borealis*. Here it is almost wholly restricted to the colder waters at the outer ends of Vineyard Sound and Buzzards Bay. Its range along our coast extends from the Arctic Ocean to off Cape Hatteras.

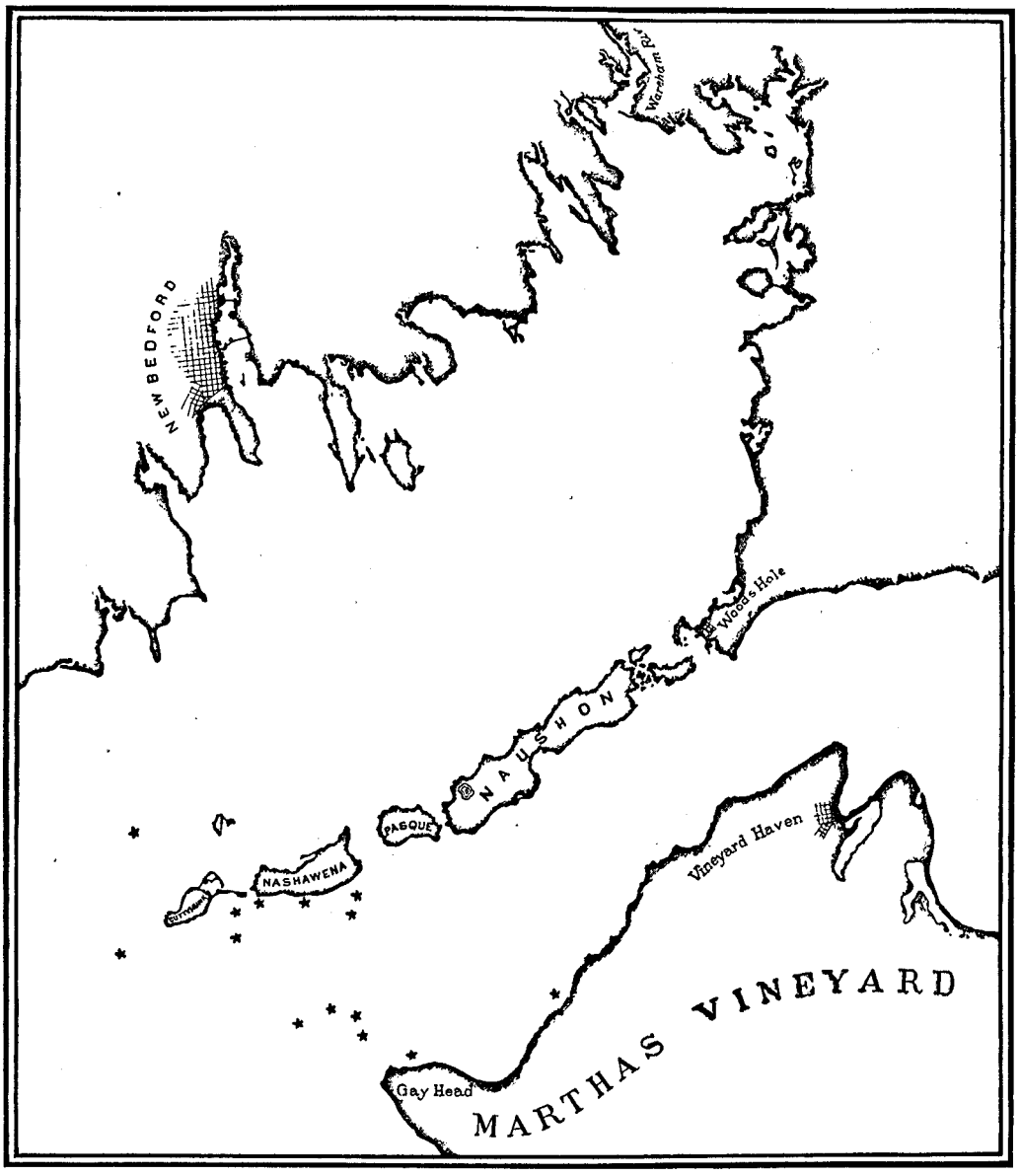

FIG. 14.—Local distribution of the actinian *Alcyonium carneum*, likewise a northern species, ranging from the Gulf of St. Lawrence to Rhode Island.

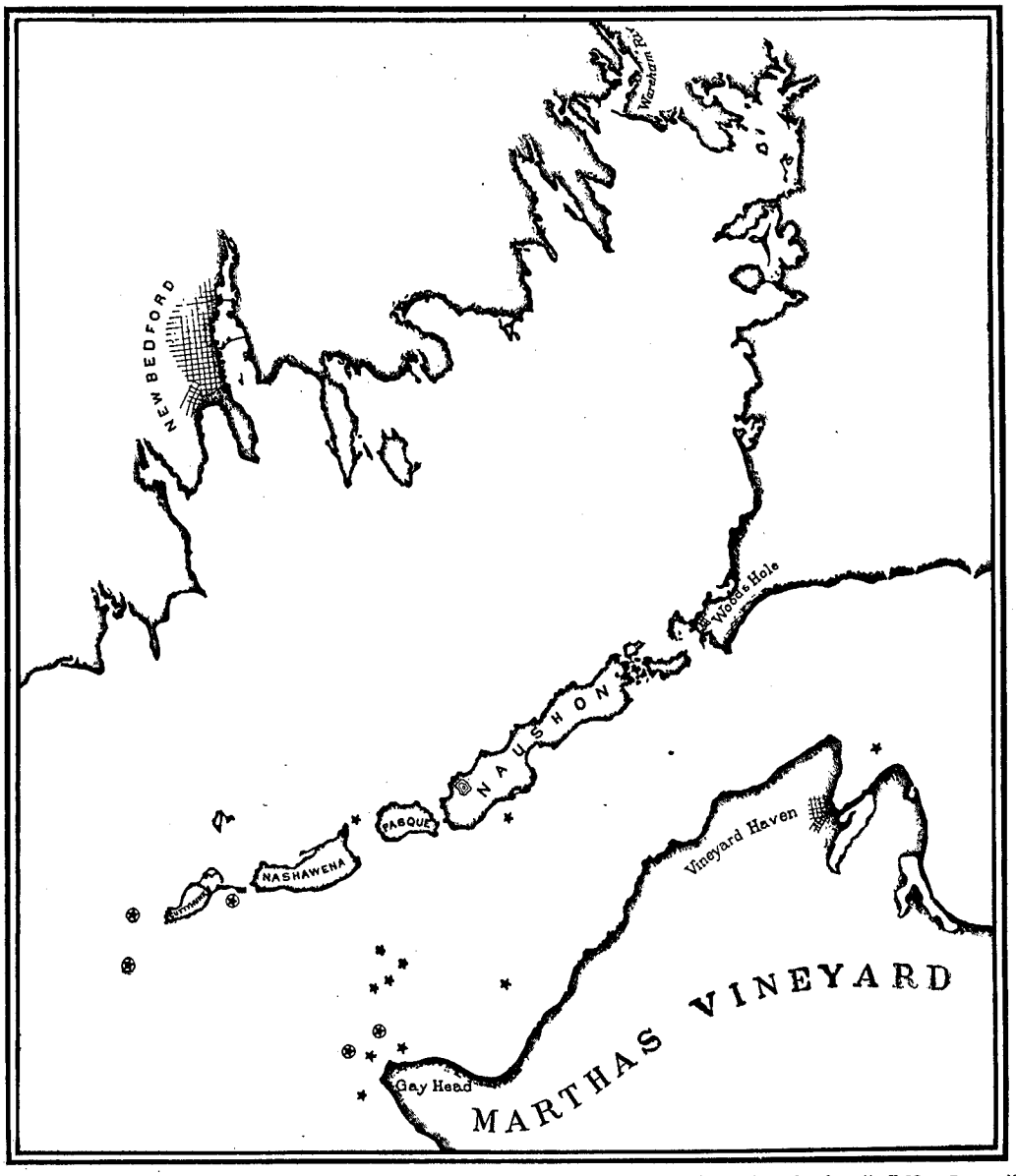

FIG. 15.—Local distribution of the "whelk" *Buccinum undatum*, whose range is from Greenland to "off New Jersey," and perhaps farther south.

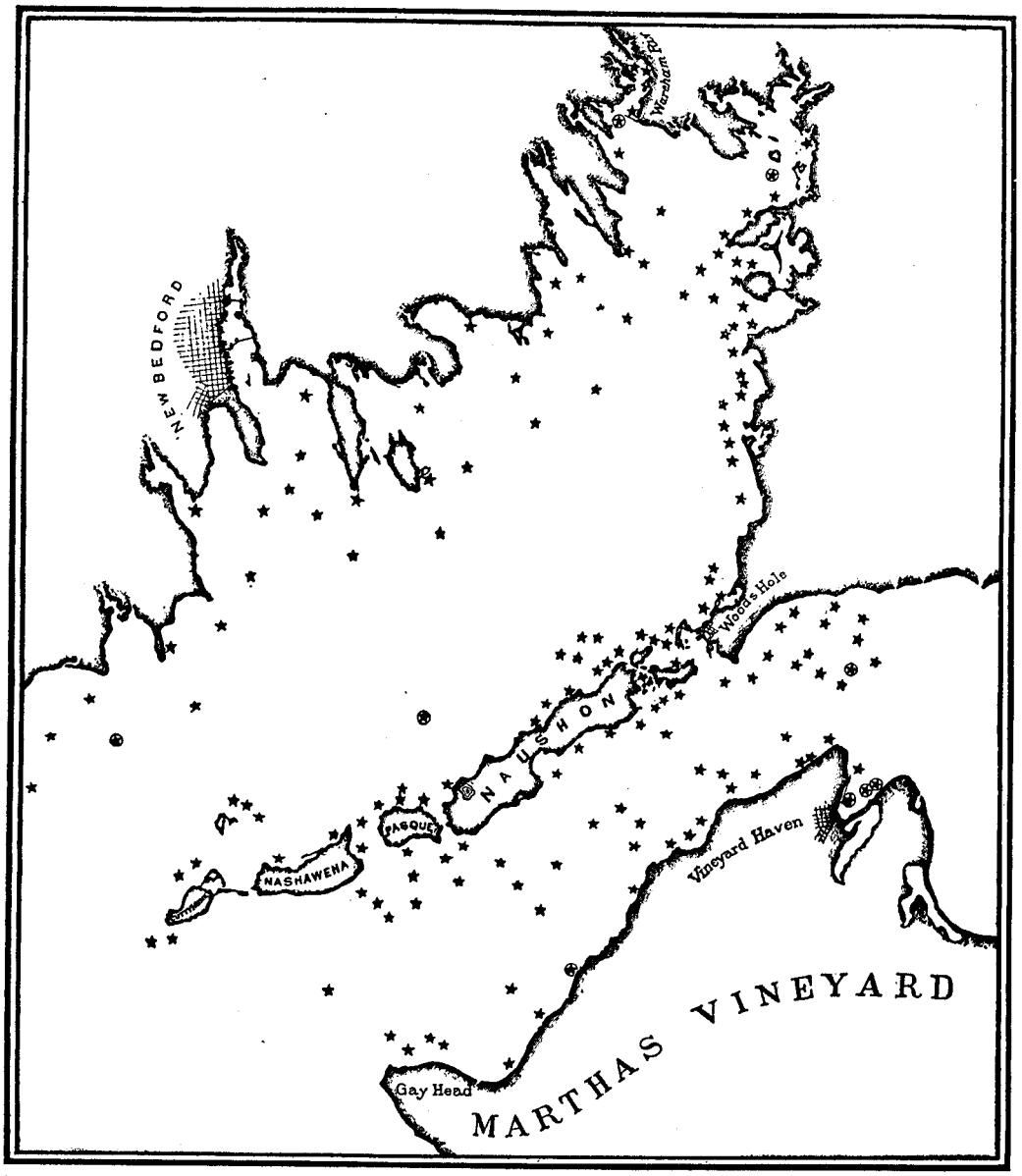

FIG. 16.—Local distribution of the common scallop, *Pecten gibbus borealis*, whose range extends from Nova Scotia to Florida.

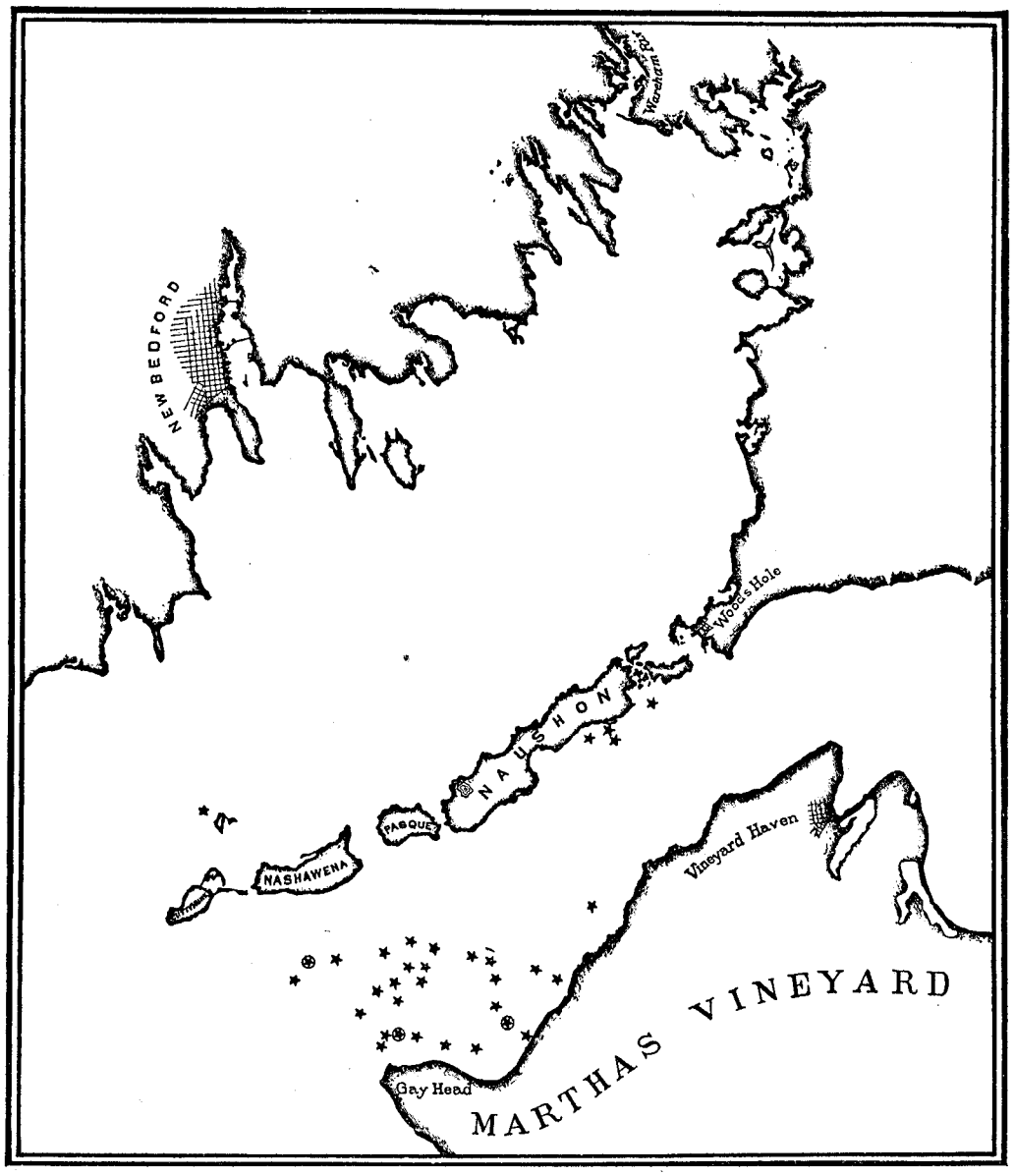

FIG. 17.—Local distribution of the "smooth" or northern scallop, *Pecten magellanicus*, which ranges, on our coast, from Labrador to (off) Cape Hatteras, but which is said to be "rare and local south of Cape Cod." A comparison with the preceding species is significant.

FIG. 18.—Local distribution of the common purple sea-urchin, *Arbacia punctulata*, which ranges from Nantucket Shoals to Yucatan.

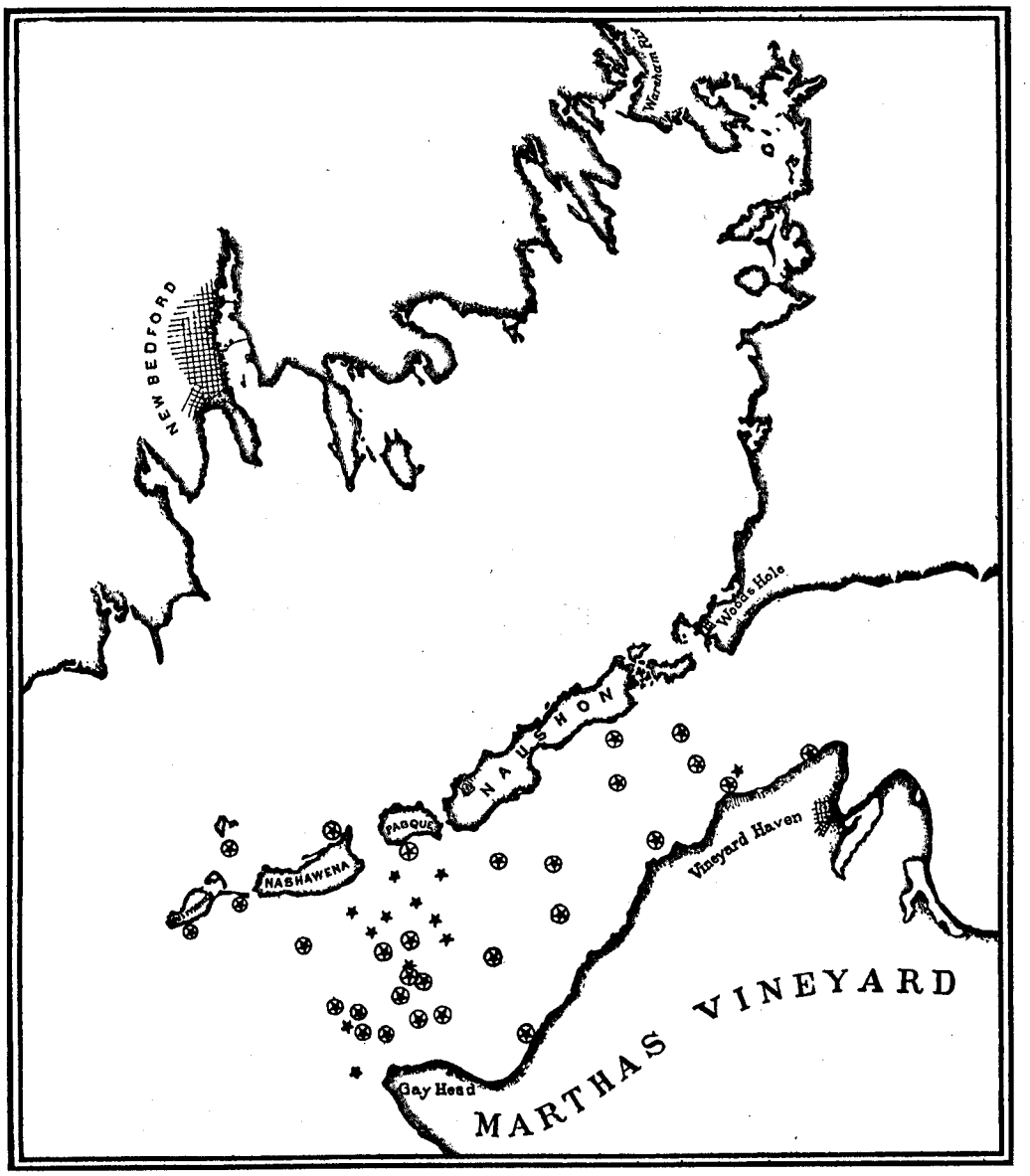

FIG. 19.—Local distribution of the green sea-urchin, *Strongylocentrotus dröbachiensis*, whose range is said to be "circumpolar; southward to New Jersey (not in shallow water south of Cape Cod)." Compare this with the preceding species.

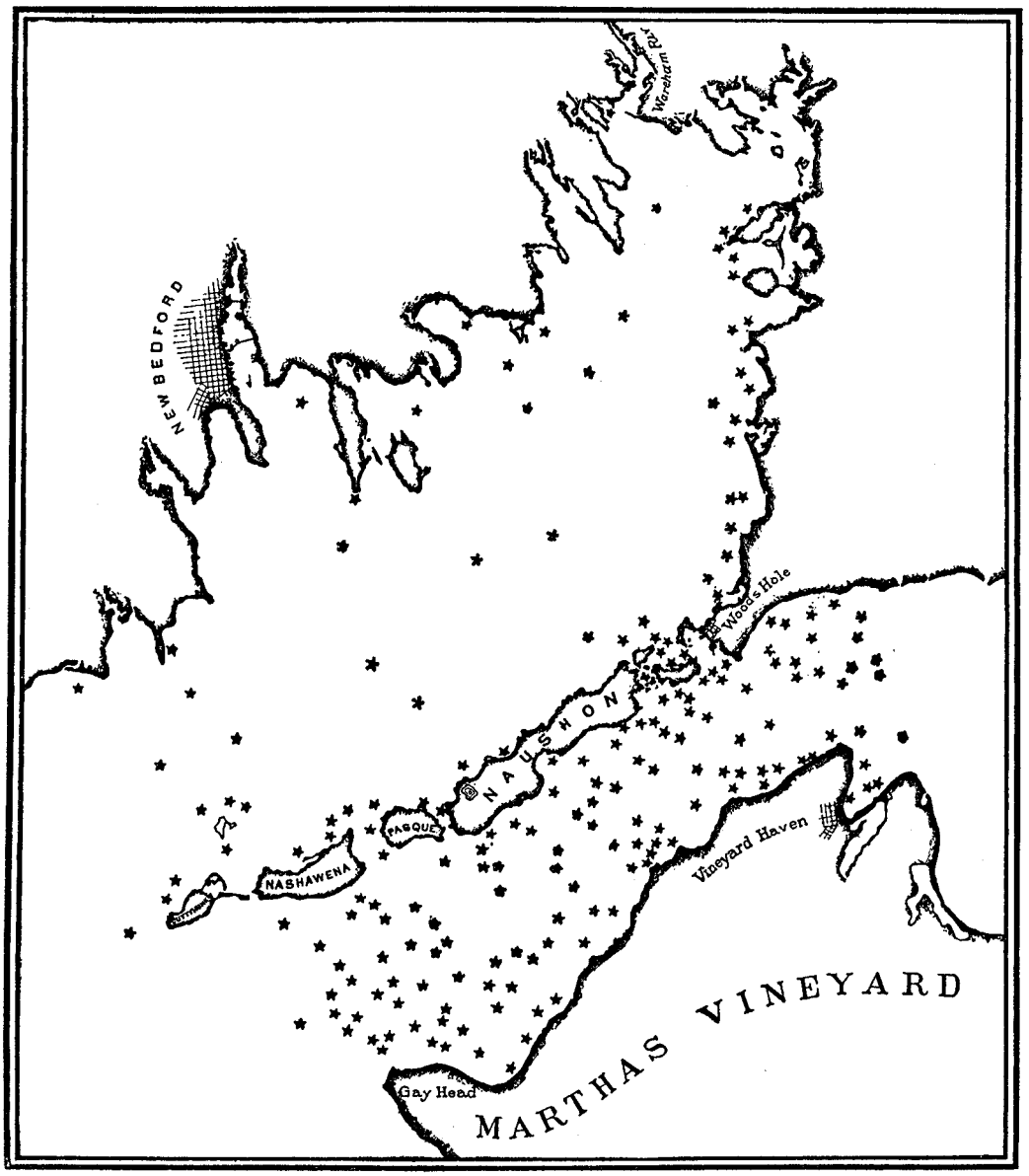

FIG. 20.—Local distribution of the common starfish, *Asterias forbesi*, whose range on our coast is from Maine to the Gulf of Mexico. Distribution in local waters very general as compared with *A. vulgaris*.

FIG. 21.—Local distribution of the purple starfish, *Asterias vulgaris*, whose range, on our coast, extends from Labrador to Cape Hatteras, it being rarely found in shallow water, however, south of Cape Cod. A concentration in the colder waters is here evident, though the distribution in Vineyard Sound is fairly general.

FIG. 22.—Local distribution of the "boat shell," *Crepidula fornicata*. This species is most commonly found upon the shells of the larger hermit crabs, though frequently taken elsewhere. It ranges on our coast from the Gulf of St. Lawrence to the Gulf of Mexico.

FIG. 23.—Local distribution of *Crepidula convexa*, a smaller species than the preceding. The present species is most frequently taken upon the shells of the small hermit crab, *Pagurus longicarpus*. It is interesting to note, however, that the distribution of the mollusk appears to be almost wholly restricted to the adlittoral zone, while that of the crab is much more general (see fig. 26).

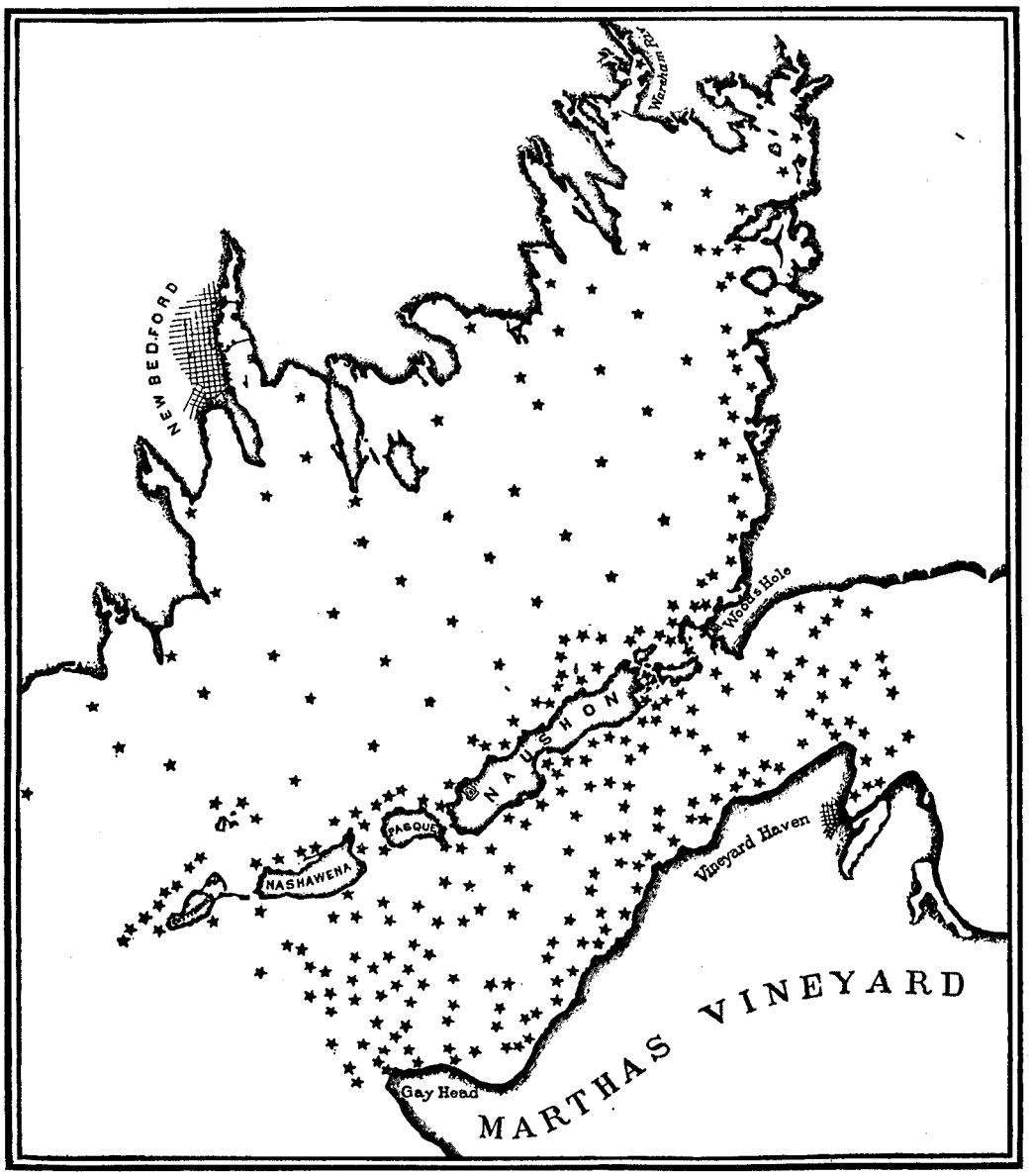

FIG. 24.—Local distribution of the hermit crab *Pagurus longicarpus*, whose range extends from Maine to Texas.

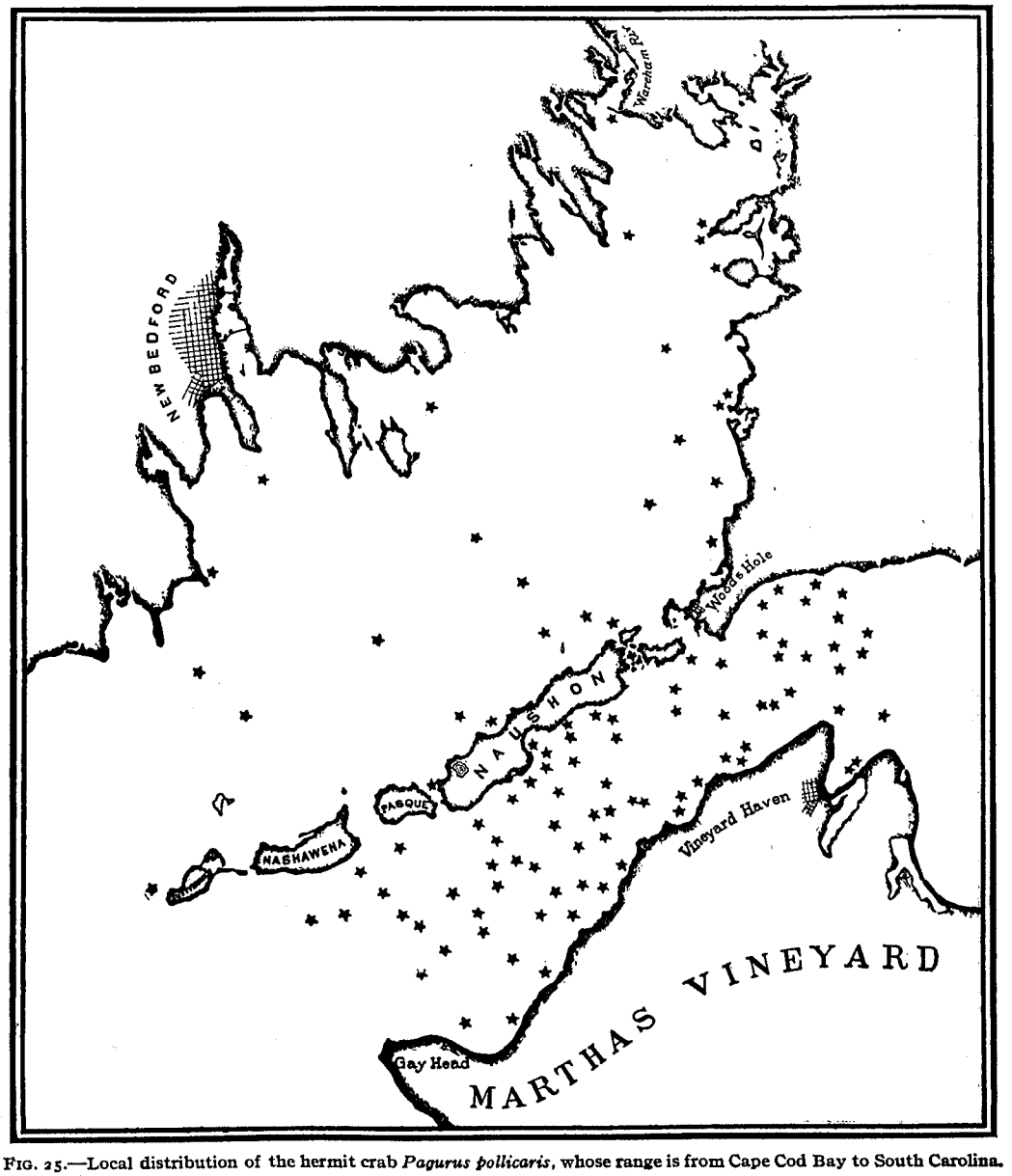

FIG. 25.—Local distribution of the hermit crab *Pagurus pollicaris*, whose range is from Cape Cod Bay to South Carolina.

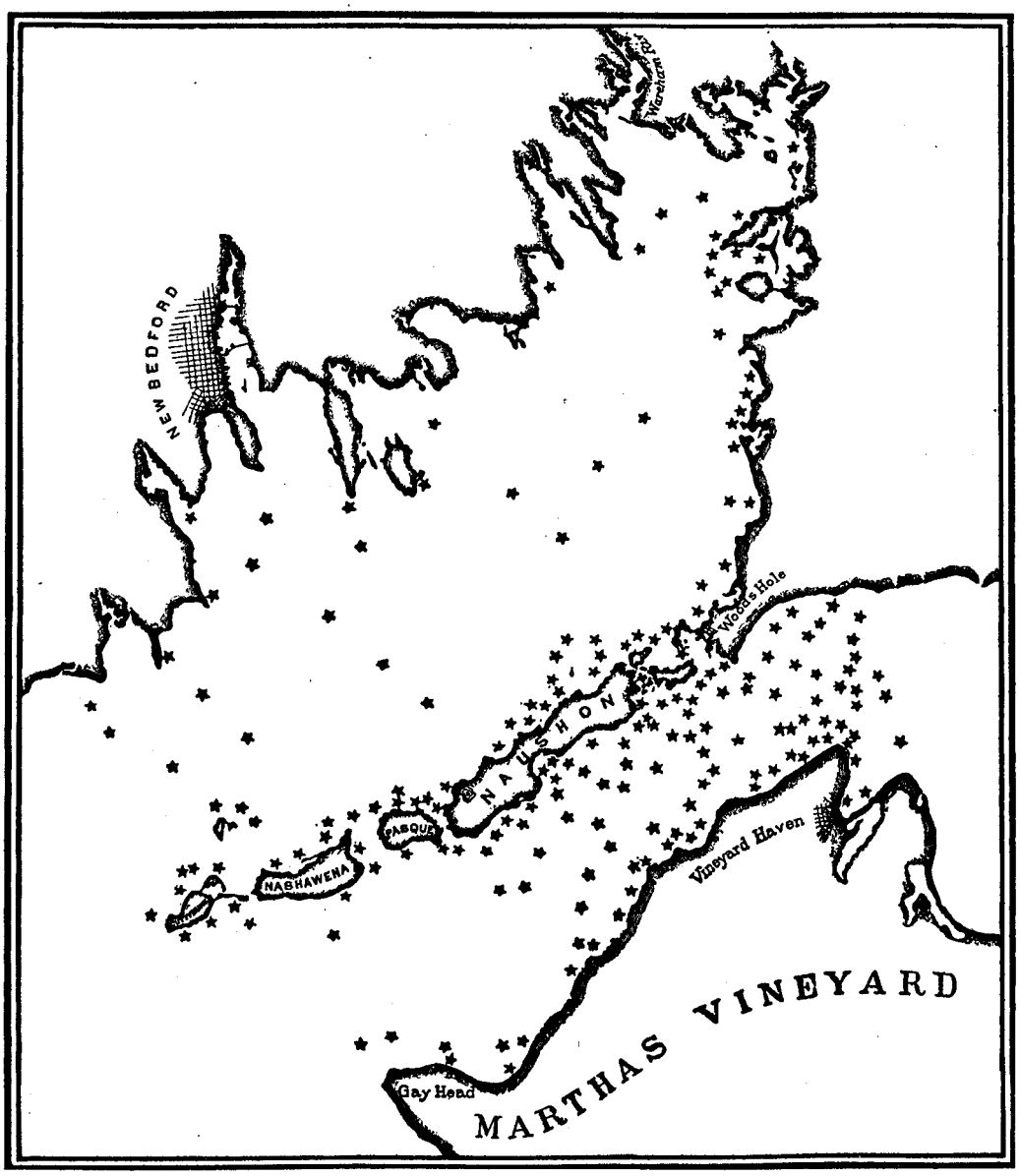

FIG. 26.—Local distribution of the hermit crab *Pagurus annulipes*, whose range is from Nantucket Sound to Florida. Note the absence of this species from the colder waters at the western end of Vineyard Sound, i. e., the very waters to which *P. acadianus* is restricted.

FIG. 27.—Local distribution of the hermit crab *Pagurus acadianus*, whose range is "from the Grand Bank of Newfoundland to the mouth of Chesapeake Bay."

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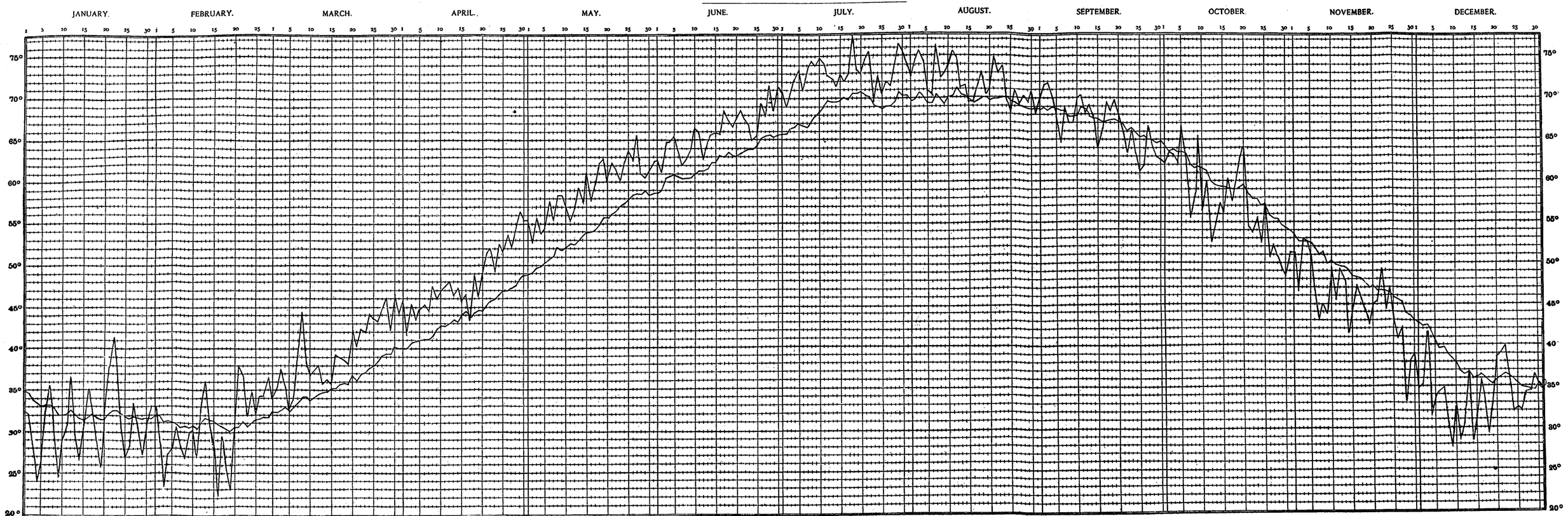
DIAGRAM SHOWING MEAN AIR AND WATER TEMPERATURE AT WOODS HOLE, MASS., FOR EACH DAY OF THE YEAR, 1902-1906, INCLUSIVE.

The less regular line represents Air Temperature, the more regular one, Water Temperature.



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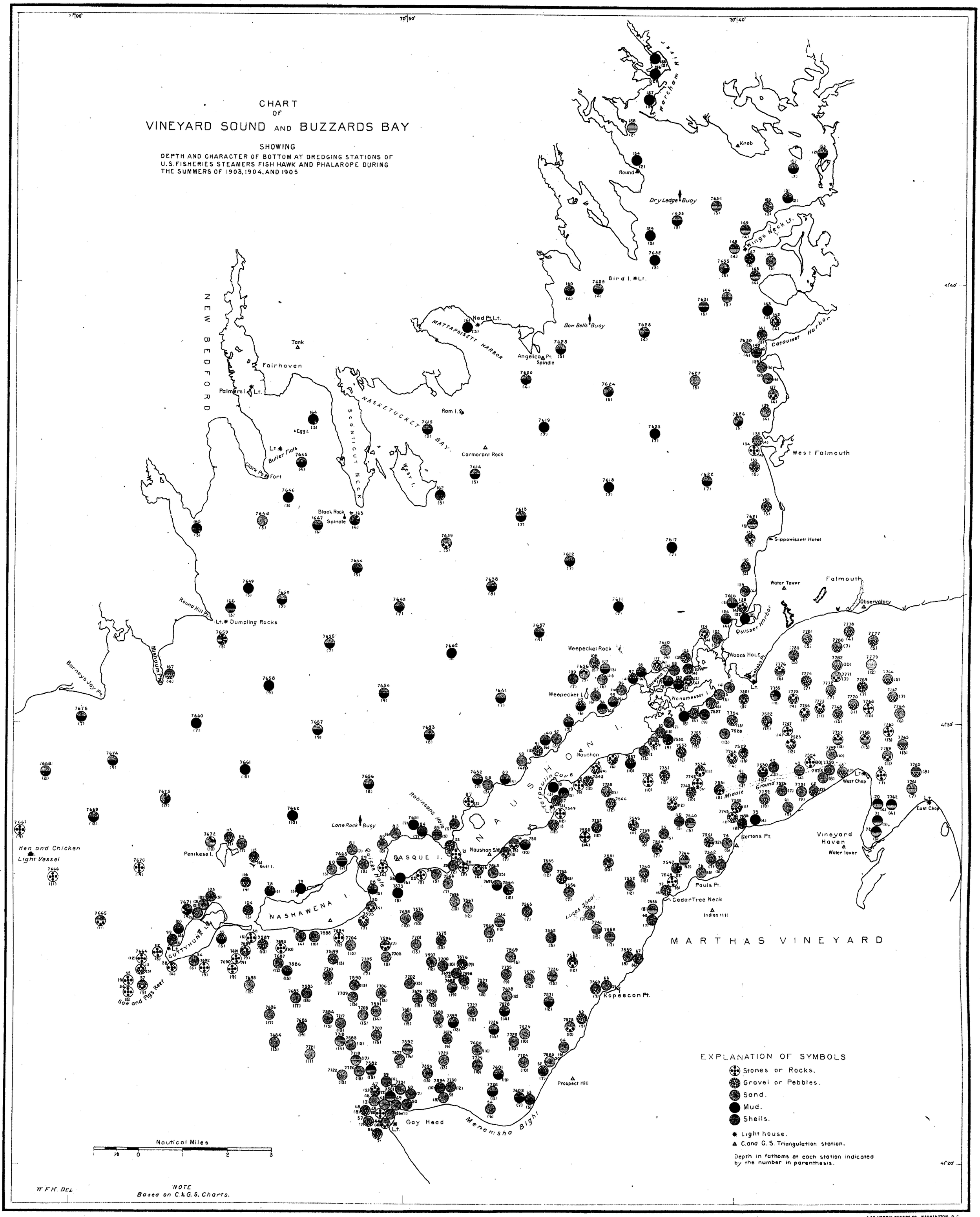

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DEVELOPMENT OF SPONGES FROM TISSUE CELLS OUTSIDE THE BODY OF THE PARENT

By H. V. Wilson

Professor of Zoology, University of North Carolina

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

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DEVELOPMENT OF SPONGES FROM TISSUE CELLS OUTSIDE THE BODY OF THE PARENT.

By H. V. WILSON,
Professor of Zoology, University of North Carolina.

About five years ago I suggested to the Bureau of Fisheries that an investigation to cover the various ways in which sponges reproduce might yield some results of value for scientific sponge culture. I had in mind the high degree of reproductive (technically, regenerative) power possessed by at least certain body cells, as distinguished from germ cells, in sponges.

This great regenerative power of somatic cells in sponges is displayed, as has long been known, in the formation of asexual masses which under proper conditions develop into new sponges. The regenerative masses of this kind that are best known are the gemmules of fresh-water sponges, but similar gemmules have been discovered by Topsent and others in marine sponges. Observations of my own, dating as far back as 1889,[a] indicated that in some marine sponges such asexual masses not only possess the power to transform into sponges, but in so doing pass through a swimming stage not distinguishable from the ciliated larva which typically develops from an egg. In a case of this kind, as I have pointed out (op. cit., 1891), the nature of the body cell as measured by its potentialities is fundamentally like that of a germ cell—it has full regenerative power, including the ability to recapitulate in some measure the ancestral history of the protoplasm. Considerations of this kind led me to doubt whether in all metazoa the protoplasm really did divide sharply into somatic and germinal cells. Rather was the idea encouraged that in the lower metazoa, such as sponges, the cellular elements all retained just so much of the nature of the germ cell (just so much of the specific idioplasm, one might say) as would enable them, under the influence of an appropriate stimulus, to develop either into ova or sperms, or into asexual reproductive masses. Assuming that sponge protoplasm had this eminently plastic character, I conceived that one might discover ways in which to call into unusual activity the reproductive or regenerative power, and so, as it were, to invent new methods of growing sponges.

[a] Wilson, H. V.: Notes on the development of some sponges, Journal of Morphology, 1891; Observations on the gemmule and egg development of marine sponges, ibid., 1894.

The results, at this time, of the investigation that I have been conducting for the Bureau during the past five summers at the Beaufort laboratory justify, it seems to me, the point of view above outlined. Two new methods by which sponges may be grown have been discovered, and both of these methods attest the remarkable regenerative power of the body cells of sponges. That both methods are applicable to the commercial sponge there can hardly be a doubt. Whether at the present time any economic advantage would accrue from the practice of either is perhaps doubtful, in view of the fact that sponges may so successfully be grown from cuttings—a method first practiced by Oscar Schmidt, and further developed in this country by Richard Rathbun, while in recent years H. F. Moore has brought it through a long series of admirable experiments to a high degree of efficiency.

But while the methods which I shall presently describe may not now be of practical utility, they add something to our knowledge of the underlying scientific principles of sponge culture. And it is a truism that such principles are the funds, so to speak, on which the practice of succeeding generations draws in the conduct of economic enterprises. I am convinced that our knowledge of these scientific principles of sponge culture may be vastly increased. Future researches will surely clear up, among other points, the relation between the formation of sexual products (ova and sperms), of asexual masses which transform directly without passing through the swimming stage (ciliated larva), and of asexual masses which imitate the egg development in passing through the stage of the ciliated larva. I may add that such a relation is "cleared up" to the eye of science (in contradistinction to metaphysics) only after the discovery of the actual treatment to which, when the sponge tissue is subjected, it responds by the development of this or that reproductive body. In this instance, as in many such biological problems, the most intimate knowledge of the structure and movements of the cells concerned in the production of each kind of body is necessary. But such knowledge of itself falls short, and remains unsatisfactory until it leads up through experiment to an actual control of the phenomena—to the power which can at will compel the sponge to produce the one or the other kind of reproductive body.

The first of the two new methods to which I have alluded has been described in Science.[a] It is briefly as follows:

If sponges are kept under appropriate conditions in aquaria, the body dies in some regions, but in localities the cells remain alive and congregate to form masses. In the production of such masses the component cells lose their individuality, fusing with one another to form a continuous mass of protoplasm studded with nuclei (a syncytium). Such masses of syncytial protoplasm are

[a] Wilson, H. V.: A new method by which sponges may be artificially reared. Science, June 7, 1907.

easily seen with the unaided eye scattered through the interior or over the surface of the remains of the original sponge. They are frequently spheroidal, but often of an irregular shape, and have the power of slow amœboid movement. In successful cases of treatment these masses, varying from a fraction of a millimeter to a few millimeters in diameter, are exceedingly abundant. The smaller ones of more regular shape at once call to mind the gemmules that are normally formed in such sponges as *Spongilla*. Experiment shows them to be physiologically like such gemmules in that they have the power to transform into perfect sponges. To bring about this transformation it was only necessary to remove the regenerative masses to the open water of the harbor at Beaufort, where they were kept in small bolting cloth bags suspended in a floating live box. The sponge especially worked on was a silicious form, a species of *Stylotella*.[a]

The second of the two methods, a description of which may be found in the Journal of Experimental Zoology,[b] is the more interesting and important. It should be said that the method succeeds best with sponges in which there is a considerable development of horny skeletal fiber. The form especially used in my work has been *Microciona prolifera* Verrill, and it has proved practically necessary to use always the large bushy specimens. The procedure is as follows:

Cut the sponge into small pieces and put them on a square of bolting cloth. Gather the cloth round the sponge fragments in the shape of a bag. Holding the upper end closed with the fingers, compress the bag repeatedly with small dissecting forceps. The bag meantime remains immersed in a little dish of sea water. The sponge cells are squeezed free of the skeleton and are strained through the pores of the bolting cloth. They fall like a fine sediment on the bottom of the dish. Collect the sediment with a small pipette and strew it over glass plates or shells immersed in sea water. The originally separate cells quickly combine with one another, exhibiting amœboid phenomena. The masses so formed go on fusing with one another through the formation of peripheral pseudopodia, and thus the whole surface of the glass slide (or other object used) may become covered with a network of plasmodial masses and cords, which adhere to it with some firmness. After perhaps half an hour the plate should be lifted from the water and cautiously drained. The sponge plasmodia are thus flattened out somewhat and their attachment to the plate is strengthened. Return the plate at once to a dish of fresh sea water, where it should be left with two or three changes of water for a day. By this time the network of plas-

[a] Otto Maas has independently discovered that the cells of calcareous sponges under the influence of reagents exhibit a behavior essentially like that above described. See my account in Science, loc. cit.

[b] Wilson, H. V.: On some phenomena of coalescence and regeneration in sponges. Journal of Experimental Zoology, vol. v, no. 2, December, 1907.

modia has probably transformed itself in whole or in great part into a thin uniform incrustation. It is best now to transfer the plate to the open water. My practice has been to tie such plates to the inside of galvanized-wire boxes, and to hang the boxes in a large live-box.

In the course of a week it will be found that the incrustation has transformed itself into a functional sponge with pores, oscula, well-developed canal system, and flagellated chambers. The steps in this gradual differentiation may be followed by examining the sponge at intervals under the microscope. The differentiation goes on, but at a slower rate, in preparations kept continuously in laboratory dishes or aquaria. While the sponge incrustation is quite thin, the currents of water and vibrations of the flagella in the flagellated chambers may be observed with a high power. For this purpose small incrustations grown on cover glasses are the best.

Until the past summer it was a question whether sponges produced in this way would continue to grow and would develop the skeleton characteristic of the species. If they would not, it was clear that the method had no value for economic sponge culture. And so, early in July, I again visited the Beaufort laboratory and with the help of my assistant, Mr. R. R. Bridgers, started some *Microciona* plasmodia on glass slides and oyster shells. It was possible for me to remain at the laboratory only two weeks, but Mr. Bridgers took charge of the sponges and continued to start other plasmodia at intervals during July and August, conducting his experiments with great care and skill.

Mishap of course overtook some of the cultures; but scores of them grew perceptibly during the summer and by the first of September a large number had developed the skeleton of the adult with the characteristic spicules and the horny columns projecting up from the basal skeletal plate. What was equally gratifying was that the sponge in many cases had not only spread and thickened and developed the species-skeleton, but had also developed quantities of reproductive bodies. These lay scattered in the deeper part of the incrustation, plainly visible to the eye. I have not yet made a sufficiently precise histological examination of these bodies to determine whether they are egg larvæ or asexual masses. The whole appearance of the sponges grown in this way, some six weeks old, is quite like that of normal *Microciona* of incrusting habit.

Looking from the utilitarian standpoint at this latter method of growing sponges, it is not at all inconceivable that it may at some time be of direct economic value. The ease with which quantities of sponge cells may be had and the opportunity afforded of attaching them to any desired object are considerations which encourage such an idea. Going farther afield from present-day practice and looking to the future, the method suggests itself as one of the possible means of altering the specific characteristics of sponges and improving races. In

a paper presented to the National Fishery Congress of 1898[a] I briefly discussed the possibility of improving sponge races, suggesting as means thereto the breeding of sponges from the egg with accompanying selection, and also the practice of grafting. Now if the cells of two closely allied races were mixed together it is on the whole probable that a composite plasmodium would result which would develop the characteristics of both races. Such a form would be something comparable to a hybrid. I have in fact carried on experiments of this character.[b] The results of my experiments were negative—the cells of each species coalesced, but there was no permanent union between the cells or cell masses of the different species. It should be said, however, that the species used were so unlike that there was at the outset but little chance of coalescence. In a more favorable locality, where a great variety of horny sponges exist, such experiments hold forth some promise.

NOTE.—In connection with the foregoing paper there was an exhibit of microphotographs illustrating some of the more important stages in the development of sponges from cells forcibly removed from the parent body.

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[a] Wilson, H. V.: On the feasibility of raising sponges from the egg. Proceedings of the National Fishery Congress, 1898, in U. S. Fish Commission Bulletin, vol. XVII, 1897.

[b] Journal of Experimental Zoology, loc. cit.

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GASES DISSOLVED IN THE WATERS OF WISCONSIN LAKES

By Edward A. Birge

Secretary Wisconsin Commission of Fisheries

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

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GASES DISSOLVED IN THE WATERS OF WISCONSIN LAKES.

By EDWARD A. BIRGE,
Secretary Wisconsin Commission of Fisheries.

In the following paper I propose to sketch briefly a small part of the work on lakes which the Wisconsin Geological and Natural History Survey has been carrying on during the past four seasons. During 1907 and 1908 our investigations have been aided by a grant of money from the United States Bureau of Fisheries, which has enabled us to extend our field work much more than would have been possible without this assistance.

LAKE DISTRICTS OF WISCONSIN.

The accompanying sketch map (fig. 1) roughly indicates the position of the lakes that have been studied. Wisconsin contains many hundreds of small lakes, most of them lying in the moraines and found in hollows occasioned by the melting of blocks of ice left during the glacial period. They occur in three pretty well-defined districts, in the southeastern, the northeastern, and the northwestern parts of the state. The water of the lakes in each district, though varying much, shows a very definite general character, especially in the matter of dissolved carbonates.

The southeastern lake district, as studied by us, extends from Waupaca on the north to Lake Geneva on the south, and from the lakes at Madison to Lake Michigan. Nearly 50 lakes in this district have been studied by our survey, and almost without exception they contain considerable quantities of dissolved carbonates, represented by 30 cubic centimeters to 50 cubic centimeters or more of carbon dioxide. Most of the work has been done upon these lakes. Very numerous observations have been made upon Lake Mendota at Madison, the headquarters of the survey, and some hundreds of series of determinations have been made on this lake at all seasons of the year. Much less frequent observations have been made on a dozen or more other lakes in the same region, giving a general picture of the annual cycle of gas changes of these lakes, though not in the same detail as for Lake Mendota.[a]

[a] The diagrams accompanying this paper have been selected from a great number which have resulted from the work of this survey, and are intended to illustrate some points in the distribution of temperature, of the various gases, and of dissolved carbonates of lime and magnesium in the waters of Wisconsin lakes. In all diagrams the vertical spaces represent the depth in meters. The horizontal spaces represent either degrees centigrade in the case of temperature, or cubic centimeters of gas per liter. The line marked "T" indicates the temperature; oxygen is marked "O"; nitrogen, "N"; carbon dioxide, "C"; and carbonates, "Cb." In the diagrams which show nitrogen, both this gas and oxygen were determined by boiling. In those without nitrogen, the oxygen was determined by titrating according to Winkler's method. The alkalinity or acidity of the water were determined by titrating

In the northeastern part of the state is a district somewhat triangular in shape, measuring roughly some 30 miles on each side, and containing several

FIG. 1.—Sketch map of Wisconsin, showing lake districts. Scale about 1 inch=66 miles, or $\frac{1}{4,000,000}$. Green Lake lies directly north of "G". The Oconomowoc district is marked "O". Lake Geneva lies close to the southern boundary. Hammills Lake in northwestern Wisconsin is marked "H".

with standard solutions of HCl or Na_2CO_3, with phenolphthalein as an indicator. The result is expressed in the diagrams in cubic centimeters of CO_2 per liter, acidity being shown as free CO_2, while alkalinity is represented by platting the number of cubic centimeters of CO_2 that would be required to bring about a neutral reaction. Where the line indicating the CO_2 passes to the left of the zero line, it indicates that the water is alkaline.

The amount of dissolved carbonates was determined by titrating with HCl, with methyl orange as an indicator. It is represented in the diagrams by the number of cubic centimeters per liter of CO_2 set

hundred small lakes. About 60 of the more important and deeper lakes in this region have been studied during the summer. The survey has found that the month of August and the early part of September represent the critical period for the distribution of gas in lakes, and that from observations made at this time the general history of a lake may be inferred when the cycle is known in detail from a number of lakes which may serve as standards. The lakes of northeastern Wisconsin contain, in general, soft water, the carbonates being much lower than in the southeastern lakes—frequently not more than one-sixth as great and not infrequently less than one-tenth.

The lakes in the northwestern district are scattered in two somewhat ill-defined elongated series extending north and south for a distance of 70 miles or more. Between 50 and 60 of these lakes also have been examined. Their water is intermediate in character between that of the two other districts, the content in carbonates averaging nearly one-half as great as that of the southeastern lakes.

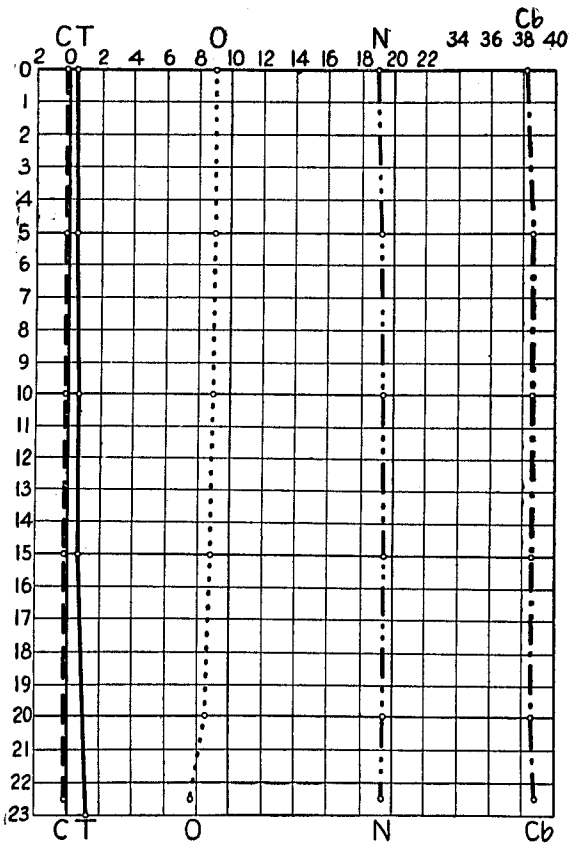

FIG. 2.—Lake Mendota. Vertical distribution of gases, carbonates, and temperature, January 26, 1906. C, carbon dioxide; Cb, carbonates of lime and magnesia; N, nitrogen; O, oxygen; T, temperature. See footnote.

GASEOUS CHANGES IN LAKE MENDOTA.

WINTER.

Let me begin my account by a short sketch of the cycle of changes in Lake Mendota. Figure 2 shows the condition under the ice in early winter. The

free from the monocarbonates. Since, in the lakes of southeastern Wisconsin, the amount of dissolved carbonates is considerable, the numeration of the horizontal scale is interrupted in order not to make the diagram too large. For instance, the numbers at the top of figure 2 change abruptly from 22 to 34. The larger numbers refer solely to the line Cb, indicating the number of cubic centimeters of CO_2 represented in the monocarbonates. A similar arrangement will be seen in other diagrams.

The points at which observations were taken are indicated by small circles in the lines of the diagrams. The lines are drawn directly from one point of observation to the next, no attempt being made to round off the curves.

temperature is nearly the same at all depths, rising from less than one degree just below the ice to something over one degree at the bottom. The water contains about 9 cubic centimeters of oxygen per liter, except in the bottom, where it has begun to disappear under the action of decomposition. Nitrogen is present to about the amount required to saturate water at the given temperature. The reaction of the water is neutral or slightly alkaline at all depths. Carbonates are present to an amount represented by about 38 cubic centimeters of carbon dioxide per liter.

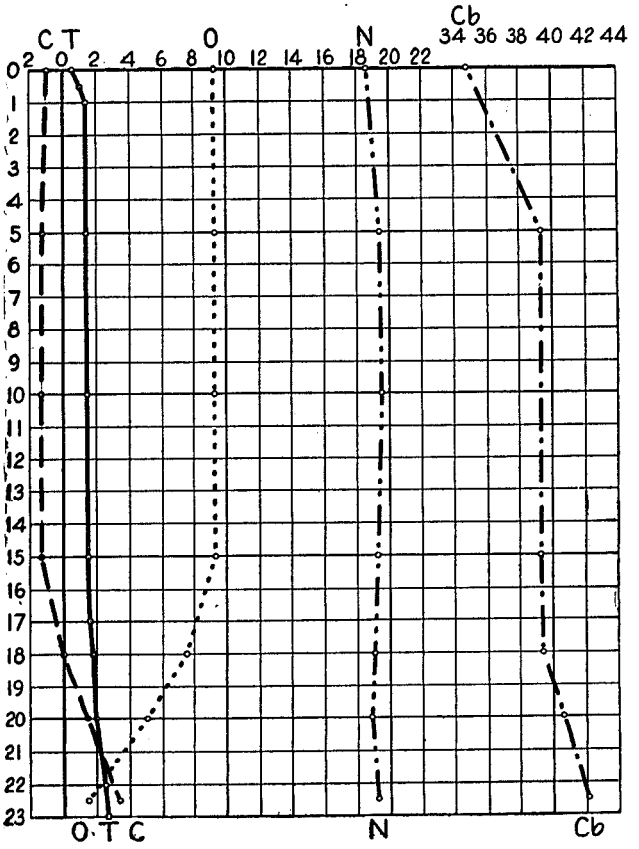

FIG. 3.—Lake Mendota, February 25, 1906.

As the winter advances (fig. 3) some changes occur under the ice. The temperature rises slowly at all depths, but most rapidly at the bottom. Slow decomposition goes on in the deeper water, where also the greater part of the fish are found. There thus results a reduction of the amount of oxygen, which may nearly or quite disappear at the bottom, and a corresponding development of carbon dioxide, so that as winter advances the bottom water may contain considerable quantities of free carbon dioxide. The reaction of the upper water becomes much more markedly alkaline than in the early winter, a change probably due to the influence of the growing plants. The carbonates may or may not decrease in the water immediately below the ice. If a diminution is found (and such decrease may be very pronounced, as in fig. 4), the change is due to the accumulation beneath the ice of water resulting from the melting of the ice or snow and containing, therefore, less dissolved matter than the water of the lake usually holds. As the season advances a rapid growth of algæ may take place beneath the ice, resulting in a considerable increase of the oxygen, which may carry it beyond the point of saturation. This increase is usually accompanied by a considerable increase in the alkalinity of the water (fig. 4).

SPRING AND SUMMER.

When the ice has disappeared in the spring (fig. 5), the water is once more mixed throughout the entire depth, and uniform conditions are again established. The reaction becomes almost or quite neutral. Oxygen is present to about the point of saturation, although, in figure 5, some trace of the winter's diminution of oxygen is still present at the bottom. Carbonates and nitrogen are distributed about uniformly at all depths. As the spring advances and the algæ begin their spring growth, the reaction of the water becomes increasingly

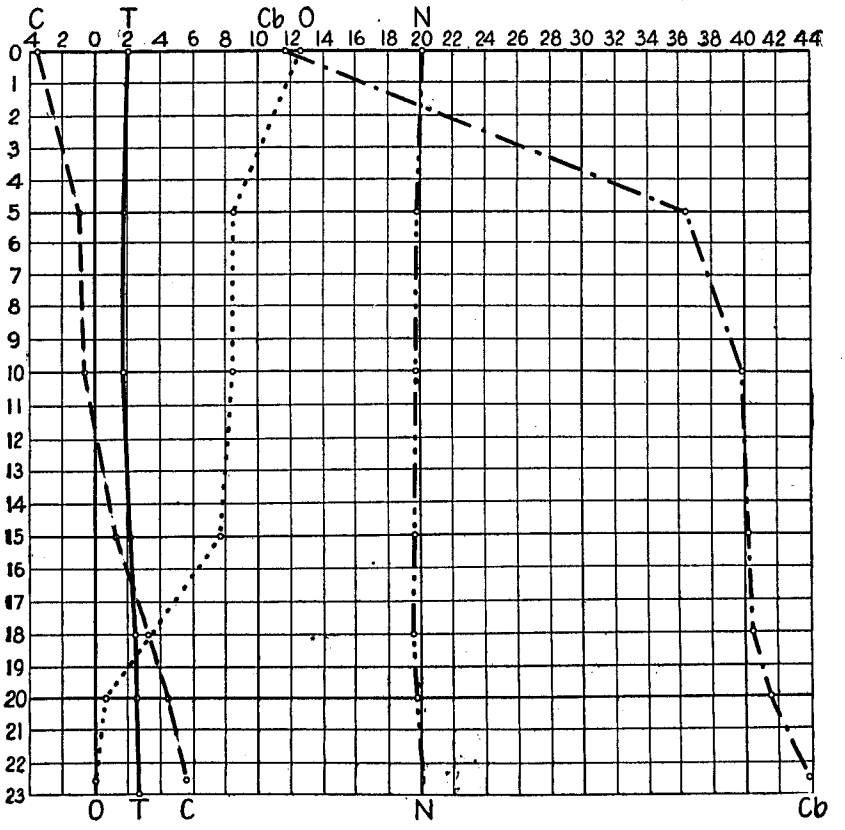

FIG. 4.—Lake Mendota, March 29, 1906.

alkaline. (Fig. 6.) The temperature rises, and soon the surface gains so rapidly in warmth that the wind is unable to distribute the surface water throughout all depths; the circulation becomes increasingly restricted, and summer conditions begin to develop. The temperature curve (fig. 7) shows a marked difference between surface and bottom temperatures, and indicates a temporary thermocline at the depth of 10 meters or more. Corresponding to this stratification of the water and consequent shutting off of the lower water with direct contact with the air, the oxygen in the lower water begins to decline

and free carbon dioxide begins to appear there. This process is accentuated as summer approaches. (Fig. 7 and 8.) The amount of free carbon dioxide increases, the thickness of the stratum of the water whose reaction is acid increases also, and the oxygen steadily and rapidly declines in the lower water. By the early part of July the permanent summer conditions of temperature are found. (Fig. 8.) The regular summer thermocline is found lying, in general, between 5 meters and 10 meters. Oxygen has disappeared wholly from the bottom waters, and is rapidly going from all parts of the lake below the thermocline. The water has divided into an upper warm stratum containing an abundance of oxygen and with an alkaline reaction, and a lower, colder layer with free carbon dioxide, and little or no oxygen except in the extreme upper part.

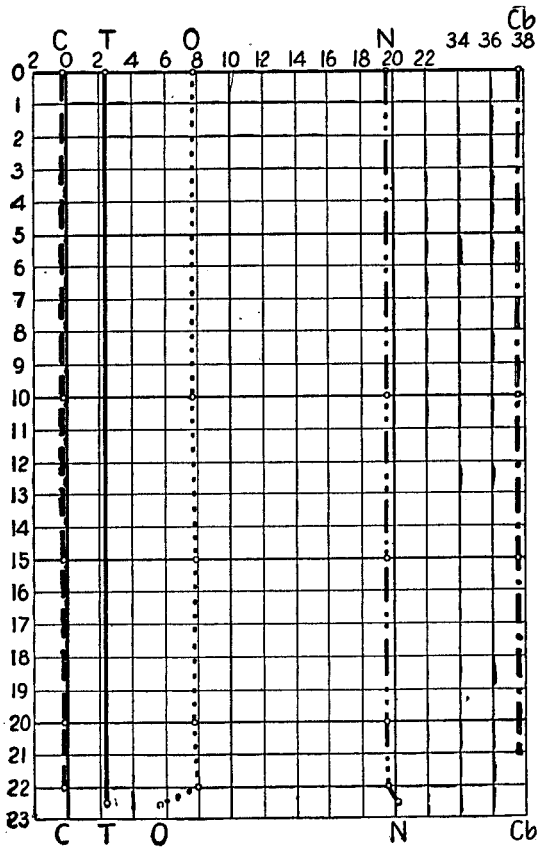

FIG. 5.—Lake Mendota, April 8, 1906.

LATE SUMMER AND AUTUMN.

By the first of August this condition has reached its maximum. (Fig. 9). The lake contains no oxygen below a depth of 10 meters. Above that level, in the warm water and in the uppermost part of the thermocline, there is abundance of oxygen for animal life. Beneath that depth no active animal life is found in the water,[a] though the inhabitants of the mud remain alive through this period, some of them in an inactive condition and some in a partially active state. The carbonates show the characteristic summer condition, in which the upper water contains a smaller amount than the lower, the transition coming in rapidly at the thermocline. This condition persists through August and early September for a period varying with the warmth of the season. As the temperature of the water begins to fall, the thermocline moves downward under the action of the wind, and this process increases the extent of circulating water and in like degree the thickness of the layer containing oxygen. Figure 10 illustrates this condition in early October. The cold weather and winds which are apt to occur at about this time soon bring about a complete mixture of the

[a] Except *Corethra* larvæ, whose presence is an apparent rather than a real exception.

water (fig. 11); and with it returns the condition of uniformity which we found at the opening of winter. From this time until the lake freezes the temperature declines almost uniformly at all depths; the amount of oxygen increases as the capacity of the water to hold it rises with the fall in temperature; and the water becomes almost or quite neutral as the vigor of the growing algæ declines and as decomposition becomes slower in the cooling water.

From this brief account it is plain that the cycle of gas changes in Lake Mendota is a very important factor in determining the conditions and possibilities of life in that lake. Here is an inland lake, one of the largest in Wisconsin,

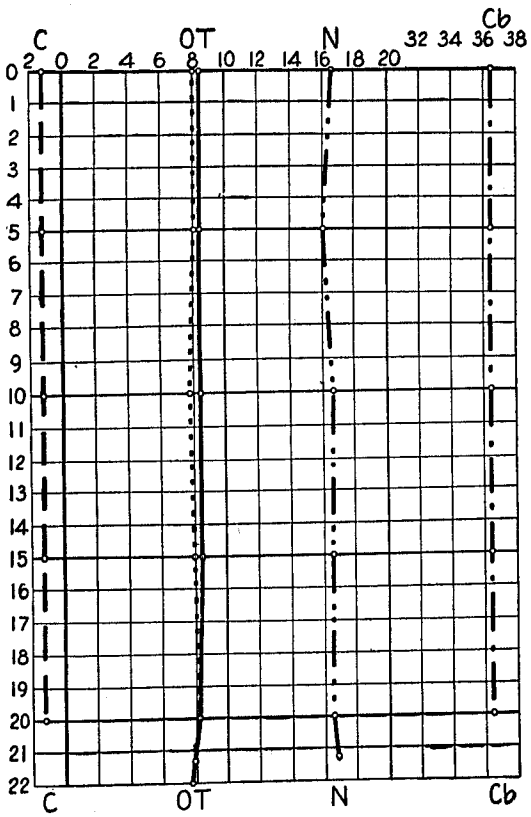

FIG. 6.—Lake Mendota, May 4, 1906.

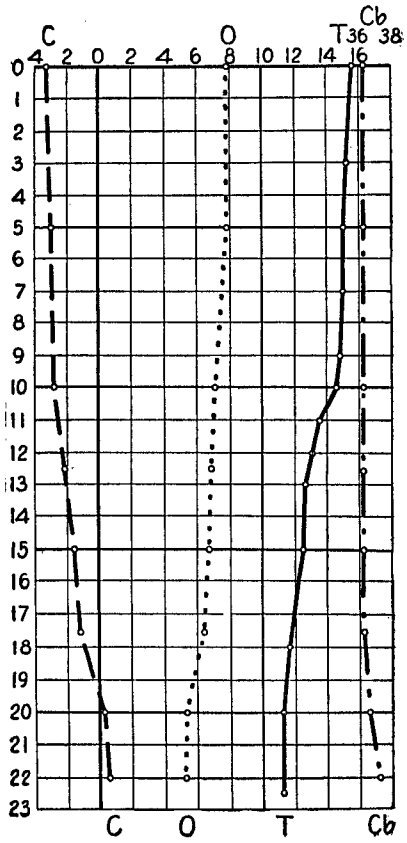

FIG. 7.—Lake Mendota, May 22, 1906.

about 9 kilometers in length and 6 kilometers in breadth, with a maximum depth of 24 meters and an average depth of about 12 meters, the lower half of whose water is wholly uninhabitable during middle and late summer and early fall. This water in the early spring is saturated with oxygen, as is the lower water of all lakes, but the supply is not great enough to meet the demands which are made upon it. The lake is peculiarly rich in plankton, and the decomposition of the great amount of animal and vegetable débris which is showered down from the upper waters into the lower soon exhausts the oxygen supply and renders the lower water unfit for the maintenance of higher life.

Thus the vital conditions in one part of the lake very sharply limit the possibilities of life in another portion. None of those fish which demand a refuge in the cold bottom water during the summer can live in Lake Mendota, nor is it possible to find there those members of the plankton which belong only in the deeper and colder water.

It is perhaps unfortunate for some reasons that Lake Mendota was necessarily the lake on which the most numerous observations were made, since this lake offers an extreme case in the matter of loss of oxygen from the lower water. The oxygen disappears more quickly and fully than in any other Wisconsin lake

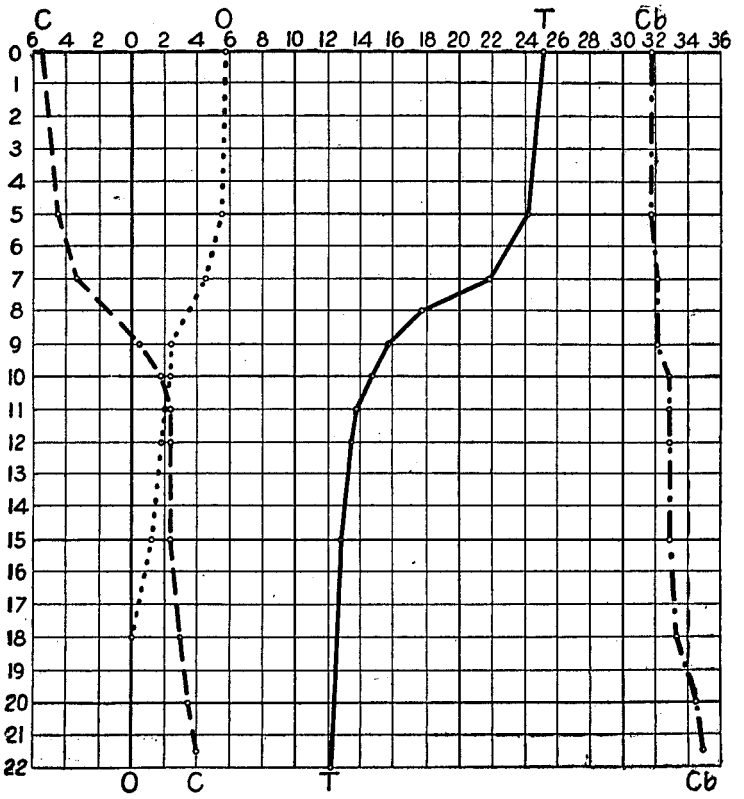

FIG. 8.—Lake Mendota, July 2, 1906.

of approximately equal size and depth. The area of the lake is so large that the bottom water has necessarily a relatively high temperature, and the plankton is so abundant that the lower water is continually receiving great quantities of decomposable matter. Moreover, the thermocline lies comparatively deep because of the large size of the lake, so that the volume of the cooler water is correspondingly reduced. All of these causes combine to make the disappearance of the oxygen very complete and unusually rapid. This lake therefore affords less opportunity than do other bodies of water for the study of the process in its details.

GASES AND CARBONATES OF OTHER LAKES IN SOUTHEASTERN WISCONSIN.

We may contrast the summer conditions in Lake Mendota with those that obtain in the deepest inland body of water in Wisconsin, Green Lake. This has a maximum depth of 72 meters, with length of about 12 kilometers and a breadth of 4 kilometers. Figure 12 shows the conditions found in Green Lake on October 4, 1906. The volume of water is so great that summer conditions of temperature still remain, and cooling has proceeded to no great depth. The water shows the characteristic summer condition of an alkaline upper stratum,

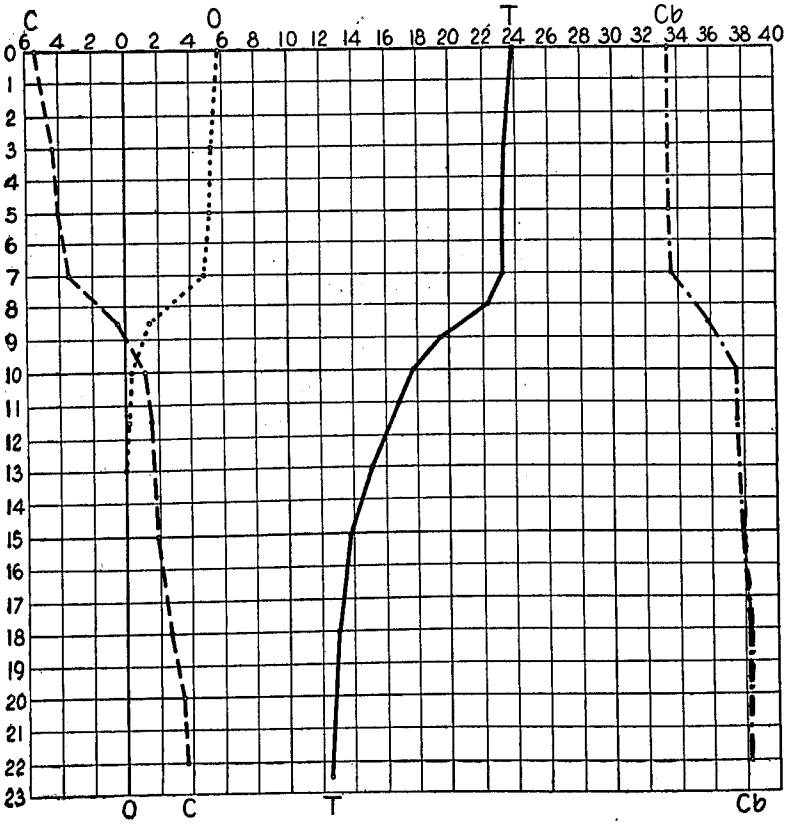

FIG. 9.—Lake Mendota, August 1, 1906.

with the cooler water acid. The dissolved carbonates are low in the warmer waters, rapidly increasing at the thermocline, and then remaining nearly constant till the bottom of the lake is almost reached, where there is again an increase. The oxygen shows a marked diminution in the thermocline (11 meters to 16 meters); it then slowly increases in quantity with the depth until a maximum is reached at about 40 meters, which remains for some 10 meters; and the amount of the gas then declines until it is nearly or quite exhausted at the bottom. The diagram shows plainly the effect of life and death on the oxygen where it is found in abundance in a large volume of water. The oxygen

curve shows that two of the regions where chemical action is going on most vigorously are the thermocline and the bottom water. The accumulation and decomposition of the plankton in the lower water is a sufficient explanation for the changes which take place there. The reduction at the thermocline is apparently due to the fact that the algæ, as they begin to die and sink, often remain for some time at the thermocline. The cool water apparently causes their life to be prolonged, and while certain parts of the filaments are dead and decomposing, others still retain sufficient vitality to keep the plant from sinking. When this period is passed, the plant sinks steadily and rather rapidly to the bottom, thus consuming comparatively little oxygen on the journey. Many forms of plankton animals also accumulate in the thermocline, finding there more food than in any other part of the cool water. Both these causes, then, lead to a diminution of the oxygen at this point. It must not be supposed that there has been no loss of oxygen in the lower water where it is at a maximum. In early spring this water would have contained between 8 cubic centimeters and 9 cubic centimeters per liter, so that at least one-third of the original stock has been consumed.

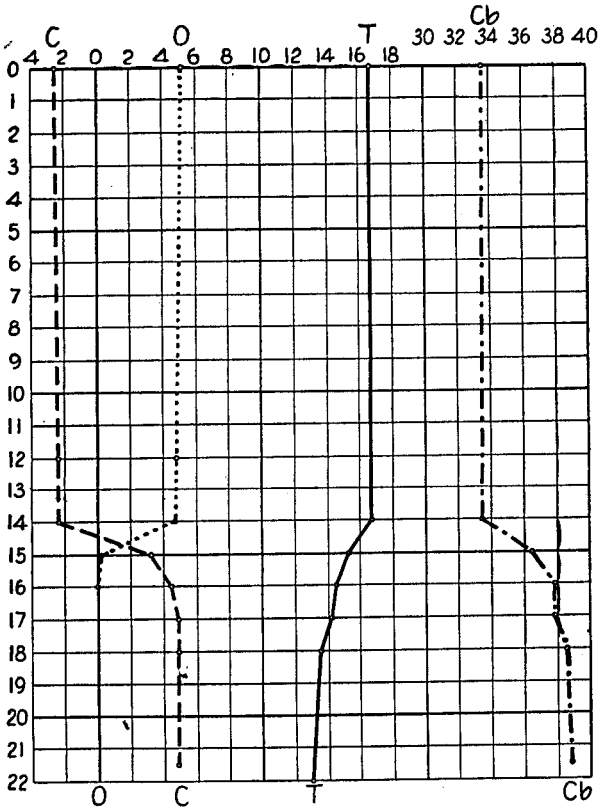

FIG. 10.—Lake Mendota, October 8, 1906.

Green Lake is the only lake in Wisconsin that shows so small a reduction of the oxygen of the lower water. Lake Geneva, near the southern boundary of the state, has about the same dimensions as Green Lake; it is the second deepest lake in the State, having a depth of 41 meters. The late summer conditions are shown in figure 13, where the same general facts are visible as in Green Lake; but the oxygen is much more reduced and shows only a trace, or is altogether absent, from the depth of 33 meters to the bottom. In North Lake, one of the Oconomowoc group, consumption of oxygen at the thermocline goes on more rapidly, and sometimes leads, as is shown in figure 14, to the disappearance of the oxygen from that stratum, while some of the gas still remains at a greater depth.

This lake has an area of about 51 hectares (126 acres) and a depth of about 22 meters. It contains an abundance of oxygen in the water above the thermocline; then follows a stratum in which the gas has almost or quite disappeared; then comes one containing a small amount, but sufficient for the maintenance of a large number of plankton animals; and beneath this to the bottom the water contains no oxygen. A little later, in September, all of the oxygen will have disappeared from the lower water, and the region beneath the thermocline will become uninhabitable by animal life.

LAKES OF NORTHEASTERN WISCONSIN.

All of these illustrations are taken from the lakes of southeastern Wisconsin, where, as shown by the diagrams, the dissolved carbonates are present in large quantities, and where the plankton life is correspondingly abundant. In the lakes of northeastern Wisconsin, where the carbonates are low, the average quantity of plankton is much less than in the hard-water lakes. It is not true that the plankton of every soft-water lake is smaller than that of every hard-water lake. The lakes of both types differ among themselves very greatly, but on the average the statement is entirely correct. European observers have found the same thing for the fish in the lakes of Switzerland that we have found for the plankton in Wisconsin. We have also found that there are fewer fish in the northern lakes than in the southern, hard-water lakes. In these northern lakes, therefore, with their poorer plankton, the oxygen persists longer than in the southern ones. It may disappear entirely, but it usually lingers late, and in the deeper lakes it is apt to remain throughout the season.

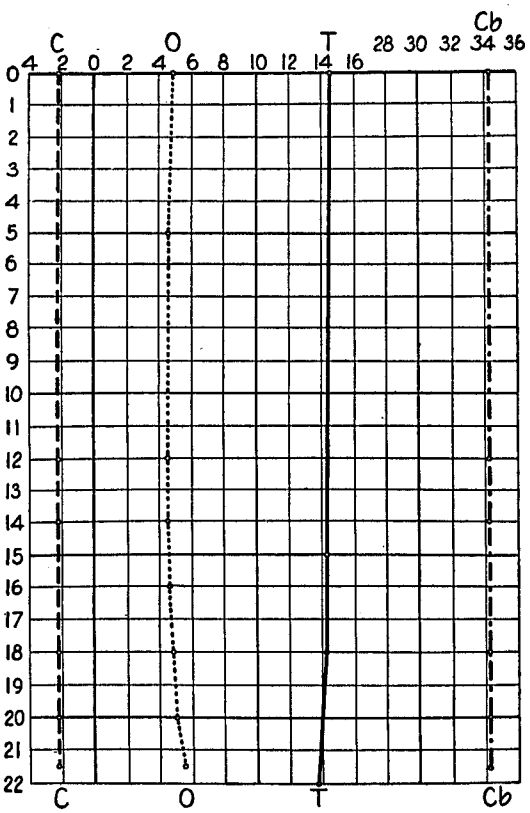

FIG. 11.—Lake Mendota, October 11, 1906.

The diagrams of Thousand Island Lake and Stone Lake (fig. 15, 16) show the summer condition in two of the larger and deeper lakes of this type. The carbonates in both are low, representing about 9 centimeters and 3 cubic centimeters of carbon dioxide, respectively. The upper water is acid, or nearly neutral, the acidity increasing below the thermocline. The oxygen curve of Thousand Island Lake closely resembles that of Green Lake, having a depression

at the thermocline, and an increase in the deeper waters, followed by a gradual decrease to the bottom, where the oxygen is nearly or quite exhausted. This Thousand Island Lake is one of the lakes in northeastern Wisconsin that contain lake trout (*Cristivomer namaycush*). The fish inhabits the bottom water during the summer, and seems to be found native only in lakes which carry an abundance of oxygen to the bottom. The oxygen curve of Stone Lake (fig. 16) shows another interesting fact which is observable in many inland lakes, namely, an increase of oxygen in the upper part of the thermocline. This is due to the presence of algæ at this depth, which still receive sufficient light to manufacture starch, and liberate oxygen in that process. This phenomenon is very commonly found in our lakes, but by no means universally. The crops of algæ, which produce oxygen, are not necessarily continuous; nor is oxygen produced in quantities beyond consumption at all periods of their growth. The thermocline may lie so deep or the water may be so opaque that algæ in the cool water do not get light enough to enable them to produce starch. Neighboring lakes, therefore, which seem quite similar, may or may not show this rise of the oxygen. In the same lake it may appear and disappear during the season, and although usually present at a corresponding time in successive seasons may vary greatly in amount. One common result of this process is the using up, at this point, of the carbon dioxide, the fact being shown by a reduction of the acidity, or an increase in the alkalinity, of the water. The contrast between the carbon dioxide curves in Thousand Island and Stone lakes is sufficiently noteworthy, and this difference is apparently due to the activity of the algæ at a depth of 9 meters

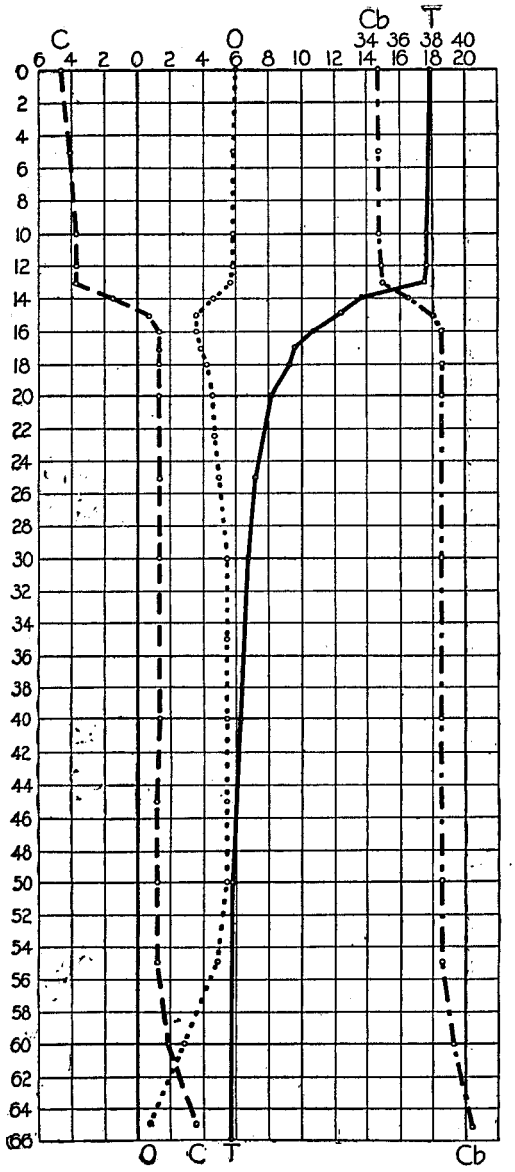

FIG. 12.—Green Lake, October 4, 1906.

and 10 meters in Stone Lake, and the consequent using up of the supply of free carbon dioxide.

MANUFACTURED OXYGEN.

In other lakes this process goes on much more vigorously than it did in Stone Lake. An illustration may be given from Beasley Lake, a little body of water in the Waupaca chain (fig. 17), where the oxygen at the thermocline rises to the maximum of about 15 cubic centimeters, and where its presence is accompanied by a marked increase of the alkalinity of the water.

It must be remembered that both the amount of oxygen and of alkalinity represent the algebraic sum of numerous complicated processes. The amount of oxygen is determined not only by the quantity manufactured, but also by that consumed, and the quantity or deficiency of carbon dioxide depends on the relation of the rate of the manufacture of starch to the rate of the decomposition of the plankton. The two processes are not necessarily parallel, and we not infrequently find, as is shown in figure 18, a great excess of oxygen, while the carbon dioxide curve shows no traces of the process which has manufactured it. In the soft-water lakes whose reaction is usually acid, the manufacture of oxygen in the cooler water may cause a change in the reaction of the water. This is illustrated by Silver Lake (fig. 19), a small pond in northeastern Wisconsin, where the oxygen maximum occurs at 7 meters, and at the same depth the reaction changes from a positive acid to an equally positive alkaline one. It returns to a slight acidity at 9 meters, and from this point the amount of free carbon dioxide rapidly increases.

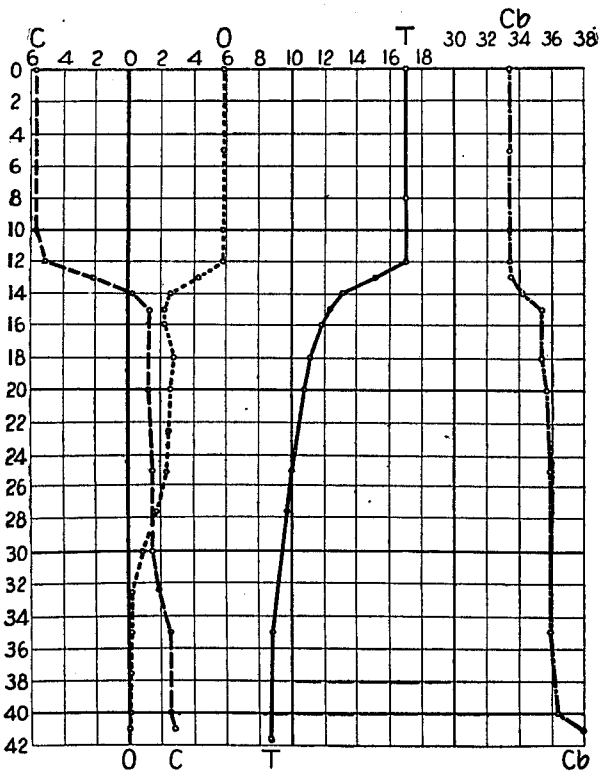

FIG. 13.—Lake Geneva, September 26, 1907.

In the smaller and shallower lakes the presence of this manufactured oxygen at the thermocline region is often of great importance in extending the inhabitable region. Beasley Lake is perhaps the best illustration of this fact. The

lake contains a great amount of fermentable material, and the oxygen disappears from the bottom water early in the spring. The lake is so small that the thermocline lies very close to the surface, remaining at 4 meters or above until late in the summer. Were it not for the manufactured oxygen, the entire body of water below the thermocline would be uninhabitable. The maintenance of the stock of this gas by the presence of the algæ doubles the thickness of the habitable stratum during the summer and the early part of the autumn. Figure 17 also shows the effect of the manufacture of oxygen on the dissolved carbonates; but that matter is too complex to be discussed here.

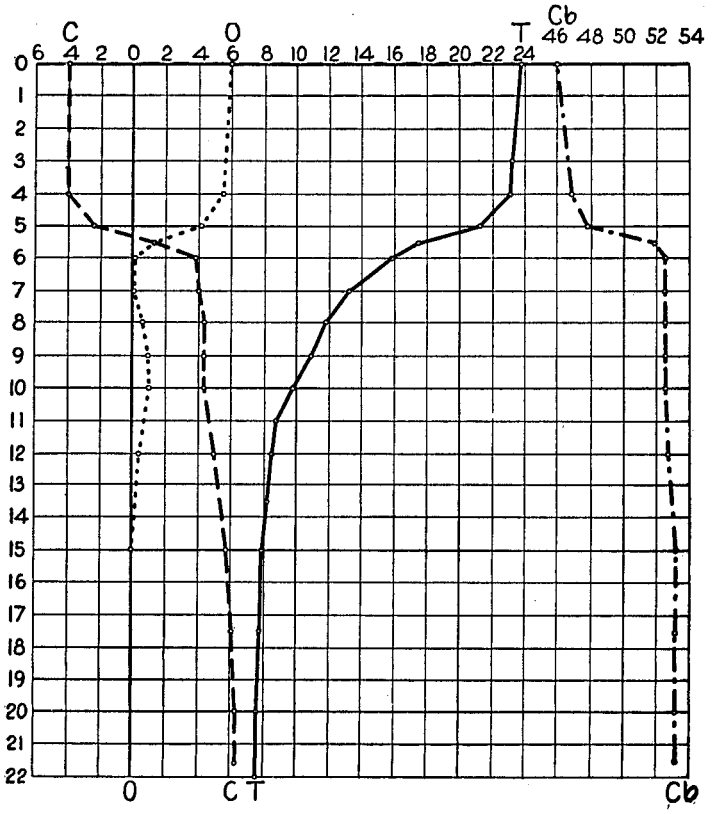

FIG. 14.—North Lake, east part, July 30, 1906.

I have spoken of Thousand Island Lake as a characteristic "lake-trout lake." So far as our observations go, the lake trout in northeastern Wisconsin is found only in lakes of this type; yet observations made in the summer of 1908 in northwestern Wisconsin show that the fish can exist in lakes of a type which would seem to be unfavorable to it. I give a diagram of the conditions in Hammill's Lake (fig. 20), a small body of water in northwestern Wisconsin, which contains a few lake trout that have been introduced. Their presence in the lake shows that they can exist in a body of water in which the oxygen extends some distance

into the cooler stratum, although the bottom water is practically or wholly devoid of the gas. Their presence in small numbers shows that such a lake is not suited to the species, and that, while it can adjust itself and survive under these unfavorable conditions, it is unable to thrive. It is not known whether it spawns under these conditions. There can be little question that the continuance of the species in this lake is due to the fact that the cool water still retains a certain amount of oxygen throughout the season.

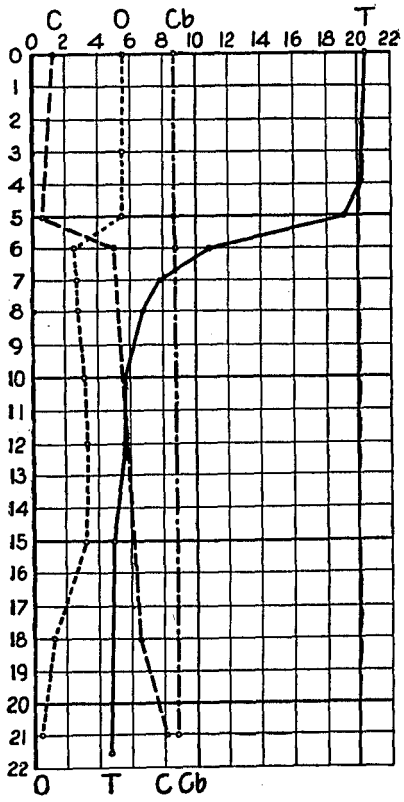

FIG. 15.—Thousand Island Lake, August 13, 1907.

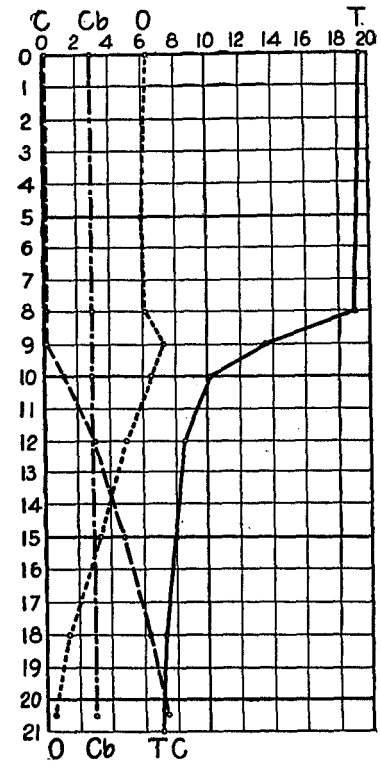

FIG. 16.—Stone Lake, August 22, 1907.

CONCLUSIONS.

I have selected for illustration these series from among the hundreds of similar observations that have been made by the Wisconsin Geological and Natural History Survey. I have not attemped to give any complete picture of the story of the gaseous changes in any lake, and many of the most important relations and results have been left unmentioned. I have brought these cases to your attention in order to illustrate two conclusions which are of importance. The first is that the cycle of the gaseous changes in a lake illustrates more readily and more conspicuously than perhaps any other facts could do what may be called the "annual life cycle" of the individual lake, showing both the

underlying resemblances of that cycle as found in different lakes and also some small part of the infinite variation in its details. These diagrams from late summer represent the culminating point of an annually recurrent series of definite changes through which the lakes pass with the season as certainly as the season returns. These changes result from the interrelation of the living beings of the lake with an environment strictly limited in its space and containing only definite amounts of food and of oxygen, to which only small additions can be made from the outside. The story of these changes is legible to him who will closely follow it. Its details differ, indeed, in each lake from those found in a neighboring lake, but on the whole it always follows along certain great lines and shows that lakes can be grouped into classes according to its major variants. Only a little of this story is now known, and many years of detailed work will be needed before even its larger facts are fully ascertained and justly interpreted. But from the few diagrams which I have given one may see that lakes present to the student a vital story, as definite, as variable, and as complex as is that of a living organism; a story to be followed by means like those needed to work out biological life histories, and one whose interest is such as to claim far more attention from science than it has received.

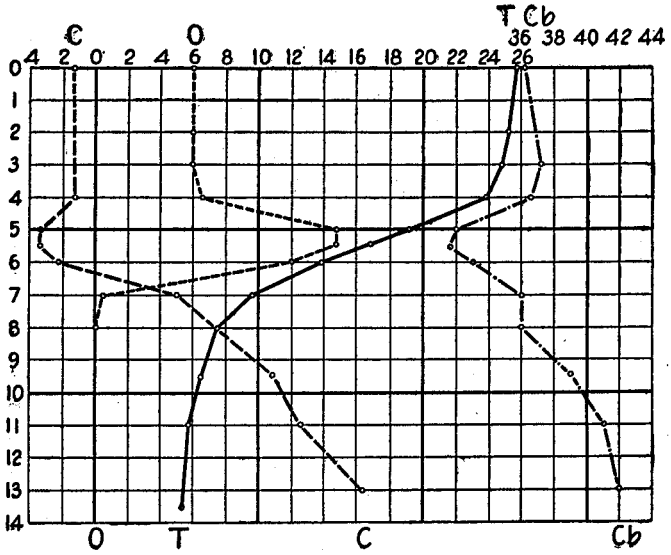

FIG. 17.—Beasley Lake, August 4, 1908.

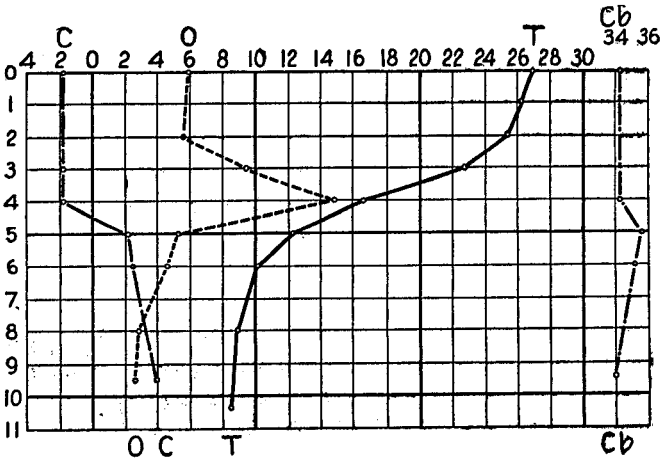

FIG. 18.—Otter Lake, August 4, 1908.

PRACTICAL IMPORTANCE OF THE SUBJECT.

If this scientific interest were all that the story affords, however, I should not have brought it to the attention of this congress, whose interest rightly lies in the fisheries. But these changes, which go on in the water of the lake, affect not only the life of lower organisms but also that of the higher ones, including the fish. No facts of environment show more clearly than do these how life determines its own conditions. On the presence of a large or a small quantity of plankton in the upper waters may depend the conditions which make the lower water habitable or uninhabitable. The relation between the volume of the lower water and the quantity of decomposing matter discharged into it

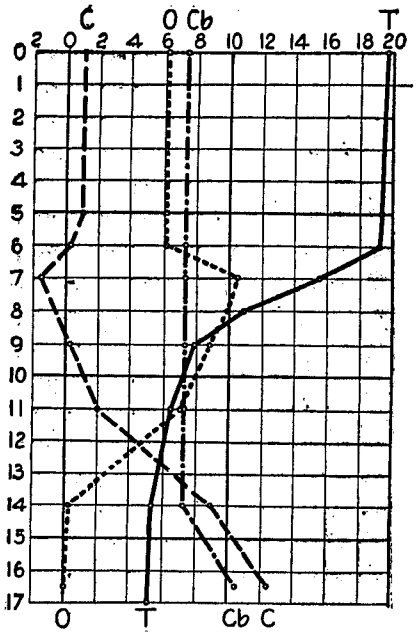

FIG. 19.—Silver Lake, August 21, 1907.

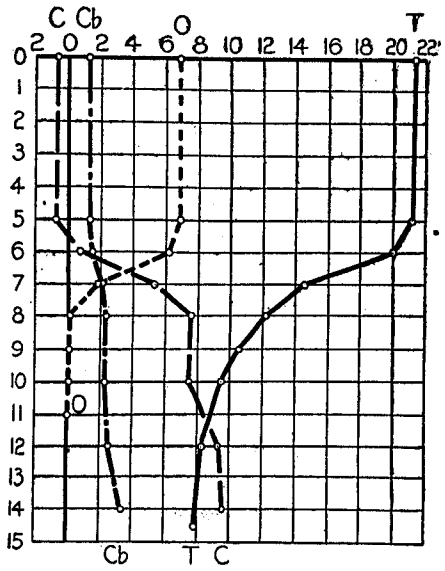

FIG. 20.—Hammills Lake, August 17, 1908.

determines whether this lower water shall be filled with animal life and support a relatively abundant population of lake trout and whitefish, or whether life of all kinds shall cease abruptly at the thermocline, or whether a scanty plankton shall indeed leave abundance of oxygen in the lower water but provide a supply of food for a scanty higher life. Thus the annual history of the lake discloses facts that are fundamentally important in determining the amount and kind of life which the lake may support and that which may wisely be introduced into it; and it becomes plain that a knowledge of them is indispensable to an intelligent use of the waters of the lake by those concerned in increasing the supply of fish.

In other words, it seems clear that a knowledge of lacustrine physics and chemistry is just as necessary to the best economic utilization of the waters of

the lakes as a knowledge of soil physics and chemistry is to the best agricultural use of the land. The problems of the lakes are complex and are not easily solved, but they are far less complex and much more easily solved than are the corresponding problems of the soil. This nation and the several states are spending hundreds of thousands of dollars annually in studying the soil. This expenditure is fully justified, not only by its scientific results but also by its practical consequences. Little or no time or money is now devoted to the similar study of the waters of the lakes. Yet no one who has followed investigations of this kind can doubt that if the lakes could be studied on the same large scale and with the same careful methods as those applied to the study of soils, results of great economic value would be obtained. It was years before the study of physics and chemistry of soils promised large economic results. Valuable practical hints have already come from the brief and imperfect study of the lakes which our survey has made, and the present situation of our knowledge indicates that a wider and more systematic study than we have been able to undertake would ultimately lead to far larger and more important conclusions. Such a study is greatly needed. The culture of fish in the innumerable inland lakes of this country should rest on the basis of scientific knowledge at least as broad and as complete as that which underlies the cultivation of our farm products. We who have in charge the maintenance of a public interest so extensive and valuable as is that of the fisheries are most of all concerned in the acquisition of that knowledge which is the only true guide of practical affairs.

DISCUSSION.

Mr. J. J. STRANAHAN (U. S. Fisheries Station, Bullochville, Ga.). I would like to ask Professor Birge a question or two. It is not closely related to this subject, although not entirely foreign. I desire to ask if you have had any experience as to the plankton and the relative amount of crustaceans and other animal life that is in soft and hard waters.

Professor BIRGE. Yes; although the matter can not be finally settled. It is a condition well known to European investigators. The hard-water lakes are much richer in plankton on the average than the soft-water, but you can not make the statement that every hard-water lake has more plankton than any soft-water.

Mr. STRANAHAN. At Guilford, in England, south of London; at Castalia, in Ohio; I think at Northville, in Michigan, and wherever I have known of exceedingly hard water, full of lime and other salts, there has been an excess of plankton. I collected plankton at Castalia to take to the World's Fair at Chicago, and with pretty carefully conducted weights the amount of crustaceans exceeded the amount of mosses and aquatic plants in which they were congregated when taken from the water. That water is so rich in lime and magnesia that it makes stone of a shingle in a year, and that is probably the greatest trout preserve in the world. At Bullochville, Ga., where I am now, our water is practically aqua pura; we can use it in photographic processes; it is exceedingly soft. We have put mollusks in it, but the different little periwinkles and other shell-covered species die in a few months, and it is not conducive to fish culture. We took two carloads of cement and buried it in our spring, and we thought we could see a marked increase in the growth of some kinds of vegetation, to say nothing of small water animals that grow in it. So I am a great stickler for the idea that we ought not to put fish hatcheries where there is not a large amount of calcareous material in the water.

Professor BIRGE. I wanted to talk about that, but with the limitations on the time I could hardly get to that part of the subject.

Doctor NORDQVIST. Those investigations Professor Birge has made are of the greatest importance in fish culture in lakes. I am of the same opinion as Professor Birge, that many of the disappointments that we have in fish culture are due to lack of knowledge about the amount of oxygen and the biological conditions of the lakes.

I would only ask Professor Birge about some slight points here in his investigations. At what time in the day was the amount of oxygen determined?

Professor BIRGE. We have made a great many attempts to discover diurnal variations in oxygen, but it is a very rare thing to find any difference in the results obtained from tests made in early morning, late afternoon, and late evening. We have continued the tests throughout the twenty-four hours. We have found very small, hardly perceptible, diurnal differences. I have received, since I came to this congress, a letter from my assistant, Mr. Juday, to whom much of this work is due, telling me that he had found such a difference in Lake Mendota.

Doctor NORDQVIST. That is just what I mean with reference to the investigations; it ought to show a difference, and I think that the curve that you have given in many of your lakes at the depths of six, seven, to ten meters may perhaps——

Professor BIRGE [interrupting]. We have spent from two to three weeks hunting for diurnal changes right on that point. I put a party on those lakes—Otter Lakes—and we got negative results all the time; the curve remained substantially the same.

Doctor NORDQVIST. It is very interesting to hear that. Then I would be glad to learn in what way the oxygen was determined.

Professor BIRGE. In two ways: One diagram showed an oxygen line determined by boiling; and in the other it showed oxygen by Winkler's method of titration, or by one of the modifications of Winkler's method, which is a standard in the books.

Doctor NORDQVIST. Oxygen by the Winkler method?

Professor BIRGE. Yes, depending on the liberation of iodine and sodium at the end.

Doctor NORDQVIST. How was the water taken up?

Professor BIRGE. The water was taken up by a pump and hose, the latter being lowered to the proper depth, and the water brought up and kept completely out of contact with the air, so that where there was no oxygen we had like results always.

The PRESIDENT. Are there others who will contribute to the discussion of this most interesting paper?

VOLUMETRIC STUDIES OF THE FOOD AND FEEDING OF OYSTERS

By H. F. Moore

Assistant, U. S. Bureau of Fisheries

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VOLUMETRIC STUDIES OF THE FOOD AND FEEDING OF OYSTERS.

By H. F. MOORE,
Assistant, United States Bureau of Fisheries.

Economically considered, probably the most important direct interrelation between a marine animal and plants is that existing between the oyster and its food. We have in the United States alone an industry valued at $18,000,000 per annum, which is immediately dependent upon the supply of microscopic vegetation in our bays and estuaries, a vast food resource useless to man in its original state, but of great present and still greater potential value when transsubstantiated into the flesh of oysters, clams, and other mollusks.

Various investigations have shown that about 95 per cent of the food of the oyster consists of diatoms and that most of the remainder is composed of other equally minute plants or organisms on the more or less debatable borderland between plants and animals. The oyster obtains these microscopic organisms by drawing feeble currents of water between the open shells, straining them through the exceedingly minute orifices in its gills, and passing the filtrate by ciliary action into its mouth, which lies ensconced between two pairs of fleshy palps close to the hinge of the valves. Though the currents induced are feeble they are constant, and during the course of twenty-four hours the water thus minutely strained is many times the volume of the oyster.

It is common knowledge among oystermen and oyster growers that different localities differ markedly in their powers or capabilities for growing and fattening oysters, and the results of various researches have shown that these diversities are correlated with the amount of food available to the sessile oysters. A deficiency may be due to a natural poverty of the waters, to an overpopulation of oysters, or to an absence of currents sufficient to carry the food within reach of the feeble external currents set up by the oysters themselves. Frequently all three of these factors are found to be involved where oysters grow slowly and fail to fatten.

Certain enthusiasts, some of whom should know better, have held forth the prospect of a time when the entire available bottom of our bays and sounds would be planted in oysters as densely as are the comparatively small areas now utilized. They fail to consider the fact that the natural fertility of the waters imposes some limit upon the production of oyster food, and that a vast increase in the oyster population, such as their imaginations contemplate, would undoubtedly exceed the limits which nature has set.

The microscopic vegetable life of our brackish bays and sounds is probably as abundant as it is capable of becoming under existing conditions. It is dependent primarily upon the quantity of certain mineral salts in solution, and is as strictly limited by the conditions as is the crop yield of a given area of land by the available salts in the soil. The soils can have their fertility artificially increased, but though experiments conducted by the author for the Bureau of Fisheries have shown that the same expedient is partially successful for limited areas of inclosed water, it can never be applied to open waters, as the fertilizer would be speedily carried away. In this connection, however, it is an interesting speculation whether our coastal waters are not to-day richer in fertilizing salts than they have been in the past. The denudation of our forest lands, the erosion due to faulty agriculture, the artificial fertilizers carried away from cultivated fields during periods of heavy rainfall, and the discharge of sewage rich in organic matter have undoubtedly added much to the available fertilizing content of our coastal waters, to the advantage of their microscopic vegetation.

The question of food supply, its availability, and the quantity required for a given area planted in oysters is one of vital importance to the oyster culturist. Of the total oyster supply of the United States, about five-eighths, valued at over $10,000,000, is produced on planted beds, and the future growth of the industry is dependent upon the increase of the area of private bottoms under culture. With the extension of the planting industry to new localities and the inevitable congestion in places naturally favorable for growing and fattening oysters, the value of definite data upon this subject will be greater in the future than in the past.

Empirical methods involving actual planting to determine the suitability of a locality are expensive and often wasteful, and operators with small capital are frequently deterred from taking the risk. Even though the work on a small scale may prove successful, an increase to a large commercial basis may overtax the food supply to such an extent as to make the growth of the oysters slow and their fattening impossible. A number of cases of this kind have come to the author's attention, the most noteworthy being in Lynnhaven Bay, where the increase in the area planted, though the quantity per acre is exceedingly small, has made it almost impossible to fatten oysters properly on certain bottoms formerly satisfactory.

As the economic importance of the subject merits, it has frequently been the matter of investigation and has probably attracted more attention from biologists than has any other direct correlation between marine plants and animals. The nature of the oyster's food was long ago determined and the work of the last twenty years has been hardly more than confirmatory of that which preceded it.

Dean appears to have been the first to attempt the quantitative determination of the oyster food available in the water. He employed a chemical analysis of the water to determine the albuminoid ammonia content, assuming that the results would indicate the comparative food values of different regions.

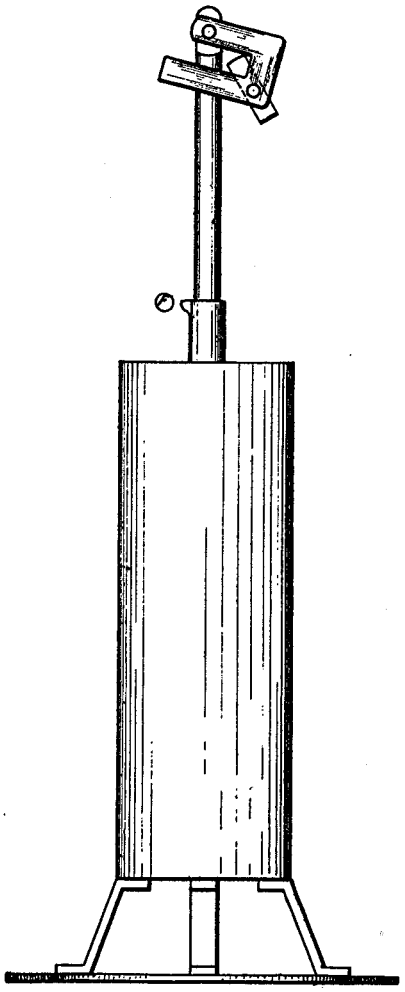
Subsequent investigators have recognized the grave defects in this method, and, including myself, have all followed the general method of Rafter. Water specimens of definite volume, usually 1 liter, have been collected either by means of a stoppered bottle or jug, from which the cork is pulled after it has been sunk to the bottom, or by a specially designed metal cylinder constructed on essentially the same principle. The suspended matter in the specimen, a large part of which often consists of sand, mud, and débris, is then concentrated in, say, 10 cubic centimeters of water by filtration through sand or precipitation in an Erlenmeyer flask after the addition of a few drops of formalin. A definite quantity of the filtrate is then removed after agitation and the food organisms counted in a Rafter cell, the calculated number of such organisms per liter being regarded as an expression of the food value of the water.

This method has two defects, the first of which is that the water specimen is not drawn from the stratum tenanted by the oyster, but solely from a height of about 12 inches above the bottom. It would be possible to correct this defect by using a shorter, broader bottle or specimen cup, but as the water flows rather slowly into the necessarily narrow inlet, there would enter with it a considerable quantity of material stirred up when the instrument strikes the bottom. As the amount of this material would vary with the bottom, the impact, and the currents, a more serious source of error would arise and the results would become worthless.

To obviate these difficulties I have designed the type of bottle illustrated in text figures 1 to 5. It consists essentially of a brass barrel of a capacity somewhat over 1 liter, two conical valves, and a tripping device. The lower valve is fixed at a height of 2 inches above a broad base, which prevents the instrument from sinking in soft mud, but the barrel and upper valve slide freely on a central column or rod. The instrument is set by engaging the lug (F) over the inclined surface (G) of the stirrup or tripping device (CDEG), which suspends the upper valve (B) and the barrel (A) so as to leave a gap of 2 inches between the two valves and their respective seats, the stirrup being maintained in position by tension on the cord by which the instrument is lowered. By rotating the cam (H) so as to pinch the cord between it and the collar on top of the upper

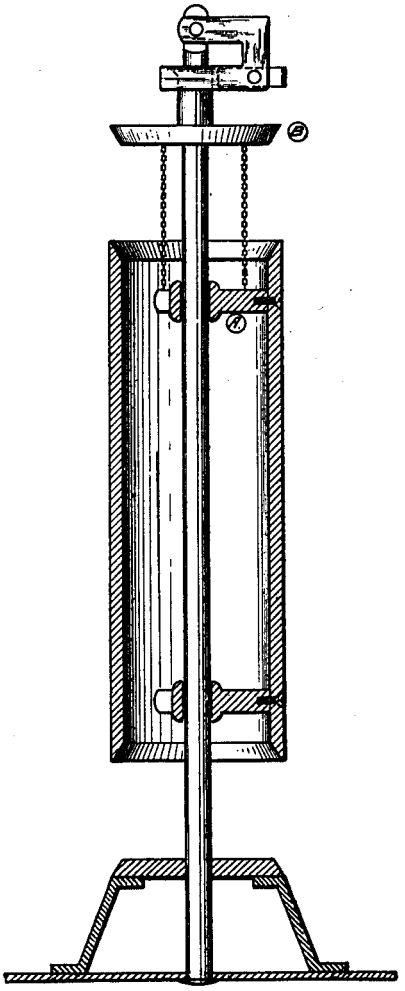
valve, the instrument may be locked in the set position, but it is automatically unlocked when it is raised by the cord.

As the instrument is lowered there is a free flow of water through the barrel, so that at any given time its contents are taken from the stratum in which it



Elevation.

FIG. 1.



Section.

FIG. 2.

Water specimen cup.

rests. When bottom is touched the tension on the cord is relaxed, the tripping device instantly releases the upper valve and the barrel suspended from it, and they fall into their respective seats, inclosing a sample of water before it can be contaminated by the stirred-up bottom deposits. As the barrel is 10 inches

long, the water inclosed is a vertical column of the stratum lying between 2 inches and 12 inches above the bottom, and as the currents do not flow over the beds in horizontal strata, but roll over and over, this specimen is regarded as a fair sample of that in which the oysters are bathed.

The instrument is now used in Massachusetts, Maryland, Virginia, and Louisiana, and actual tests have shown that it takes a water specimen much cleaner and freer from mud and extraneous materials than do the instruments previously employed.

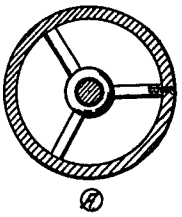


FIG. 3.—Cross section at A, figure 2.

The other defect of the old method of determining the food value of oyster-producing waters arises from the practice of using the number of diatoms or organisms per liter as the measure of their productiveness. It is well known that diatoms, which usually constitute upward of 95 per cent of the food of oysters, differ greatly in size and the species vary in comparative abundance in different regions and from season to season in the same locality. When a numerical expression is employed, it follows therefore that a multitude of small organisms may give an apparent superiority to a water specimen as compared with another containing a smaller number of a species of vastly larger size and much greater aggregate volume, and my own experience has shown cases where this error amounted to nearly 400 per cent. The method is attended with grave error as applied to even limited regions and is wholly untrustworthy as a basis of comparison between widely separated localities. It gives seemingly quantitative results, but these, not being volumetric, are deceptive.

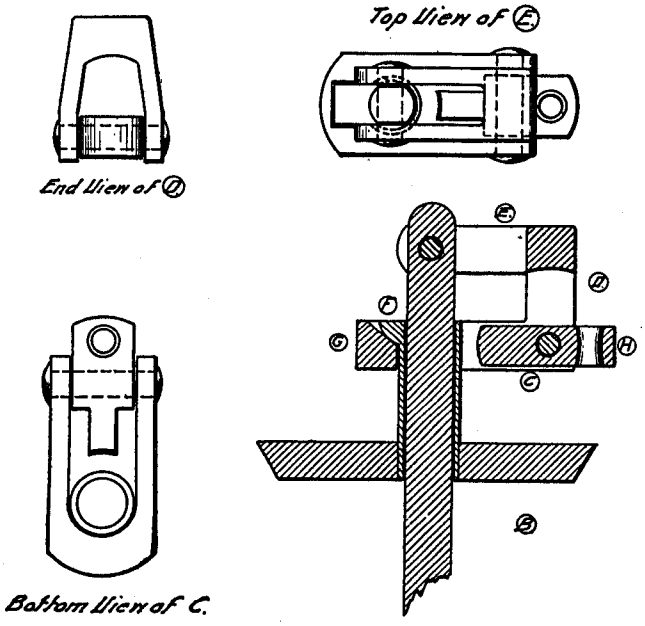


FIG. 4. FIG. 5.

Details of tripping device of water specimen cup in figures 1 and 2.

Direct volumetric determination can not be made on account of the presence of considerable volumes of sand, mud, and extraneous débris in the filtrate, these materials greatly exceeding the food organisms in volume. Grave attempted to overcome the difficulty by listing the food organisms by species,

but this arrangement, though an advance on previous work, is not capable of comparative use, and any error in identification, not unlikely to occur with persons not diatomists, would be misleading to future investigators.

To overcome these difficulties I have for several years used the following indirect method, which has given satisfactory results. The diatoms and other food organisms are collected and counted, as before indicated, and are listed by species, although their identification by their correct names is not essential. Careful outline camera lucida drawings are made of the zonal and valvular aspects of a number of specimens of each species, and their cubic contents are calculated by geometric methods from planimeter measurements of the drawings. The average of a number of such calculations will give the average relation of the volume to the product of length, breadth, and thickness of the species. Using this relation and the average of a number of micrometer measurements of the specimens themselves, a simple calculation will furnish an approximately correct expression of the average volume of the species in the region under investigation. If these volumes be employed as multipliers into the numbers of the respective species, determined from the counts in the Rafter cell, we have an approximately correct volumetric expression for the amount of the food content of each specimen of water. As the most convenient unit of measurement I have adopted Van Heurck's "c. d. m." (0.01 millimeter), the unit of volume being the cube of this, "cu. c. d. m." (0.000,001 cubic millimeter). The following is an illustration of the data required for each species:

Synedra commutata (Matagorda Bay); average length, 4.7 c. d. m.; breadth, 0.5 c. d. m.; thickness, 0.5 c. d. m.; volume $= 0.6\ (l \times b \times t) = 0.7$ cu. c. d. m.

This method sounds elaborate in its narration, but has not shown itself to be cumbersome in practice, and, moreover, it appears to be the only method so far proposed which gives data of real value. The results are directly comparable with those obtained in other waters or with those reached in the same waters at different seasons. Five hundred or 600 determinations have been made in the past two years, and, for reasons shown below, the procedure generally was found to require but little more labor than the older misleading and less accurate method.

In oyster investigations it is customary to take a large number of water specimens at adjacent stations, and as the nature of the food content of each varies in quantity rather than in the character of the organisms, the measurements of eight or ten species will apply to all water samples from the locality. Only those organisms need be measured which examinations of the stomach contents of the oysters show to be important as food. The counts have to be

made, whatever method be employed. In Matagorda Bay, where the present method was first used, about 150 specimens of water were examined and the additional time required was not over 10 per cent. The following table shows the results and the manner of tabulation, as well as the differences in results attained by the numerical and the volumetric methods:

FOOD VALUE OF WATERS OF MATAGORDA BAY.[a]

[Roman figures indicate volume of organisms, or food value. **Bold-face figures** indicate number of organisms.]

No.	Species.	A. Between Sand and High Mound signals.	B. Between High Mound and Lake signals.	C. Between Mad Island, West, and Lake signals.	D. Between Shell Island and Mad Island reefs.	E. Between Dog Island and Shell Island reefs.	F. Between Dog Island and Pavilion signal.
1	Coscinodiscus crassus	**500**	----------	**917**	**250**	**100**	**500**
2	lineatus	121,805 **3,483**	141,470 **4,042**	142,905 **4,083**	183,750 **5,250**	141,750 **4,050**	122,500 **3,500**
3	excentricus	10,500 **1,750**	17,502 **2,917**	17,760 **2,960**	12,000 **2,000**	5,550 **925**	12,000 **2,000**
4	Navicula didyma	4,125 **875**	6,413 **583**	9,625 **875**	11,000 **1,000**	----------	----------
5	elliptica	1,250 **125**	1,660 **166**	4,160 **416**	2,500 **250**	1,000 **100**	5,000 **500**
6	arenaria	937 **375**	1,145 **458**	1,688 **675**	3,750 **1,500**	250 **100**	1,250 **500**
7	Amphora ovalis	2,500 **500**	----------	625 **125**	----------	500 **100**	----------
8	Pleurosigma fasciola	**250**	----------	**125**	----------	**425**	----------
9	obscurum	----------	----------	**125**	----------	----------	----------
10	intermedium	**125**	----------	----------	----------	**225**	**500**
11	tenuissimum	**375**	**292**	**125**	**1,250**	**850**	**500**
12	angulata major	----------	----------	----------	----------	----------	**250**
13	Synedra commutata	5,600 **8,000**	6,650 **9,500**	9,100 **13,000**	25,550 **36,500**	8,155 **11,650**	1,400 **2,000**
14	sp	1,750 **500**	1,225 **333**	3,790 **1,083**	1,750 **500**	2,275 **650**	875 **250**
15	Melosira distans	52,500 **2,625**	68,340 **3,417**	73,340 **3,667**	35,000 **1,750**	18,160 **908**	20,000 **1,000**
16	sp	**250**	----------	**675**	----------	----------	----------
17	Pyxilla sp	----------	----------	----------	----------	**200**	**250**
18	Other diatoms	**1,250**	**500**	**292**	**250**	**300**	**1,000**
19	Prorocentrum micans	18,375 **2,625**	29,456 **4,208**	8,750 **1,250**	8,750 **1,250**	----------	3,500 **500**
	Total volume, or food value	219,342	273,861	271,743	284,050	177,640	156,525
	Total number of organisms	**23,108**	**26,416**	**30,833**	**51,750**	**20,083**	**13,250**
	Prairie shore	208,527	287,737	239,024	259,875	159,937	89,925
	Middle of bay	259,774	345,200	267,000	274,350	177,900	254,925
	Peninsula shore	190,049	188,450	314,412	317,625	193,770	153,725

[a] From Survey of Oyster Bottoms in Matagorda Bay, Texas, by H. F. Moore. Bureau of Fisheries Document 610.

FOOD VALUE OF WATERS OF MATAGORDA BAY—Continued.

No.	Species.	G. Between Pavilion and Three-mile signals.	H. Between Three-mile and Seven-mile signals.	I. Between Seven-mile and Grass signals.	J. Between Grass and Dressing Point signals.	K. Live Oak Bay.	L. Above Dressing Point.
1	Coscinodiscus crassus	375	292	792	200	----------	----------
2	lineatus	135,625 3,875	163,310 4,666	198,310 5,666	118,720 3,392	157,500 4,500	140,000 4,000
3	excentricus	17,250 2,875	13,248 2,208	16,002 2,667	9,150 1,525	---------- ----------	3,498 583
4	Navicula didyma	---------- ----------	2,750 250	3,212 292	2,013 183	---------- ----------	4,587 417
5	elliptica	2,500 250	4,170 417	12,500 1,250	---------- ----------	---------- ----------	2,500 250
6	arenaria	3,438 1,375	730 292	1,458 583	2,500 1,000	3,750 1,500	5,420 2,167
7	Amphora ovalis	625 125	1,250 250	---------- ----------	830 166	3,750 750	1,665 333
8	Pleurosigma fasciola	----------	166	166	----------	----------	166
9	obscurum	----------	----------	125	----------	750	250
10	intermedium	----------	----------	166	492	----------	583
11	tenuissimum	1,500	750	166	883	750	883
12	angulata major	125	166	167	----------	----------	----------
13	Synedra commutata	962 1,375	1,517 2,167	642 917	1,686 2,408	1,575 2,250	1,166 1,666
14	sp	5,250 1,500	1,793 541	581 166	4,812 1,375	5,250 1,500	11,081 3,166
15	Melosira distans	10,000 500	---------- ----------	20,000 1,000	13,500 675	---------- ----------	---------- ----------
16	sp	250	542	167	208	----------	333
17	Pyxilla sp	250	167	125	100	750	----------
18	Other diatoms	----------	125	----------	517	2,250	500
19	Prorocentrum micans	2,625 375	5,832 833	7,875 1,125	14,581 2,083	5,250 750	11,669 1,667
	Total volume, or food value	178,275	194,600	260,580	167,792	177,075	181,586
	Total number of organisms	14,750	13,832	15,540	15,207	15,750	16,964
	Prairie shore	151,050	162,900	191,700	182,470	----------	----------
	Middle of bay	186,599	182,925	357,650	152,525	----------	----------
	Peninsula shore	189,675	238,349	232,250	168,674	----------	----------

In the study of the food actually consumed by the oyster, it has been regarded, heretofore, as sufficient to remove the stomach contents by means of a pipette inserted in the mouth or through an incision in the body walls. This method extracts but an indeterminate portion of the undigested food in the stomach, a considerable proportion remaining in the folds of that organ and in the wide openings of the hepatic ducts, and it removes practically nothing of the intestinal contents. For quantitative work the method is very defective, and it is useless as a basis for those studies of food consumption and the rate of feeding which must have an important place in the oyster investigations of the future.

In order to remove the entire contents of the alimentary canal, I am now using the apparatus illustrated in figure 6, which is essentially a combination of stomach pump and enema, effectually irrigating the entire digestive tube. It consists of a reservoir (A), connected by a flexible siphon tube with a glass canula (B) ligated in the rectum, and of an aspirator (C) connected through the medium of a vial or test tube (D) with another canula (E) inserted in the mouth.

The canulas are made of glass tubing, and their tips are held for a moment in a Bunsen flame to produce a burr, which prevents their slipping from the ligature.

The operation of the apparatus is as follows: The reservoir (A) is lowered until the water surface is about level with the stage F. The oyster is carefully

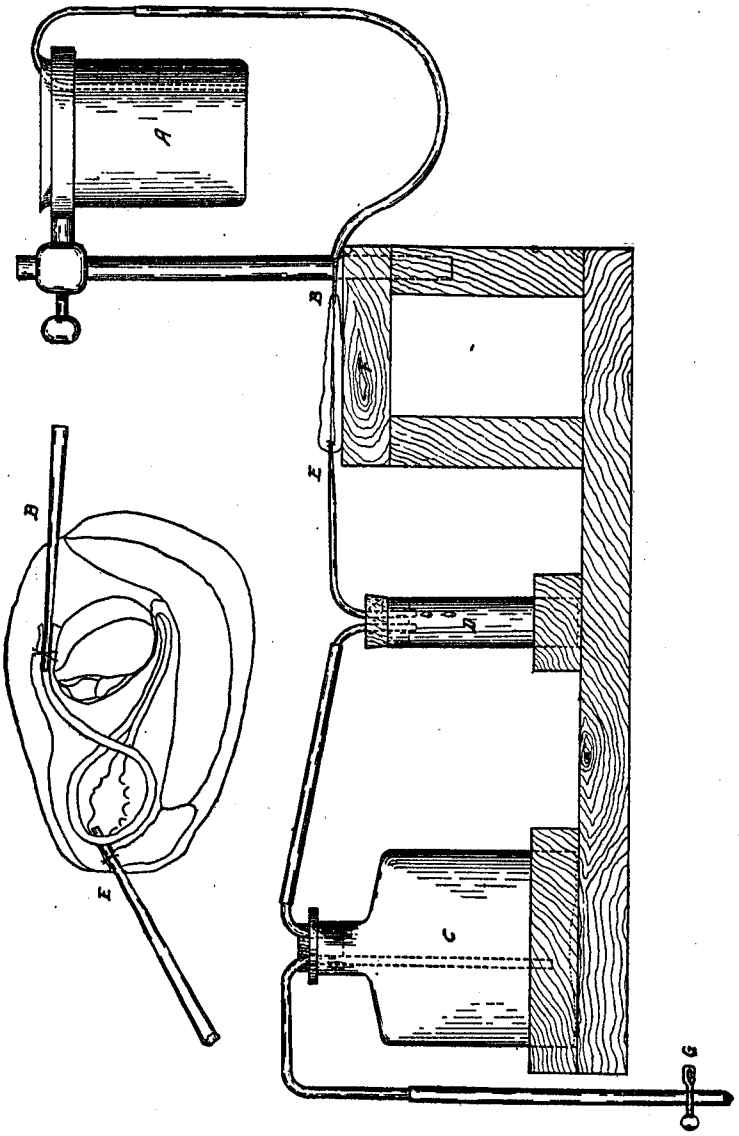


FIG. 6.—Apparatus for extracting contents of alimentary tract of oysters.

removed from its shell and placed on the stage, its rectum is slit for a distance of about one-eighth inch from the anus to facilitate the insertion of the canula, which is ligated in position by means of a needle and thread. The oral canula, which has a wider opening, is inserted in the mouth and ligated by means of a

needle and thread carried through the tissues. The pinch cock (G) is then released on the siphon of the aspirator, which exhausts the air from the vial or tube (D), draws out some of the stomach contents, and causes a slight collapse of the walls of the alimentary canal. The reservoir (A) is then raised until a flow of water is established through the rectum with a resultant slight turgescence of the intestine. There is thus established a current of water running into the rectum, through the intestine, and out of the mouth, carrying with it eventually the entire alimentary contents, which collect in the tube (D). To facilitate the dislodgment of the more or less impacted fæces, the intestine is occasionally gently tapped with the handle of a scalpel or dissecting needle. With one apparatus about six oysters per hour can be opened and operated on, and dissection shows the entire alimentary canal to be freed of contents. The contents of the tube are treated with a few drops of preservative and are concentrated, by precipitation and the removal of the supernatent water, to a standard volume of 5 or 10 cubic centimeters, after which the organisms are counted by the Rafter method and the volume calculated as previously described. It is usual to take the average of five specimens as the measure of the food content of a given lot of oysters.

For studying the rates of feeding of oysters under different environmental conditions, I have recently used the following experimental methods, which have been found effective:

Pieces of sheet rubber (dentists' "rubber dam") about 8 inches square, called "aprons," are prepared by cutting out of the middle semicircular "windows" of about 2 inches radius, over which pieces of no. 25 bolting cloth are cemented with a thick ethereal solution of rubber. A slit about 5 inches long is cut in the rubber parallel to and about ½ inch below the long diameter of the window.

A number of oysters, about 5 inches long, are then thoroughly scrubbed with a brush, washed in fresh water, the shells covered with a thin layer of Portland cement so as to fill all cavities and smooth irregularities in their surfaces, and thoroughly dried in the air.

Each is then inserted in the slit in the middle of an "apron" in such position that the edges of the slit approximate the line running from the dorsal side of the hinge to the point of insertion of the gill at the edge of the mantle. The edges of the slit are then pasted to the shell with rubber solution, care being taken to provide a small fold in the apron at the lip of the shell, to carry it around the dorsal side of the hinge so as not to interfere with the opening of the valves, and to see that there are no gaps between the shell and the rubber at any point.

Security of adhesion can be promoted by first giving the proper parts of the shell several coats of thin rubber solution, the final cementing being performed with a thick paste made by squeezing the ether-softened crude rubber through cheese cloth and reducing it to the desired consistency by shaking it in ether.

The oysters prepared in accordance with the foregoing description are then placed for about three days in filtered sea water, renewed morning and night, at the end of which time they are practically purged of food and usually gaping with hunger. The intestinal contents of five are then determined by means of the apparatus and methods already described.

The remaining oysters are now placed each in a 6-inch Petri dish, the shells resting on a wire support to raise them above the bottom and lying so that the deep valve is downward and in such position that the cloacal or excurrent chamber of the oyster lies below the apron and the oral or incurrent chamber above it. The "apron" is then confined to the sides of the dish by means of a rubber band or cord, and a layer of sand is placed over the window and the surrounding rubber to serve as a filter, as shown in figure 4. A piece of cheese cloth tied over the sand will prevent its being washed away by currents or disturbed by inquisitive fishes and crabs.

When the oysters thus prepared are transferred to their natural environment they are as free to open their valves and feed as if they had never been removed from their beds; the oral chamber is in unobstructed communication with outside waters while the excurrent chamber discharges into the Petri dish, where the fæces are retained while the expelled water passes through the filter. Oysters prepared as described have been kept under close observation under otherwise natural conditions and appeared to feed as freely and normally as neighboring specimens that had never been disturbed. The fæces drop into the dish in a little heap of demicylinders, while extraneous matter was excluded by the apron and filter.

At the end of three and six days, respectively, lots of five of these oysters are taken up, their intestinal contents removed by the method already described and added to the fæces collected from the dishes. As about 95 per cent of the food consists of diatoms whose tests pass unchanged through the alimentary canal, it is evident that by calculating the volume of the combined food organisms of the fæces and alimentary canals by the methods described and deducting the volume of the residual intestinal contents, as determined from the lot of five starved check oysters, we can arrive at a volumetric expression of the average rate of feeding. Determinations of the diatomaceous content of the surrounding water made at intervals during the experiment supply the data for the necessary correction to be applied for dead diatom frustules ingested by the oysters under experiment.

It is perhaps not necessary to use starved oysters for these experiments, but they have been used in order to insure the prompt commencement of feeding as soon as returned to the water, unstarved specimens sometimes "sulking" after repeated handling. A check upon possible error due to any abnormal

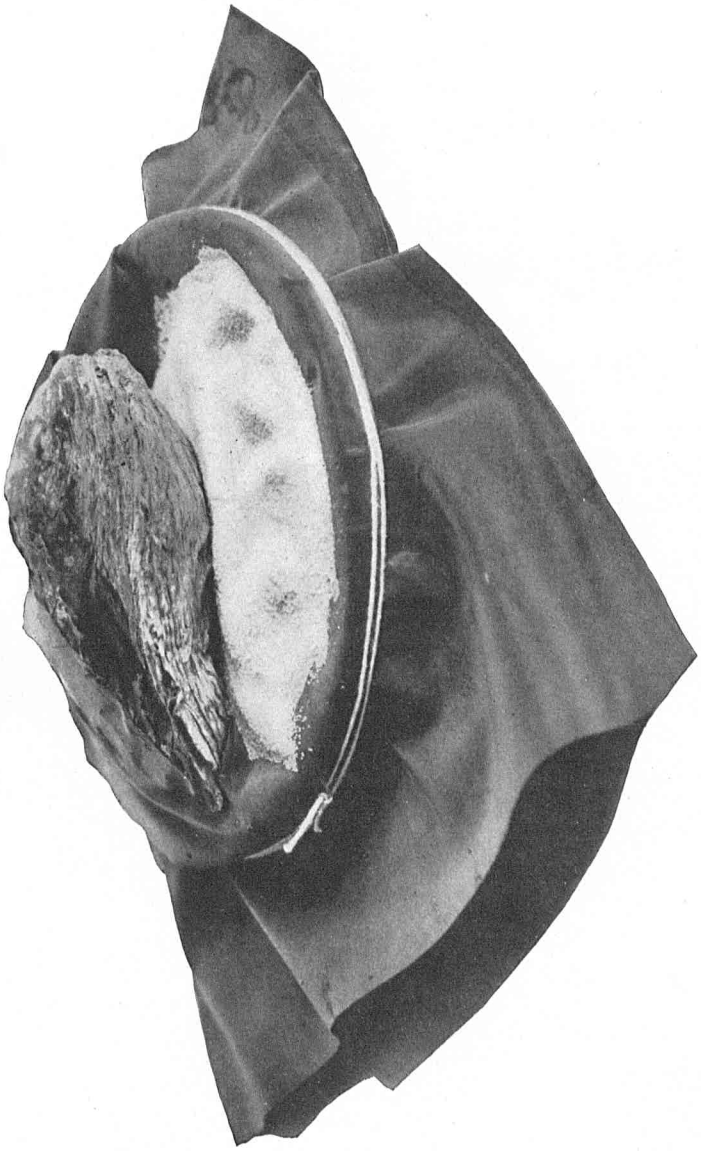
appetite at the beginning of the experiment is provided by comparison of the results obtained in the two lots fed for different periods.

My first experiments were with bolting cloth aprons, but it was found difficult to keep them covered with sand, especially close to the edges of the dish, and also to secure good adhesion between the shell and the apron. These defects in some cases permitted the infiltration of fine mud and other extraneous matter. Such difficulties have been obviated by the use of sheet-rubber "aprons" as described. The latter have been in use for four or five months and have proved satisfactory, but there has not been time for the tabulation of the quantitative results.

It is believed that the apparatus and methods of research above described furnish for the first time efficient instruments for strictly quantitative studies of the food and feeding of oysters and similar mollusca, and they also furnish data for determining the amount of water filtered through the gills. In addition to the scientific interest attaching to the studies it is believed that they will lay the foundation for valuable economic data. As is well known to those who have made a study of the oyster fisheries, much time and money is lost in futile attempts to grow oysters in localities which eventually prove unsuitable. In many cases these failures are due to a paucity of food, the oysters failing to fatten. If there could be determined the minimum food unit requisite under varying conditions of bottom, currents, and density of oyster population, the waste of time, money, and effort in useless planting could be largely prevented.

As a preliminary to the determination of such unit, it is necessary to determine with accuracy the relations existing between the oysters and the plants which constitute their diet. We must know the exact relation existing between the food consumed by oysters which are rapidly growing and fattening and by those which are not. We must determine how much more food an oyster will consume in strong currents than when living in sluggish waters equally rich per unit of volume, and it will be necessary to learn also the water food content required to supply the minimum requisite under varying conditions of current.

The experiments already conducted have shown that all of these data can be obtained with considerable accuracy by the means above described, and by conducting further research in regions such as Lynnhaven Bay, where the quantity of oysters on the bottom over considerable areas can be approximately arrived at, they can be given concrete application. The formulation of the desired unit will require much patient research and observation, the study of currents, of the behavior of oysters under various natural conditions, and possibly of the reproductive activity of diatoms and other food organisms, but it is believed that we are now in possession of instruments which warrant an attempt at the solution of the problem.



Oyster with filter apron for study of feeding.

A PLAN FOR AN EDUCATIONAL EXHIBIT OF FISHES

By Charles F. Holder

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

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A PLAN FOR AN EDUCATIONAL EXHIBIT OF FISHES.

By CHARLES F. HOLDER.

In preparing an educational collection of fishes I should divide the subject into the two classes of game fishes and economic or edible fishes.

The game fishes would include in a general way tarpon, bonito, white sea bass, black sea bass, gray and other snappers, grunts, barracuda, ladyfish, bluefish, weakfish, swordfish (*Tetrapturus*), black grouper, yellowtail, long-finned tuna, yellow-finned tuna, whitefish (California), sheepshead (Florida), swordfish, amberfish, channel bass, striped bass, salmon (various kinds), trout (all kinds), black bass, and all the game fishes that can be taken with a rod and afford good sport, eliminating all doubtful ones, such as rock bass, sunfish, etc.

I would have papier-maché casts made, showing a side of the fish colored to life, to hang on a wall; or, better, half of a fish, the skin drawn over a model of wood or plaster. A label under it would give its common and technical name, geographical range, and a number for reference to a catalogue, which would be called "Guide to the Exhibit of Fishes." Near the fish I would have a framed photograph of a living specimen, taken in a tank where the natural surroundings have been provided. At Avalon, Cal., I have such a tank about 3 feet long and 8 inches wide. I can arrange this tank with natural grouping of weed in which the fish lives, place the specimen in it, and with camera near the glass obtain a perfect picture. I have photographed all the southern California small fishes in this way. I would exhibit also a drawing of the eggs, or photograph of the nest, if the fish makes one. The catalogue number, we will say, is no. 1, "Tarpon, not edible, very valuable as game fish; scales valuable in commerce. Range, the world, in latitude ——; — species. Tackle, 9-ounce rod over 6 feet, nine-thread —— line; bait, mullet. Famous tarpon fishing grounds, Aransas Pass, Tex.; Tampico, Mexico; Florida (south coast); India. Authorities (——)." Here quote the best angling authorities and the books in which technical descriptions can be found. Also give the name of authoritative tackle dealers who are specialists; size of adult fish; food, seasons, fresh or salt water, etc. This book could be sold for cost, say 10 cents, or the data could be printed cheaply and given away. By this means a visitor walking down the room would contemplate a life-size facsimile of the fish, beside its

skeleton would read its name and geographical range, see a picture of it alive, a photograph or cut of its nest, and in the guide read in a few words its complete story and economic value; and he could, if desirous of studying it, make a note of the various works referred to. If the fish has a decided economic value, as the salmon, I would have near an album of photographs showing the complete history of the fishing on the Columbia, photographs of nets in use, canning, etc.; and if very important, show models of the nets used.

In some part of the room in the game fish section I would have a case of tackle for game fishes, tackle which could be provided by a good firm. Here would be shown the tackle for tarpon, tuna, swordfish, black sea bass, etc., according to the accepted classification. There would be a perfect 9-ounce rod, with samples of nine-thread lines from all the big makers. Then the reels used for this rod, the gaffs that go with it, photographs of the boats of the angler who follows these fishes, photographs of the fishing localities in California, Florida, and elsewhere. This would refer to a number in the book in which would be given an account of the economic value of the sport, an estimate of the amount invested in rods, reels, and lines. It could be shown, as an example, that California considers that anglers alone spend over $1,000,000 annually in that State. Each rod, reel, and line would have prices marked on them showing cost. There would be the reference to books on rod making, line manufacturing, etc., to be found in public libraries. Then would come the 6-ounce sea rod, the casting (bait) rods, and the various other rods; then salmon rods (salt-water salmon, fresh-water salmon), showing every possible rod and line. Then flies numbered on cards—English, American, Irish; spoons, imitation live baits, nets, gaffs, fish baskets; and with each rod a photograph of an angler holding that rod, showing it in action. In a word, the whole story would be told, and in the guide would be read the number of thousands of dollars invested in salmon as sport, for the renting of rivers, maintenance of hatcheries, cost of tackle. Then the trout rods of all kinds, flies, leaders, pictures showing silk, worm, or gut maker, bamboo from which the rod is made, fly hooks, creels, nets, etc., bait cans, gut leader cans, worm cans, bait minnow cans, etc.; pictures of trout, anglers casting, records of long-distance casting for accuracy, etc. Coming to black bass, there would be the same plan—rods, pictures of the black bass, skiffs of the St. Lawrence River, etc. In fact, collect about this tackle section every possible factor that will tell the story of the utilization of the fish, its value to man, the number of guides and boats employed, cost of boats, reference to manufacturers.

In this way, passing tarpon, trout, tuna, salmon, and other rods the visitor would come to boats. Here I would show a typical St. Lawrence skiff with dummy figures, the angler in the stern holding the rod, the boatman behind him. I would show also a typical Catalina launch for big game fishes, fully

equipped with figures. Then other boats could be shown in photographs. All the dealers in fishing boats would contribute cuts or photographs of their models and equipment, such as steel fishing boats, the engines used in modern fishing boats, etc.

In the section relating to bait for game fishes I would show "cast" and other nets, flying-fish gill nets, etc., used by boatmen to catch bait; the colored cotton lures used by Japanese in America for sardines, etc. In a corner I would have a complete photographic set of California game fishes, showing the angler standing with the fish, and the exact tackle used.

Next I would show photographs or models of famous angling clubhouses, as Tuna Club, Aransas Pass Tarpon Club, Asbury Park Club, New York Club, Salmon Club, California Light Tackle Club; and in the guides would be found the estimated value of club houses. For example, Avalon, Cal., has the $7,000 house of the Tuna Club; the two angling clubs there have 2,000 members and $1,500 in cups; the boatmen have $150,000 invested in angling boats, glass-bottom boats, and others, all relating to sport. Over 175,000 persons go to this place every year for the fishing alone. Transportation to the island and back costs $2.50, living expenses $2 to $10 a day, and from $5 to $10 per day is expended for hire of guides and launch; all of which amounts to a large sum, representing the economic value of the sport at this one island. A collection of photographs of the famous angling piers of the Pacific coast could be shown. Some of these cost $100,000 and are given over entirely to the angler.

In one section of the sport appliances I would show all kinds of spears, as grain, harpoons, turtle pegs, floats, lances, etc., shark harpoons, etc., and every appliance used in taking a game fish in sport. This collection could be augmented by photographs of anglers taken at the great angling tournaments of the country, as that of the California Tuna Club, from May to October, and the various casting tournaments of the trout, bass, and salmon clubs. There should be in this hall copies (photographs) of the most famous paintings of trout, salmon, etc., by the best artists, and series of photographs could be given showing the peculiar economic uses to which game and other fishes are put, such as the light of the candlefish, tarpon scales as post cards, fish scales in art, shark skin as leather, ear stones of white sea bass (California) as jewelry, etc., eyes of Santa Catalina fish as pearls, hardened by a peculiar process. In connection with the exhibit of game fish tackle I would have a case or collection called "ancient angling appliances." Here I would show the fishing tackle of the ancient Americans, as, for California, the abalone hooks, and others in all stages of making from the circular disk to the punctured disk, and then the complete hook as found in the mounds; hooks with the barb on the outside; the kelp line; spears used for fishing, bone, stone, wood; fish clubs of whalebone; in fact, make

this tell the complete story of ancient fishing methods in America. I would follow this with the fishing appliances of the last two centuries, so that it would be possible for a student or angler to observe at a glance the complete evolution of the rod, line, or hook, sinker, or the art of angling as a sport in America. He could turn from the shell hook to the perfect series of modern hooks of all kinds and varieties.

In connection with this educational display of fishes, if in a large museum, I would advocate the placing of a library of sport where the principal books on angling from the time of Walton down to to-day could be seen or consulted daily. Thus a visitor could turn from the ocular demonstration to the literature of the subject. I would also include a map or maps colored to show the localities and distribution of all game or food fishes. Thus could be seen at once the localities for tarpon, salmon, black bass, etc., as on the sportsman's or angler's map published by various railroad interests.

If the museum had special days or had lectures to teachers or others, a series of lectures could be illustrated by the stereopticon, showing the great trout streams of the country and the famous fishing grounds of California.

In the field of economic fishes, interesting histories could be given and illustrated by photographs, valuable fisheries to be given as types being the sardine fisheries and canneries of San Pedro, Cal.; the sardine fisheries of France and Italy; the tuna fisheries of Sicily; tuna fishing at Santa Catalina; jack fishing in Florida; the shad fisheries of St. Johns River, St. Marys River, etc.; the various fishes of New York; bluefish fishing in New England; the whitefish fisheries of the Great Lakes; grouper fishing in California; sand-dab fishing at Santa Catalina; the red-snapper fisheries of the Gulf of Mexico; the mackerel fisheries of Gloucester; the cod fisheries of the Grand Banks; the mullet fisheries of Florida; swordfishing off Cape Cod, Block Island, etc.; all of which have their literature, and photographs of which can be had to form a most interesting collection.

Under each fish model, or facsimile, I would place a perfect skeleton of the fish as before, with specimens of its scales mounted, and in the guide would be given brief references telling the story of the economic value of the fish, its use as food for other fishes, or as guano, as in the case of dogfishes on the Maine coast.

In this connection some data should be collected to show the work of private organizations, the national and the state governments in stocking streams and otherwise aiding the interests of the angler and commercial fisherman, so that there would be represented the evolution of angling and the complete history of the fishes, either in sport or in economics, not as a dry and prosaic exhibit, but as a great popular picture of a valuable public interest.

A PLAN FOR AN EDUCATIONAL EXHIBIT OF FISHES

By Roy W. Miner

Assistant Curator, American Museum of Natural History

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908 and awarded one-half the prize of one hundred dollars in gold offered by the Museum of the Brooklyn Institute of Arts and Sciences for the best plan for an educational exhibit of fishes

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A PLAN FOR AN EDUCATIONAL EXHIBIT OF FISHES.

By ROY W. MINER,
Assistant Curator, American Museum of Natural History.

An exhibit to be educational must be attractive as well as instructive; that is, its features must be so arranged as to stimulate attention, and when that is accomplished, to offer instruction that will be appreciated not only by the casually interested observer, but also by those who have come for the express purpose of learning, namely, the pupils and teachers of the public schools, university students, and others specially interested. Its lessons therefore must be simple, direct, and systematically arranged.

But when we endeavor to accomplish this end with an exhibition of fishes, certain special problems are involved. In the first place, the material is refractory and difficult to prepare effectively for exhibition; in the second place, the very monotony of the fish form makes the study of arrangement a matter of special concern. The consideration of these questions will be taken up as follows: (1) The nature of the material available for exhibition will be discussed; (2) various methods for arranging and labeling the exhibit will be brought forward; (3) supplementary suggestions will be offered for rendering the exhibit instructive and attractive, and (4) the paper will close with a provisional list of fishes to be exhibited.

The writer does not pretend that he has solved the question of fish exhibition, but offers these suggestions partly as the result of his attempts in this direction and partly as tentative schemes which may aid in meeting some of the difficulties.

NATURE OF THE MATERIAL TO BE EXHIBITED.

The material for exhibit may be (1) alcoholic specimens, (2) mounted and painted skins, (3) casts, (4) models, (5) skeletons, (6) colored plates and photographs, (7) groups.

(1) *Alcoholic specimens* should be used but sparingly, as for the most part they have little exhibition value because of distortion, shrinkage, and loss of color. A few good anatomical preparations might be used to show certain

peculiarities of structure (pl. CXXVII), or certain kinds of accessory material, such as sharks' and skates' eggs, for example, may add to the value of the exhibit.

A rare and interesting form like the goblin shark (*Mitsukurina owstoni*) might be shown, especially if placed beside a model of the living fish; but on the whole alcoholic specimens decidedly detract from the interest of the exhibit.

(2) *Mounted and painted skins* are sometimes effective for exhibit, especially with fish like the gar-pike (*Lepisosteus osseus*), the enameled scales of which are very successfully treated in this way. (Pl. CXXVIII.) In fact, this method may be used with many forms that have close-set, substantial scales (see yellow perch, pl. CXXIX), and is especially effective in a fish of either gaudy or dark colors (e. g., the angel-fish, or the groupers). It does not, however, effectually reproduce the smooth, gleaming, iridescent body of other fishes, as the shrinkage and hardening of the drying skin and the paint that is applied obscure the original quality of the surface. Hence, painting a skin practically amounts to nothing more than painting on an inferior surface.

(3) *Casts*, however, though but a reproduction, are faithful, if well executed, and furnish a surface much better adapted for coloring. Transparent colors over a metallic silver paint may be made to give the effects of iridescence, especially with such fish as the mackerels, pompanos, and the lookdown. But even the plaster cast, no matter how well painted, nevertheless does not perfectly succeed in giving the surface bloom of the living fish.

(4) *Models.*—Some fishes, especially the rarer forms, are hard to procure except as distorted alcoholic specimens, yet it may be desirable to represent them in the exhibit. In such cases, if sufficient data can be procured, a model may be constructed giving a restoration of the original and it may be well to exhibit the alcoholic specimen beside the model.

(5) *Skeletons.*—The exhibit may be varied and its value greatly increased by the use of mounted skeletons of typical forms. These may be correlated by appropriate labeling so as to bring out their chief differences.

(6) *Colored plates* taken from published works will add to the attractiveness of the exhibit and may be used to represent rare species which could not otherwise be shown. Many of these plates possess artistic beauty and represent the living fish better than any known method of artificial preparation. At the same time they portray the extraordinary variety of color and form possessed by the fishes of tropical seas. Some of these plates are shown in plate CXXX.

(7) *Groups.*—It is the pictorial group, however, that calls forth the greatest display of interest on the part of the visitor. Groups are the attractive feature, the drawing card of an exhibit. In bird and mammal collections they have been employed with great success. There are, however, comparatively few fish groups, and in these the mistake is often made of producing an aquarium

effect without a central point of interest. A fish or school of fish swimming among seaweed and rocks is not sufficient excuse for the time and expense incurred in producing a fish group. There must be a central idea or theme, such as the life history of some interesting species, an instance of peculiar breeding habits, or an illustration of some biological phenomenon, like adaptation, protective coloration, symbiosis, or sexual dimorphism, which can be emphasized in a descriptive label for the benefit of the visitor. Instead of being merely a spectacle, the group now has educational value; while it is the pictorial effect which at first arrests the attention of the observer, the lesson it has to teach is impressed on the mind more vividly than by any other method. (See appendix, p. 1340, for specific suggestions for these groups.)

The nature of a fish exhibit is such that no one kind of material should be used to the exclusion of the rest. To show to the best advantage it should be so arranged that casts are interspersed with mounted skins, skeletons, and colored plates, while the monotony of single specimens is broken by groups at judicious intervals.

METHODS OF ARRANGEMENT.

In general, the synoptic or systematic arrangement is the best to follow. This is most readily effected by using single specimens in the bulk of the exhibit, which should, however, be varied with groups and accessory exhibits of a faunistic, commercial, and biological character. The synoptic series has great teaching value for the student of elementary zoology, since the orderly grouping of fishes carries with it an orderly grouping of facts readily retained by the mind. It is true that many casual visitors may not appreciate the advantages of the system, but when well arranged it sets forth, rather than obscures, the attractive and striking forms. For the benefit of such visitors the individual labels are made clear, simple, and interesting, while those placed with the groups are particularly adapted to their requirements. The student, however, needs a classification that is more in line with his studies, and this is furnished by the synoptic method of arrangement.

The classification to be followed will vary of course according to individual judgment. The writer has found that a combination of the American system of Jordan and Evermann with the English system of Boulenger is best adapted for purposes of exhibition. Valuable help in this connection has been derived from W. K. Gregory's article on "The Orders of Teleostomous Fishes."[a] The scheme of classification will be given later in connection with the provisional list of fishes already referred to.

Three methods of arranging the exhibit in the hall are offered in the present paper, as follows: (1) the corridor arrangement; (2) the alcove arrangement; (3) the gallery arrangement.

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[a] Annals New York Academy of Sciences, vol. XVII, part II, no. 3, p. 437–508, pl. XXIX–XXX.

(1) *The corridor arrangement.*—This method is in use in the American Museum of Natural History, where the fish exhibit is at present placed in an L-shaped corridor (text fig. 1) connecting two wings of the museum. Here the cases are placed in end-to-end series along the walls on both sides, an arrangement well adapted for this style of hall. The cases for the synoptic series are of similar size and shape, of the variety shown in plate CXXVI. The two doors in front open outward. The back is solid and covered with a fabric (in this instance a blue denim), which sets off well the varied colors of the fishes. The specimens are attached directly to the back of the case and are removable. Nineteen cases are used at present for the synoptic series.

The main features of the arrangement and classification may be readily seen in the accompanying plates. The class Pisces is defined in a general label (pl. CXXXI) to be found at the entrance of the hall and also at intervals throughout the exhibit. Its subdivision into three subclasses is indicated at the bottom of the label. The parts of the hall devoted to the individual subclasses are shown by the large signs suspended from the ceiling (pl. CXXXII), while the orders are identified by

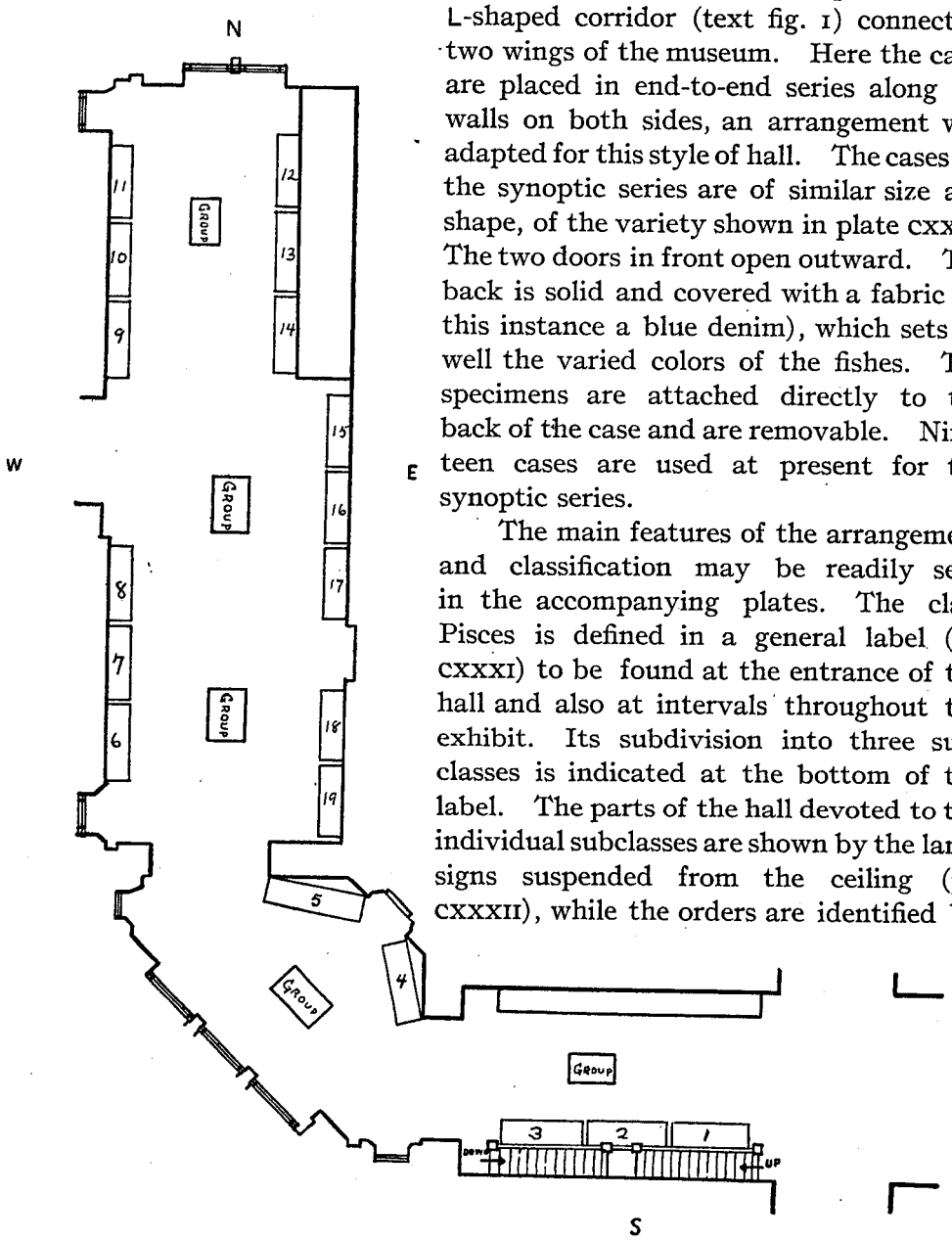

FIG. 1.—Plan of fish hall in the American Museum of Natural History, illustrating the "corridor method" of arranging the cases. The synoptic cases are numbered 1 to 19. The illustrative group cases are represented in the middle of the corridor.

small white-lettered boards at the top of each case (pl. CXXXIII). A case may contain as many as four or five suborders, or if many forms are shown, as in the Perciformes (pl. CXXX), or if the specimens are large, as in the Selachii (pl. CXXXV), two cases may be devoted to a single suborder. The location of each suborder is indicated by black lettering on the glass doors of the cases (pl. CXXXVI), and a definition of the group, together with a list of such of its included families as are represented in the exhibit, are found in descriptive case-labels hung on the doors of the cases (see pls. CXXXVI, CXXXVIII, and fig. 4, p. 1324).

The families are separated from each other by narrow bands of adhesive tape (pl. CXXXVII), harmonizing in color with the background, and are identified by small family-labels (text fig. 2) giving both the popular and scientific names and fastened to the back of the case in each family group. Under each specimen is a special descriptive label (text fig. 3) which gives the popular name

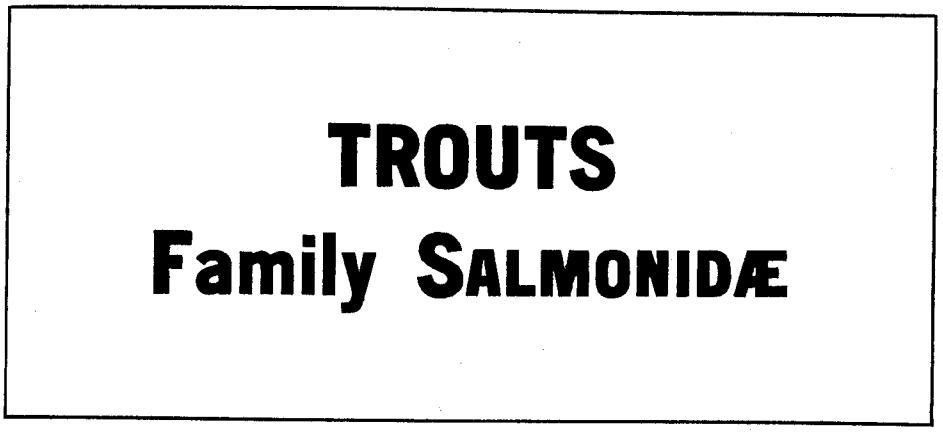

FIG. 2.—Example of family label.

in prominent type, while the scientific name is printed in smaller italic characters below. The name is followed by a brief popular description of the fish's habits, peculiarities, economic value, and geographical distribution. No effort, however, has been made to exhibit anything like a complete fish fauna, as the exhibit is entirely synoptic in character, only the principal families being shown and the typical and most interesting species in each family. Geographical distribution maps are being provided for the typical forms. Through the center of the hall will be placed groups illustrating life habits and other biological features. These will be of the general style shown in plate CXXXII. None are completed as yet, but in their places a few reptile groups have been installed temporarily.

The arrangement of the fish plates may be seen in plates CXXX, CXXXIII, CXXXIV, CXXXVI, and CXXXVII. They are mounted in passe-partout style and are hung to the backs of the cases in their proper synoptic position.

Very large and striking specimens are grouped in panels or friezes extending the length of the hall in the space between the ceiling and the tops of the cases (pl. CXXXVIII).

The labeling in this hall is based on the principle that since the exhibit has a double aim, being intended for both the general public and the students and instructors of the city schools and colleges, there should be a double system of labeling to meet the needs of the two classes. To this end the method of utilizing the exhibit by each class has been studied.

RAINBOW TROUT

Salmo irideus Gibbons

The so-called Rainbow Trout comprise several closely related species, and are noted for their gameness, dash, and beauty. They are found in mountain streams of the Pacific States and on the slopes of the Sierra Nevada Mountains. The typical Rainbow Trout (*Salmo irideus*) is found only in small brooks of the Californian Coast Ranges, and considering its size is perhaps the gamest of the series. It takes the fly with great readiness, even leaping from the water to meet it, and the struggle that follows is sure to be a long and keen one.

The weight of the Rainbow Trout varies from a half to 5 or 6 pounds, though the latter weight is exceptional.

FIG. 3.—Example of popular label for individual specimens.

The average person who enters the hall simply to see the exhibit is attracted first by the group cases. Then he passes before the synoptic cases, stopping here and there as his eye is attracted by some specimen. That is, it is the pictorial effect of the groups, or the striking features of some specimen, that draws his attention. In either case, if his interest is sufficiently aroused, he reads more or less of the accompanying label. Therefore the pictorial group labels and those with the individual specimens should be popular in character to meet his requirements (see fig. 3, p. 1322).

The elementary student of fishes, on the other hand, requires a systematic presentation of the subject, which will supplement and illustrate his studies.

To him the exhibit should appeal somewhat as an enlarged text-book, with object lessons for illustrations. It is to the elementary student, therefore, that the systematic arrangement is primarily directed—though it doubtless has its unconscious effect of orderliness upon the casual visitor as well—and the labels which bring out this classificatory side are aimed more directly at the student's understanding. Such are the labels indicating the larger groups, and especially the descriptive case labels defining the orders and suborders (see fig. 4, p. 1324). As these are based on anatomical features, especially those of the skeleton, they are necessarily more technical. An attempt, however, has been made to simplify them as much as possible, and to eliminate or explain technical terms. These labels also endeavor to bring out the phylogenetic relationship of the larger groups.

Accessory labels are freely used (fig. 5, p. 1325) to illustrate special features of biological interest.

(2) *The alcove arrangement.*—This is really an adaptation of the preceding method to a museum hall lighted by many windows from the side, thus permitting the cases to be placed alcove fashion with their ends to the windows, as in figure 6, page 1326. With this arrangement, instead of having a solid back, the cases are provided with glass on both sides, while a solid partition is constructed midway between, thus making it possible to utilize both sides of the case, in two adjoining alcoves.

The partition is covered with a colored fabric, e. g., blue denim, as in the preceding arrangement, and is framed in at top, bottom, and sides by light boards (fig. 7, p. 1327) inclined at an angle of about 45 degrees and wide enough to slant from the partition to the front edge of the case area, thus giving a beveled or countersunk effect. These inclined surfaces are covered with the same material as the partition and may be utilized for accessory labels, diagrams, etc. The bottom incline may also be utilized for such specimens as flatfishes, which would appear out of place when hung on a vertical surface.

THE TROUT-LIKE FISHES

Order MALACOPTERYGII

Suborder Isospondyli

Families

Elopidæ	*Clupeidæ*
Albulidæ	*Salmonidæ*
Mormyridæ	*Thymallidæ*

The fishes of this group include many of the most important food and game fishes, such as Tarpons, Trouts and Salmons, and the Herrings and Sardines. They are distinguished from the Ostariophysi (Case 6) by having the four anterior vertebræ of the spinal column unaltered and separate, and from the Eels (Apodes—Case 9) by the complete and well-developed skull. These characters, together with the soft-rayed dorsal fin and the cycloid scales—rounded in form and with smooth edges—also distinguish them from the Spiny-Rayed Fishes (Order Acanthopterygii—Case 9–14), most of which have ctenoid scales (i. e., scales rounded but with finely toothed edges) and fins partly supported by spines.

Like the Ostariophysi (Case 9) and the Pikes (Case 11) the Trouts have their ventral fins well separated from the pectorals and placed far back on the abdomen. This is a primitive arrangement and may be seen in all the lower fishes (e. g., the Sharks, Lungfishes, and Ganoids) and contrasts with the more specialized Acanthopterygian condition, in which the ventrals are attached close to the pectorals.

FIG. 4.—Example of descriptive case-label defining a suborder.

The fish in this case illustrate the natural phenomenon of degeneration, or rather specialization to an inactive life. The five suborders represented form a graded series of steps leading from fishes adapted to an extremely active existence down to relatively inactive, sluggish forms, incapable of rapid motion, but protected from their enemies by coats-of-mail or by the poisonous alkaloids in their flesh.

In the left-hand section may be seen the large, active wrasse-fishes and parrot-fishes (**Suborder PHARYNGOGNATHI**) well furnished with means of locomotion (i. e., fins), and with large gill-openings which permit the rapid oxygenation of the blood necessary to swiftly moving animals. The large cycloid scales are evenly distributed over the body and allow the greatest flexibility of movement. The teeth are adapted for seizing, and indicate carnivorous habits. Everything seems adapted to an extremely active life. On the other hand, there is a significant tendency toward fusion in certain bones of the skull, and (e. g., the parrot-fishes) in the teeth as well. This tendency is still more evident in the Scaly-Fin group (**Suborder SQUAMIPINNES**), where it appears in the fusion of the upper jaw elements, and in the gradual reduction of the gill-slits and the ventral fins. The body becomes laterally compressed and the transition to the type found in the next suborder (**SCLERODERMI**) is very clear. This suborder is represented in the upper right-hand section of this case by the trigger-fishes and file-fishes. Here the same flattened form is seen, and the reduction of the spinous dorsal and ventral fins to a few stiff spines is very evident. The bones of the skull have further fused, the gill-opening is a mere slit, and the upper jaw-teeth are compressed or even completely united, while the scales are reduced till, in the file-fishes, they become mere prickles. With the trunk-fishes (**Suborder OSTRACODERMI**) an immovable box-like armor takes the place of scales; the bones of the skull are almost completely joined; the gill-slit is extremely small; while the ribs and other skeletal elements have been practically reduced to a mere bony axis bracing the weak, soft dorsal, anal, and caudal fins. The spinous dorsal and the ventral fins have disappeared.

Finally, in the puffers (**Suborder GYMNODONTES**) we have the last stage of degeneration or specialization to a sluggish existence. Scales, spinous dorsal fin, and distinct teeth are gone. Pelvis, ribs, and caudal vertebræ are degenerate and, in extreme forms, even absent. The remaining fins, like those of the trunk-fish, are weak, and the body incapable of rapid motion, while the leathery skin, power of inflation, and poisonous flesh act as protective factors. The largest example of the group, the head-fish or mola, sluggishly floats on the surface of the sea, leading an inactive and lazy existence.

FIG. 5.—An accessory label to illustrate a biological phenomenon.

Each alcove should be devoted to one or two related subdivisions of fishes, arranged synoptically, as already described, and in the center of the alcove may

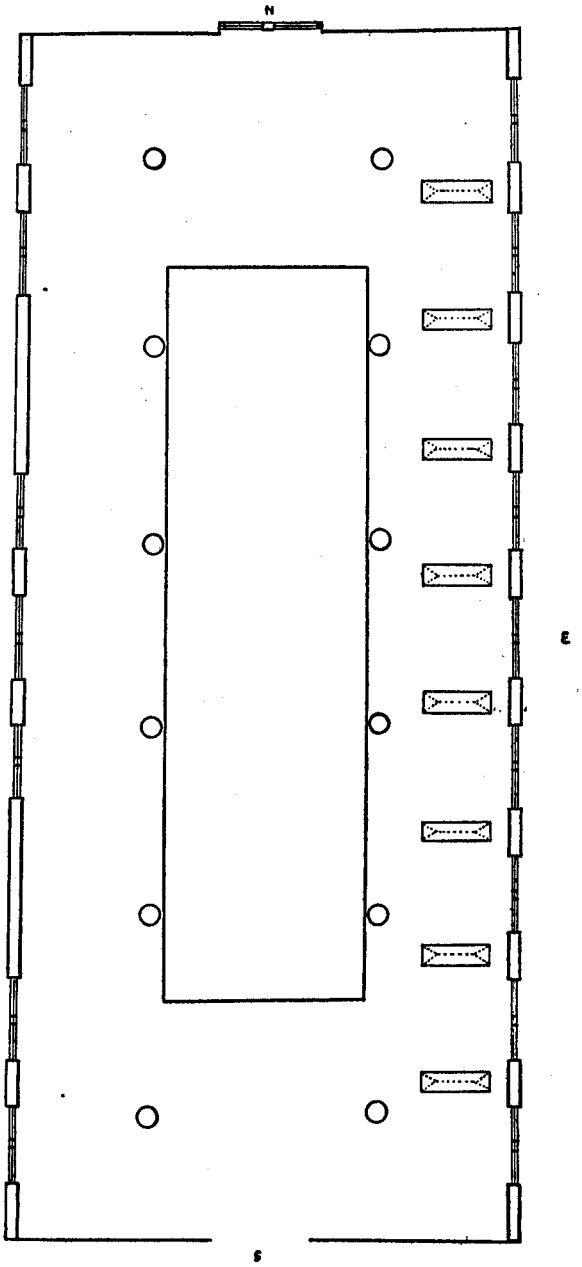

FIG. 6.—Plan showing hall adapted to the "alcove arrangement" of cases.

be placed a group case illustrating some features connected with one or more of the species in the surrounding cases.

(3) *The gallery arrangement.*—The idea for this somewhat more elaborate method was suggested by the gallery of habitat bird groups in the American Museum, but differs from it in that it combines a synoptic with a group exhibit. It is adapted for a gallery surrounding a hall occupying the space of two stories, such as occurs in most museums. At the side of the gallery farthest from the windows is a continuous screen to cut off all light from other parts of the hall (fig. 8, p. 1328), while the window side is entirely taken up with a series of exhibits, framed in by a casing, which, while it shuts off the light from the gallery, yet diverts it so as to illuminate the exhibit from within.

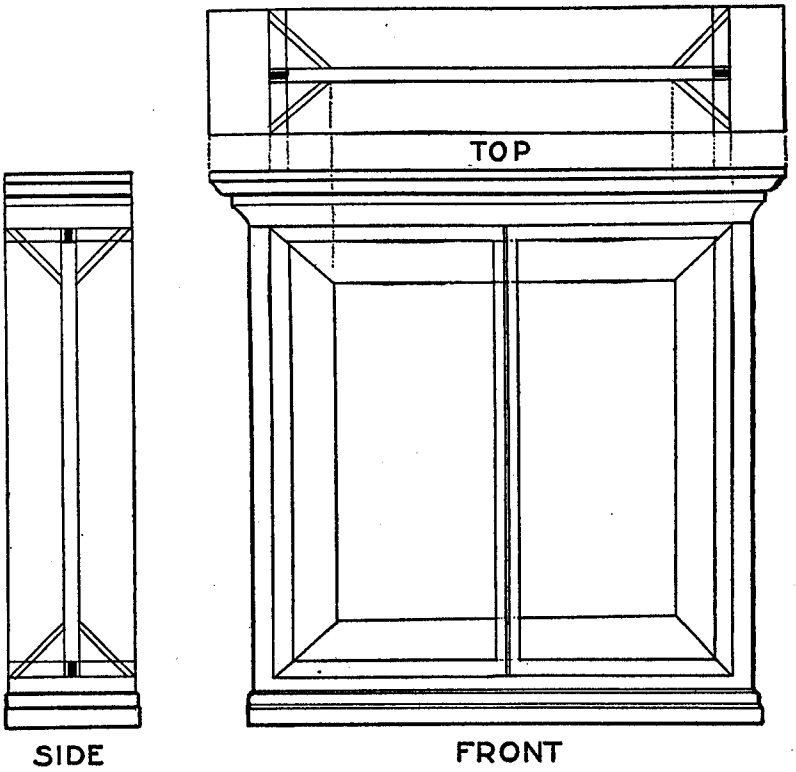

FIG. 7.—Diagram of fish case to be used in hall with "alcove arrangement," showing central partition with countersunk effect.

The adaptation of this method to a fish exhibit is shown in figure 9, page 1329. Through the opening (*A*) is seen a pictorial fish group representing some interesting feature. In the sketch an exhibit of fish life in the vicinity of a coral reef in tropical waters has been indicated in outline. This group is the central feature of that portion of the synoptic exhibit containing the suborders Pharyngognathi, Squamipinnes, Sclerodermi, and Gymnodontes, which contain so many of the brilliantly colored tropical species.

The panels *B* and *C* are devoted to the synoptic portion of the exhibit and contain representative species of the typical families included in the above-mentioned suborders. These specimens are fastened to a cloth-covered backing

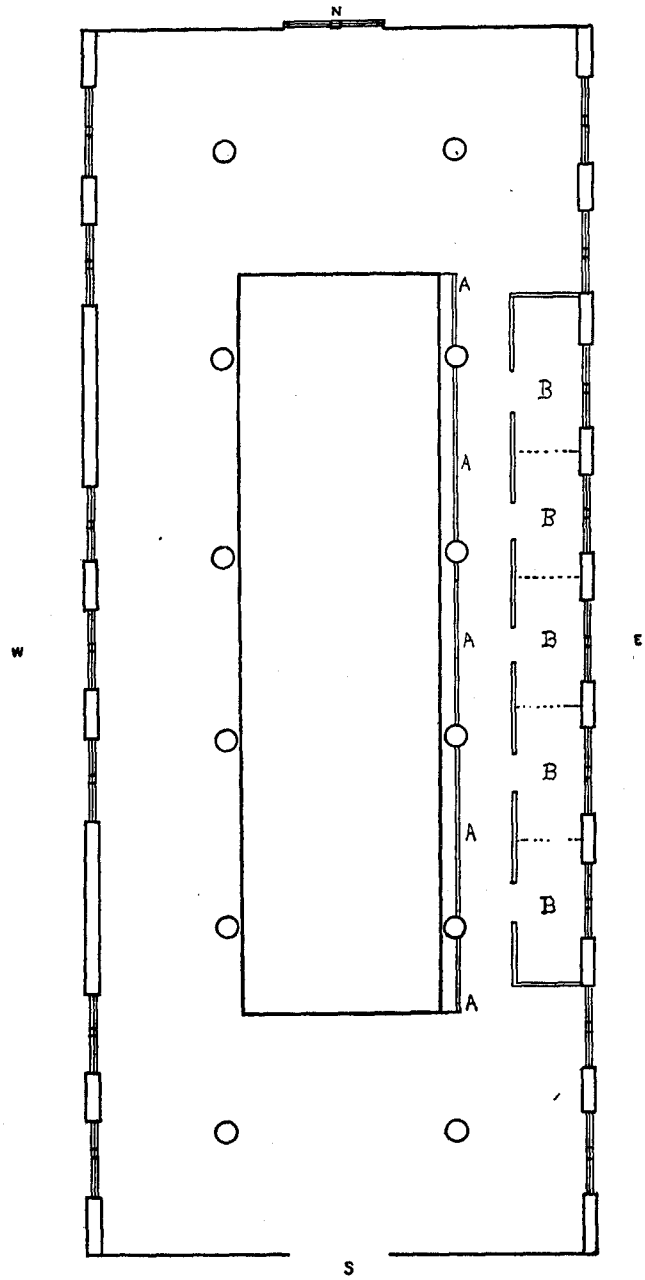

FIG. 8.—Plan illustrating the "gallery arrangement" of fish exhibits, showing screen (A) and row of group exhibits (B) of the kind shown in figure 9, page 1329.

placed just far enough behind the glass to comfortably accommodate the fish and show them off well. Small labels identify each specimen. The names of the suborders are lettered in black on the glass. The panels are lighted electric-

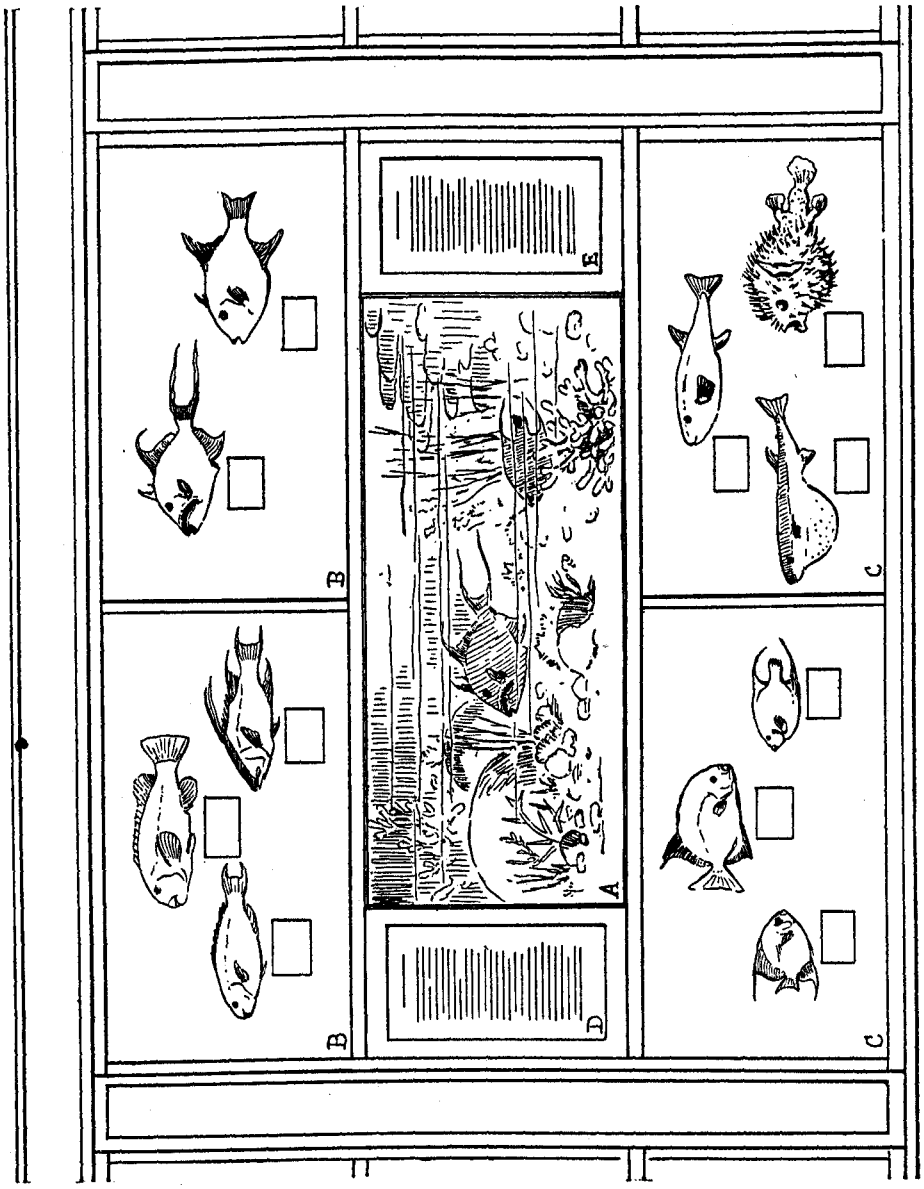

FIG. 9.—Sketch illustrating combination of pictorial fish groups, with synoptic method of exhibition. (A) Group illuminated from within. (B, C) Panels devoted to synoptic portions of the exhibit. (D, E) Illuminated ground glass descriptive labels.

ally from above and below. At *D* and *E* are placed illuminated ground glass descriptive labels defining the synoptic divisions and describing the interesting features of the central group (*A*). The light from the windows behind may

be utilized to a large extent during the daytime for illuminating these exhibits with the help of properly arranged reflectors. Colored plates and photographs may be used to good effect on the walls of the hall at the ends of the gallery. (The two latter methods are offered as tentative suggestions for adapting to other museum conditions some of the ideas contained in method no. 1.)

SUPPLEMENTARY SUGGESTIONS.

(1) *Small fishes.*—Some species which should be represented in a synoptic series are so small that they would appear lost if placed directly against the case background. A good setting for such forms is shown in plate CXL. Here two specimens of *Hippocampus hudsonius* are mounted against a colored plaster panel, modeled in relief to give a suggestion of seaweed.

(2) *Small balanced aquaria* of living fishes may be used with good effect at or near the windows of the exhibition hall (pl. CXXXII). They may be either fresh water or marine, and forms may be exhibited from time to time that will be objects of interest in themselves. In such instances, small descriptive labels may be placed near the aquaria to bring out the interesting features. These labels should have removable backs to permit the insertion of new descriptive material as the fish exhibited are changed.

(3) *Colored plates* like those used in the synoptic series may be arranged in panels as wall decorations, as in plate CXXXII. These panels should harmonize with the general color scheme of the exhibit setting and may be devoted to the fauna of specific regions.

(4) *Photographs* of living fish, or illustrating the commercial fisheries, etc., may be used to add interest and attractiveness to the halls.

(5) A *plan* of the hall should be placed at the entrance to aid the visitor in orienting himself and in finding groups of which he may be in search.

(6) Many of the descriptive labels may be effectively illustrated either by indexed outline drawings for the sake of added clearness (pl. CXXXI) or by water-color sketches illustrating interesting habits (pl. CXXXIX).

(7) A *special exhibit* of the fishes most abundant locally could be made an attractive feature, or this could be arranged as a seasonal exhibit by changing the fishes to correspond with their seasonal abundance in local waters.

(8) Single specimens may sometimes be artistically mounted on a pedestal, with just a suggestion of accessory setting, as in plate CXLI.

PROVISIONAL LIST OF FISHES FOR A SYNOPTIC EXHIBIT.

In the following list selection has been made from species which would fall under the five following classes: (1) Typical forms; (2) commercial forms; (3) peculiar and striking forms; (4) forms with interesting life-habits; (5) forms valuable for illustrating biological phenomena like protective coloration, symbi-

osis, adaptation, etc. Only a tentative selection is given, and many of the species named could be replaced by other forms.

The classification used in the list, as above mentioned, is a combination of the English and American systems, adapted for exhibition purposes.

It is natural that particular emphasis should be laid on North American fishes, and these are chosen to represent the families where possible. More room is also given to commercial fishes than to others.

CLASS PISCES.

SUBCLASS ELASMOBRANCHII.

ORDER PLAGIOSTOMI.

Suborder Selachii.

Family Notidanidæ.
- *Notidanus (Hexanchus) griseus* (cow shark).

Family Scylliidæ.
- *Ginglymostoma cirratum* (nurse shark).

Family Galeidæ.
- *Mustelus canis* (dog shark).
- *Carcharinus lamia* (cub shark).

Family Carchariidæ.
- *Carcharias littoralis* (sand shark).
- *Prionace glauca* (great blue shark).
- *Scoliodon terræ-novæ* (sharp-nosed shark).

Family Sphyrnidæ.
- *Sphyrna zygæna* (hammer-head shark).
- *Sphyrna tiburo* (bonnet-head shark).

Family Alopiidæ.
- *Alopias vulpes* (thresher shark).

Family Lamnidæ.
- *Carcharodon carcharias* (man-eater shark).
- *Lamna cornubica* (porbeagle).

Family Cetorhinidæ.
- *Cetorhinus maximus* (basking shark).

Family Squalidæ.
- *Squalus acanthias* (dogfish).

Family Rhinidæ.
- *Rhina squatina* (angel shark).

Suborder Batoidei.

Family Pristidæ.
- *Pristis pectinatus* (common sawfish).

Family Rhinobatidæ.
- *Rhinobatus lentiginosus* (guitar-fish).

Family Raiidæ.
- *Raia erinacea* (common skate).
- *Raia lævis* (barndoor skate).

Family Torpedinidæ.
- *Tetronarce occidentalis* (torpedo).

Family Dasyatidæ.
- *Dasyatis centrura* (sting ray).

Family Myliobatidæ.
- *Myliobatis freminvillei* (eagle ray).
- *Manta birostris* (sea devil).

ORDER HOLOCEPHALI.
Suborder Chimæroidei.
Family Chimæridæ.
Chimæra monstrosa (chimæra).
Chimæra colliei (ratfish).
Chimæra purpurascens (purple chimæra).

SUBCLASS DIPNEUSTI.

ORDER MONOPNEUMONA.
Family Ceratodontidæ.
Neoceratodus forsteri (Australian lungfish).

ORDER DIPLOPNEUMONA.
Family Lepidosirenidæ.
Protopterus dolloi (African lungfish).
Protopterus annectens (African lungfish).
Protopterus æthiopicus (African lungfish).
Lepidosiren paradoxa (South American lungfish).

SUBCLASS TELEOSTOMI.

ORDER CROSSOPTERYGII.
Suborder Cladistia.
Family Polypteridæ.
Polypterus bichir (bichir).

ORDER CHONDROSTEI.
Family Polyodontidæ.
Polyodon spathula (paddlefish).
Family Acipenseridæ.
Acipenser sturio (common sturgeon).
Acipenser rubicundus (lake sturgeon).
Scaphirhynchus platyrhynchus (shovel-nose sturgeon).

ORDER HOLOSTEI.
Suborder Rhomboganoidea.
Family Lepisosteidæ.
Lepisosteus osseus (long-nose gar).
Lepisosteus platostomus (short-nose gar).
Lepisosteus tristæchus (alligator gar).
Suborder Cycloganoidea.
Family Amiidæ.
Amia calva (bowfin).

ORDER OSTARIOPHYSI.
Suborder Nematognathi.
Family Siluridæ.
Ameiurus catus (white cat).
Felichthys marinus (gaff-topsail).
Ictalurus punctatus (channel cat).
Ameiurus nebulosus (common bullhead).
Schilbeodes insignis (mad tom).
Suborder Eventognathi.
Family Catostomidæ.
Catostomus commersonii (common sucker).
Family Cyprinidæ.
Moxostoma aureolum (common redhorse).
Ictiobus cyprinella (red-mouth buffalo-fish).

ORDER OSTARIOPHYSI—continued.
- Suborder Eventognathi—Continued.
  - Family Cyprinidæ—Continued.
    - *Cyprinus carpio* (golden carp).
    - *Campostoma anomalum* (stone roller).
    - *Semotilus atromaculatus* (horned dace).
    - *Notropis* sp. (shiner).
    - *Rhinichthys atronasus* (black-nose dace).
- Suborder Heterognathi.
  - Family Erythrinidæ.
    - *Macrodon microlepis* (trahira).
  - Family Characinidæ.
    - *Brycon dentex* (characin).
    - *Hydrocyon goliath* (characin).
    - *Tetragonopterus argentatus* (sardina blanca).
- Suborder Gymnonoti.
  - Family Gymnotidæ.
    - *Giton fasciatus* (carapo).
    - *Gymnotus electricus* (electric eel).

ORDER APODES.
- Suborder Colocephali.
  - Family Murænidæ.
    - *Lycodontis moringa* (common spotted moray).
    - *Lycodontis ocellatus* (spotted moray).
    - *Lycodontis funebris* (black moray).
    - *Muræna retifera* (moray).
    - *Echidna nebulosa* (moray).
- Suborder Enchelycephali.
  - Family Anguillidæ.
    - *Anguilla chrysypa* (American eel).
  - Family Leptocephalidæ.
    - *Leptocephalus conger* (conger eel).
  - Family Nemichthyidæ.
    - *Nemichthys scolopæus* (snipe eel).
  - Family Myridæ.
    - *Myrophis punctatus* (worm eel).
  - Family Ophichthyidæ.
    - *Ophichthys gomesii* (sea serpent).

ORDER MALACOPTERYGII.
- Suborder Isospondyli.
  - Family Elopidæ.
    - *Tarpon atlanticus* (tarpon).
    - *Elops saurus* (ten-pounder).
  - Family Albulidæ.
    - *Albula vulpes* (ladyfish).
  - Family Hiodontidæ.
    - *Hiodon tergisus* (moon-eye).
  - Family Clupeidæ.
    - *Clupea harengus* (common herring).
    - *Alosa sapidissima* (American shad).
    - *Pomolobus pseudoharengus* (alewife).
    - *Brevoortia tyrannus* (menhaden).

ORDER MALACOPTERYGII—continued.
- Suborder Isospondyli—Continued.
  - Family Salmonidæ.
    - *Coregonus clupeiformis* (common whitefish).
    - *Oncorhynchus tschawytscha* (quinnat salmon).
    - *Salmo irideus* (rainbow trout).
    - *Salmo sebago* (landlocked salmon).
    - *Salmo salar* (common Atlantic salmon).
    - *Salvelinus fontinalis* (brook trout).
    - *Cristivomer namaycush* (Mackinaw trout).
  - Family Thymallidæ.
    - *Thymallus ontariensis* (Michigan grayling).
  - Family Argentinidæ.
    - *Osmerus mordax* (American smelt).

ORDER MESICHTHYES.
- Suborder Haplomi.
  - Family Synodontidæ.
    - *Synodus varius* (lizard-fish).
    - *Synodus fœtens* (lizard-fish).
  - Family Ipnopidæ.
    - *Ipnops murrayi* (lantern-eye).
  - Family Dalliidæ.
    - *Dallia pectoralis* (Alaska blackfish).
  - Family Esocidæ.
    - *Umbra pygmæa* (eastern mud minnow).
    - *Esox masquinongy* (muskallunge).
    - *Esox reticulatus* (pickerel).
  - Family Pœciliidæ.
    - *Fundulus heteroclitus* (common killifish).
    - *Cyprinodon variegatus* (sheepshead minnow).
    - *Anableps dovii* (four-eyed fish).
    - *Heterandria formosa.*
  - Family Amblyopsidæ.
    - *Typhlichthys subterraneus* (small blindfish).
    - *Amblyopsis spelæus* (blindfish of Mammoth Cave).
- Suborder Synentognathi.
  - Family Belonidæ.
    - *Tylosurus caribbæus* (needlefish).
  - Family Hemirhamphidæ.
    - *Hyporhamphus roberti* (common half-beak).
    - *Scombresox saurus* (saury).
  - Family Exocœtidæ.
    - *Fodiator acutus* (sharp-nose flying-fish).
    - *Exocœtus volitans* (flying-fish).

ORDER THORACOSTRACI.
- Suborder Hemibranchii.
  - Family Gasterosteidæ.
    - *Gasterosteus bispinosus* (common eastern stickleback).
    - *Gasterosteus aculeatus* (European stickleback).
  - Family Fistulariidæ.
    - *Fistularia tabacaria* (trumpet-fish).

ORDER THORACOSTRACI—continued.
- Suborder Lophobranchii.
  - Family Syngnathidæ.
    - *Siphostoma fuscum* (common pipefish).
    - *Hippocampus hudsonius* (common sea-horse).
    - *Hippocampus stylifer* (sea-horse).
    - *Hippocampus punctulatus* (caballeto de mar).
    - *Hippocampus zosteræ* (sea-horse).

ORDER ACANTHOPTERYGII.
- Suborder Percesoces.
  - Family Atherinidæ.
    - *Menidia gracilis* (silverside).
  - Family Mugilidæ.
    - *Mugil cephalus* (common mullet).
    - *Mugil curema* (white mullet).
  - Family Sphyrænidæ.
    - *Sphyræna borealis* (northern barracuda).
  - Family Mullidæ.
    - *Upeneus maculatus* (red goatfish).
    - *Upeneus martinicus* (yellow goatfish).
  - Family Holocentridæ.
    - *Holocentrus ascensionis* (squirrel-fish).
  - Family Ammodytidæ.
    - *Ammodytes americanus* (sand launce).
- Suborder Scombriformes.
  - Family Scombridæ.
    - *Gymnosarda pelamis* (oceanic bonito).
    - *Thunnus thynnus* (tunny).
    - *Scomber scombrus* (common mackerel).
    - *Sarda sarda* (bonito).
    - *Scomberomorus maculatus* (Spanish mackerel).
  - Family Trichiuridæ.
    - *Trichiurus lepturus* (cutlass-fish).
  - Family Istiophoridæ.
    - *Istiophorus nigricans* (sailfish).
  - Family Xiphiidæ.
    - *Xiphias gladius* (common swordfish).
  - Family Carangidæ.
    - *Oligoplites saurus* (leather-jacket).
    - *Caranx hippos* (crevallé).
    - *Caranx crysos* (runner).
    - *Vomer setipennis* (moonfish).
    - *Selene vomer* (lookdown).
    - *Trachinotus goodei* (great pompano).
    - *Trachinotus carolinus* (common pompano).
  - Family Pomatomidæ.
    - *Pomatomus saltatrix* (bluefish).
  - Family Coryphænidæ.
    - *Coryphæna hippurus* (common dolphin).
  - Family Stromateidæ.
    - *Poronotus triacanthus* (butterfish).
  - Family Rachycentridæ.
    - *Rachycentron canadum* (sergeant-fish).

ORDER ACANTHOPTERYGII—continued.

Suborder Perciformes.

Family Centrarchidæ.

Centrarchus macropterus (round sunfish).
Lepomis auritus (redbreast bream).
Lepomis pallidus (blue-gill).

Family Percidæ.

Stizostedion canadense (sauger).
Perca flavescens (yellow perch).
Ammocrypta pellucida (sand darter).

Family Serranidæ.

Roccus chrysops (white bass).
Roccus lineatus (striped bass).
Morone americana (white perch).
Bodianus fulvus punctatus (nigger-fish).
Epinephelus striatus (Nassau grouper).
Epinephelus adscensionis (rock hind).
Epinephelus guttatus (red hind).
Epinephelus morio (red grouper).
Garrupa nigrita (black jewfish).
Centropristes striatus (black sea bass).

Family Priacanthidæ.

Priacanthus arenatus (catalufa).

Family Lutianidæ.

Neomænis griseus (gray snapper).
Neomænis guttatus (flamenco).
Neomænis jocu (dog snapper).
Neomænis apodus (schoolmaster).
Lutianus aya (red snapper).
Lutianus analis (mutton-fish).
Ocyurus chrysurus (yellow-tail).

Family Hæmulidæ.

Hæmulon album (margate-fish).
Hæmulon plumieri (common grunt).
Bathystoma rimator (red-mouth grunt).
Orthopristis chrysopterus (hogfish).

Family Sparidæ.

Calamus bajonado (jolt-head porgy).
Stenotomus chrysops (common scup).
Archosargus probatocephalus (sheepshead).
Archosargus unimaculatus (salema).

Family Gerridæ.

Gerres olisthostomus (Irish pompano).

Family Sciænidæ.

Cynoscion regalis (common weakfish).
Cynoscion nebulosus (spotted weakfish).
Bairdiella chrysura (mademoiselle).
Sciænops ocellatus (channel bass).
Micropogon undulatus (croaker).
Menticirrhus americanus (Carolina whiting).
Menticirrhus saxatilis (kingfish).
Pogonias cromis (drum).
Aplodinotus grunniens (freshwater drum).

ORDER ACANTHOPTERYGII—continued.

Suborder Perciformes—Continued.

Family Pomacentridæ.

Eupomacentrus leucostictus (Beau Gregory).
Eupomacentrus fuscus (Maria Molle).
Abudefduf saxatilis (cow pilot).

Suborder Pharyngognathi.

Family Labridæ.

Tautogolabrus adspersus (cunner).
Tautoga onitis (tautog).
Lachnolaimus maximus (hogfish).
Halichœres sp.

Family Scaridæ.

Sparisoma abildgaardi (red parrot-fish).
Callyodon cœruleus (blue parrot-fish).
Scarus vetula (old wife).

Suborder Squamipinnes.

Family Ephippidæ.

Chætodipterus faber (spade-fish).

Family Chætodontidæ.

Megaprotodon trifascialis.
Pomacanthus arcuatus (black angel).
Holacanthus tricolor (rock beauty).
Holacanthus ciliaris (blue angel-fish).
Chætodon ocellatus (isabelita).
Chætodon capistratus (parché).
Chætodon striatus (butterfly-fish).

Suborder Sclerodermi.

Family Balistidæ.

Balistes vetula (old wife).
Balistes carolinensis (leather-jacket).
Balistapus rectangulus.

Family Teuthididæ.

Teuthis cœruleus (blue tang).
Teuthis hepatus (common surgeon-fish).

Family Monacanthidæ.

Monacanthus hispidus (filefish).
Alutera schœpfi (orange filefish).

Suborder Ostracodermi.

Family Ostraciidæ.

Lactophrys trigonus (common trunkfish).
Lactophrys bicaudalis (spotted trunkfish).
Lactophrys triqueter (rock shellfish).
Lactophrys tricornis (cowfish).

Suborder Gymnodontes.

Family Tetraodontidæ.

Lagocephalus lævigatus (smooth puffer).
Spheroides maculatus (puffer).

Family Diodontidæ.

Diodon hystrix (porcupine-fish).
Chilomycterus schœpfi (common burrfish).

Family Molidæ.

Mola mola (ocean sunfish).

ORDER ACANTHOPTERYGII—continued.

Suborder Scleroparei.

Family Scorpænidæ.

Sebastes marinus (rosefish).
Sebastodes constellatus (spotted rockfish).
Sebastodes rosaceus (corsair).

Family Cottidæ.

Cottus ictalops (miller's-thumb).
Myoxocephalus octodecimspinosus (long-spined sculpin).
Hemitriperus americanus (sea-raven).

Family Triglidæ.

Prionotus carolinus (common gurnard).
Prionotus strigatus (northern striped gurnard).

Family Cephalacanthidæ.

Cephalacanthus volitans (flying robin).

Family Cyclopteridæ.

Cyclopterus lumpus (lumpfish).

Family Liparididæ.

Liparis liparis (sea-snail).

Suborder Gobiiformes.

Family Gobiidæ.

Dormitator maculatus (pañeca).
Gobius oceanicus (esmeralda).
Typhlogobius californiensis (blind goby).

Suborder Discocephali.

Family Echeneididæ.

Echeneis naucrates (shark-sucker).
Remora remora (remora).

Suborder Jugulares.

Family Malacanthidæ.

Malacanthus plumieri (matajuelo blanco).
Caulolatilus princeps (blanquillo).
Lopholatilus chamæleonticeps (tilefish).

Family Uranoscopidæ.

Astroscopus y-græcum (electric stargazer).

Family Batrachoididæ.

Opsanus tau (toadfish).
Porichthys notatus (singing-fish).

Family Gobiesocidæ.

Gobiesox virgatulus (clingfish).

Family Blenniidæ.

Pholis gunnellus (butterfish).
Lumpenus lampetræformis (snake blenny).
Labrisomus nuchipennis.

Family Anarhichadidæ.

Cryptacanthodes maculatus (wry-mouth).
Anarhichas lupus (wolf-fish).

Family Zoarcidæ.

Zoarces anguillaris (eel pout).

Family Fierasferidæ.

Fierasfer affinis (pearlfish).

ORDER ACANTHOPTERYGII—continued.

Suborder Tæniosomi.

Family Regalecidæ.

Regalecus glesne (oarfish).[a]

Family Trachypteridæ.

Trachypterus rex-salmonorum (king-of-the-salmon).[a]

Suborder Anacanthini.

Family Merlucciidæ.

Merluccius merluccius (European hake).

Merluccius bilinearis (whiting).

Family Gadidæ.

Gadus callarias (common cod).

Microgadus tomcod (tomcod).

Pollachius virens (pollock).

Melanogrammus æglefinus (haddock).

Lota maculosa (burbot).

Molva molva (ling).

Urophycis tenuis (squirrel hake).

Enchelyopus cimbrius (four-bearded rockling).

Brosme brosme (cusk).

Family Macrouridæ.

Macrourus bairdii (common rat-tail).

Suborder Heterosomata.

Family Pleuronectidæ.

Hippoglossus hippoglossus (halibut).

Paralichthys dentatus (summer flounder).

Paralichthys oblongus (four-spotted flounder).

Limanda ferruginea (rusty dab).

Pseudopleuronectes americanus (winter flounder).

Hippoglossoides platessoides (sand dab).

Lophopsetta maculata (window-pane).

Family Soleidæ.

Achirus fasciatus (American sole).

Symphurus plagusia (tongue-fish).

ORDER PEDICULATI.

Family Lophiidæ.

Lophius piscatorius (common angler).

Family Ceratiidæ.

Cryptopsaras couesii (sea-devil).

Family Antennariidæ.

Pterophryne histrio (sargassum-fish).

Antennarius ocellatus (frogfish).

Family Malthidæ.

Ogcocephalus vespertilio (batfish).

Malthe malthe.

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[a] Rare. To be represented by colored plates or drawings.

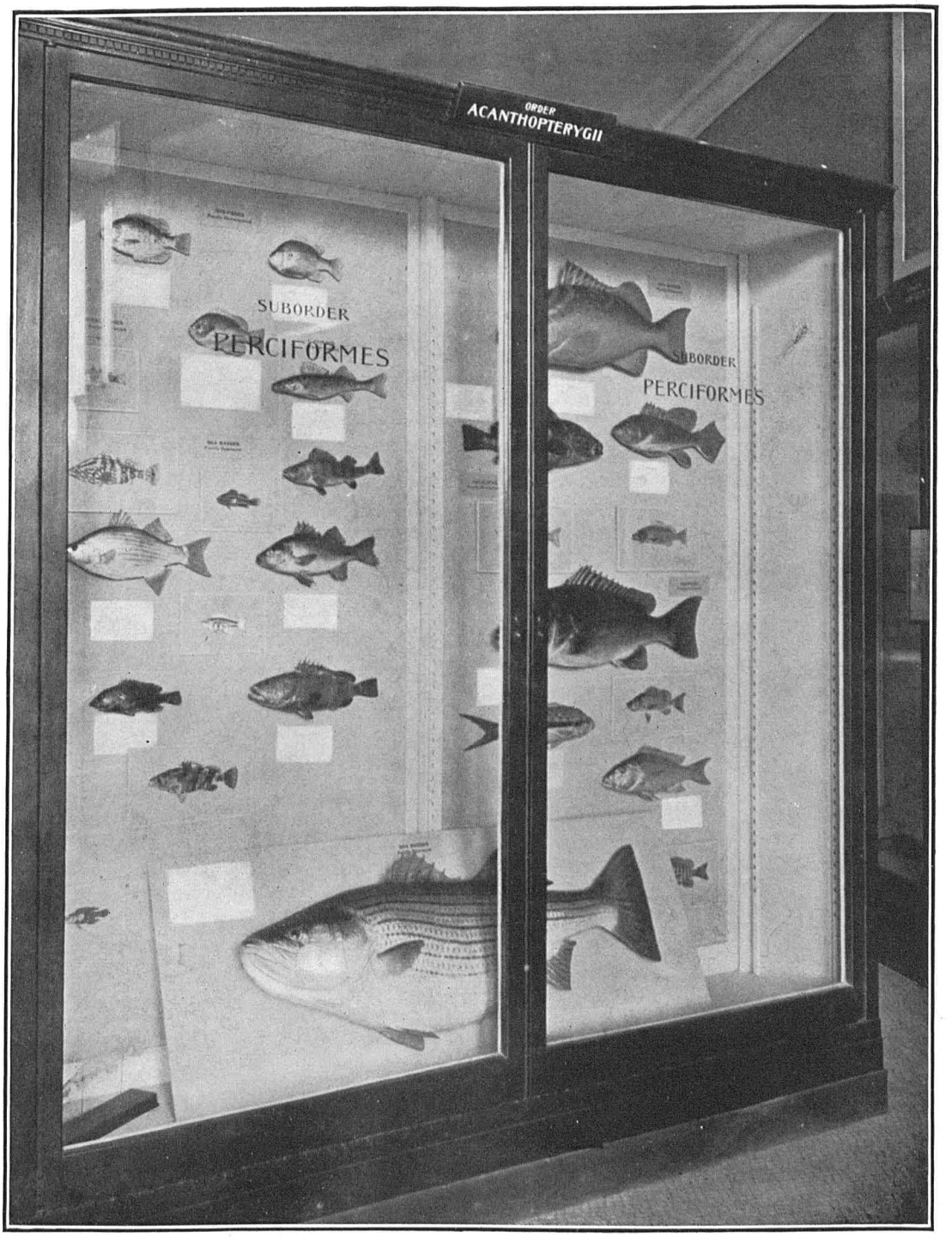
APPENDIX.

SUGGESTIONS FOR SUBJECTS FOR ILLUSTRATIVE MUSEUM FISH GROUPS.

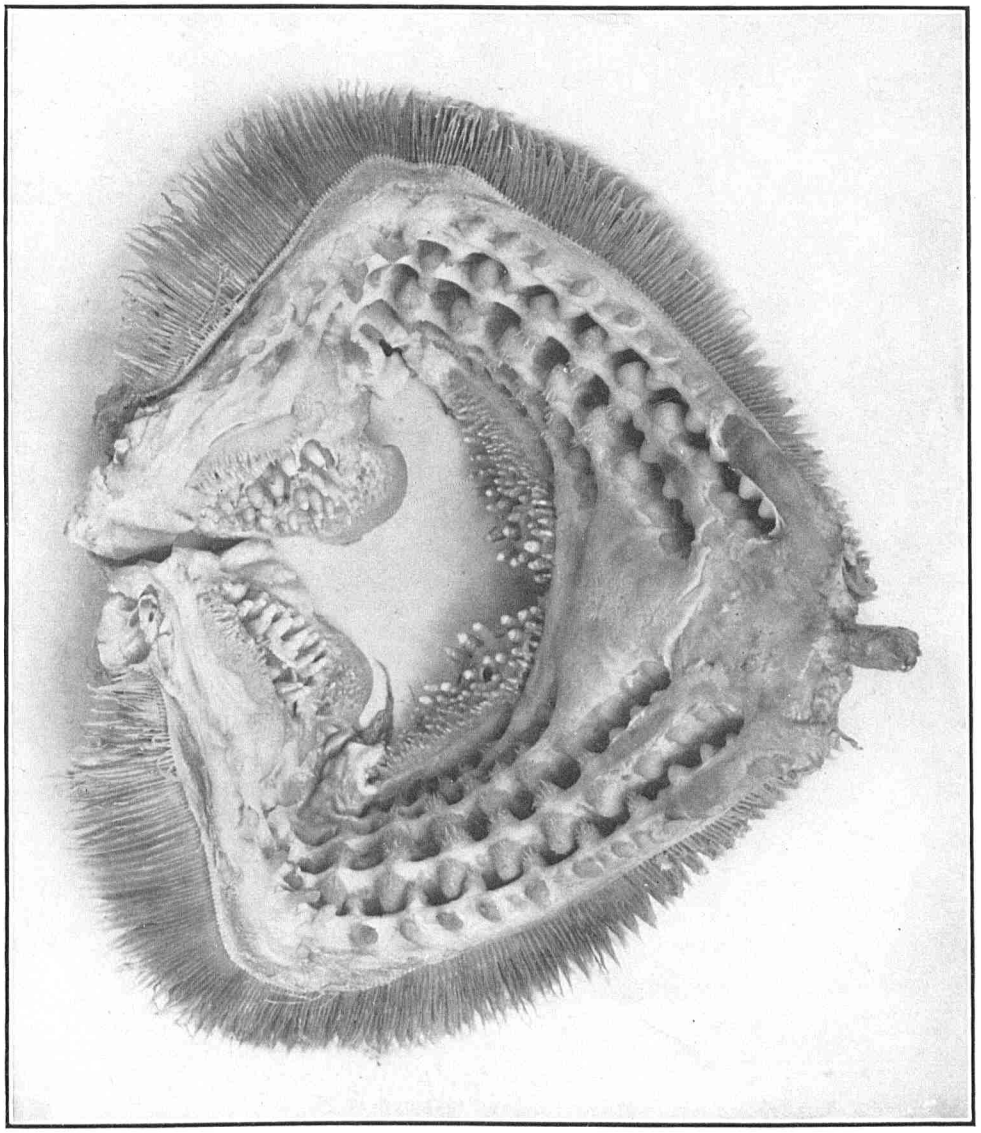
(See pages 1318–1319.)

Order Plagiostomi: Cub-shark with shark-sucker. (Commensalism.)
Transitional forms—shark to skate. (Evolution and adaptation.)
Order Holocephali: Life history of *Chimæra colliei*. (Growth and development.)
Subclass Dipneusti: Nesting and burrowing habits of *Protopterus*.
Order Chondrostei: Feeding habits of *Polyodon spathula*. (Also adaptation.)
Order Holostei: Nesting and feeding habits of *Amia calva*. (Instincts.)
Order Ostariophysi: Land habits of *Doras*. (Possible evolution in progress.)
Order Apodes: Life history of the common eel. (Metamorphosis.)
Group of morays. (Adaptation.)
Deep sea saccopharyngids. (Adaptation.)
Order Malacopterygii: Humpbacked or hooknosed salmon. (Sexual dimorphism.)
Salmon leaping. (Instincts.)
Order Mesichthyes: Four-eyed fish (*Anableps dovii*). (Adaptation.)
Blindfish—cave fauna. (Degeneration; adaptation.)
Group of flying fishes. (Adaptation.)
Order Thoracostraci: Breeding habits of stickleback. (Instincts.)
Group of sea horses. (Specialization; protective resemblance.)
Order Acanthopterygii:
Suborder Percesoces: Habits and adaptations of *Anabas scandens*.
Suborder Scombriformes: Life history of *Selene vomer*. (Metamorphosis.)
Nomeus gronovii and *Physalia arethusa*. (Symbiosis.)
Suborder Perciformes: Nesting habits of the gourami (*Osphromenus olfax*). (Instincts.)
Suborders Perciformes, Pharyngognathi, Squamipinnes, Sclerodermi, and Gymnodontes: Tropical coloration and degeneration.
Suborder Scleroparei: Group of toadfishes, sea-robins and sea-ravens to illustrate adaptation to bottom life and protective resemblance.
Suborder Jugulares: Group of *Fierasfer acus* and holothurians to illustrate symbiosis.
Suborder Heterosomata: Life history of flounder. (Metamorphosis, adaptation to bottom life, and protective resemblance.)
Order Pediculati: Group of deep-sea fishes illustrating adaptation.

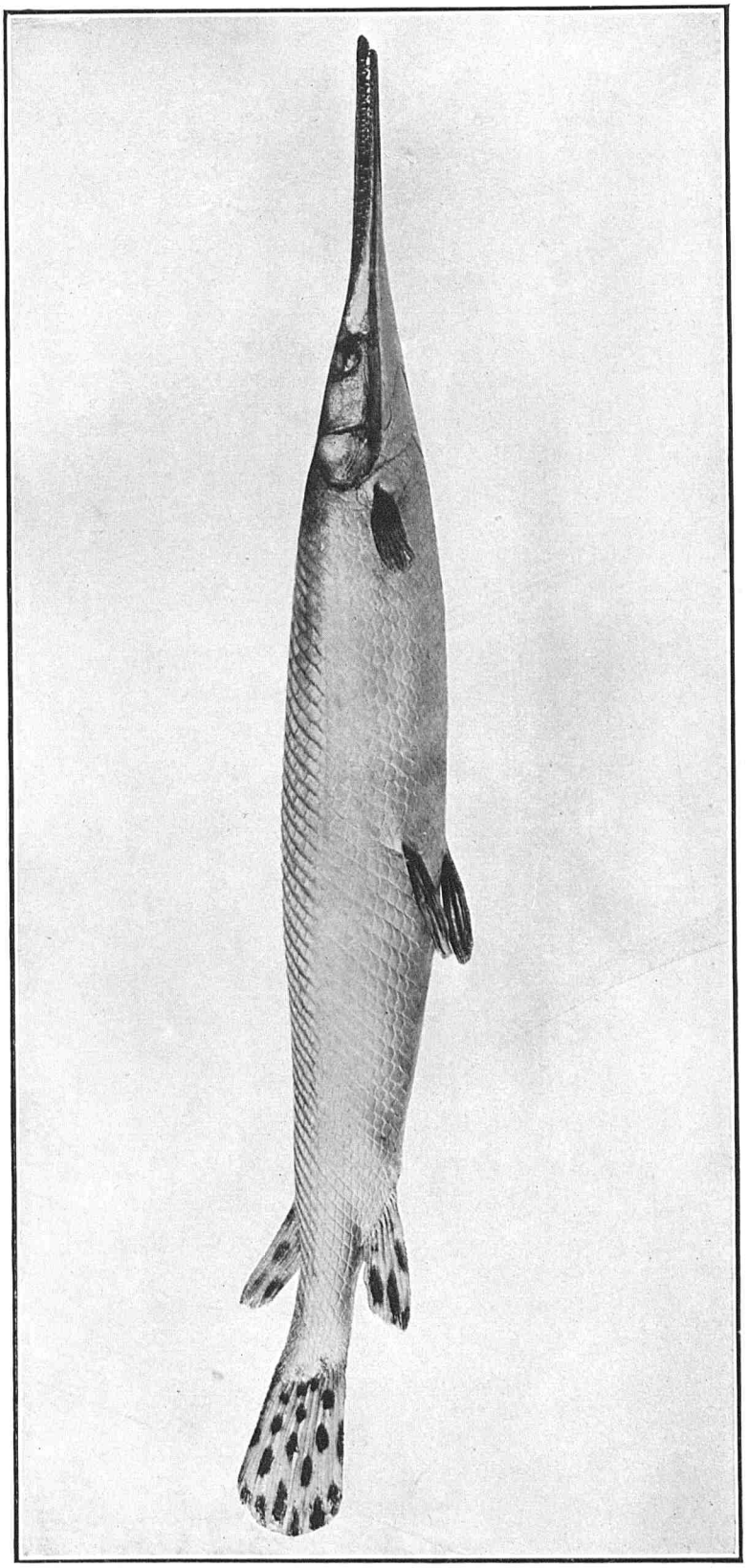
NOTE.—In several instances two or more of the above suggestions could be advantageously combined in a single group, illustrating several biological principles in one exhibit.



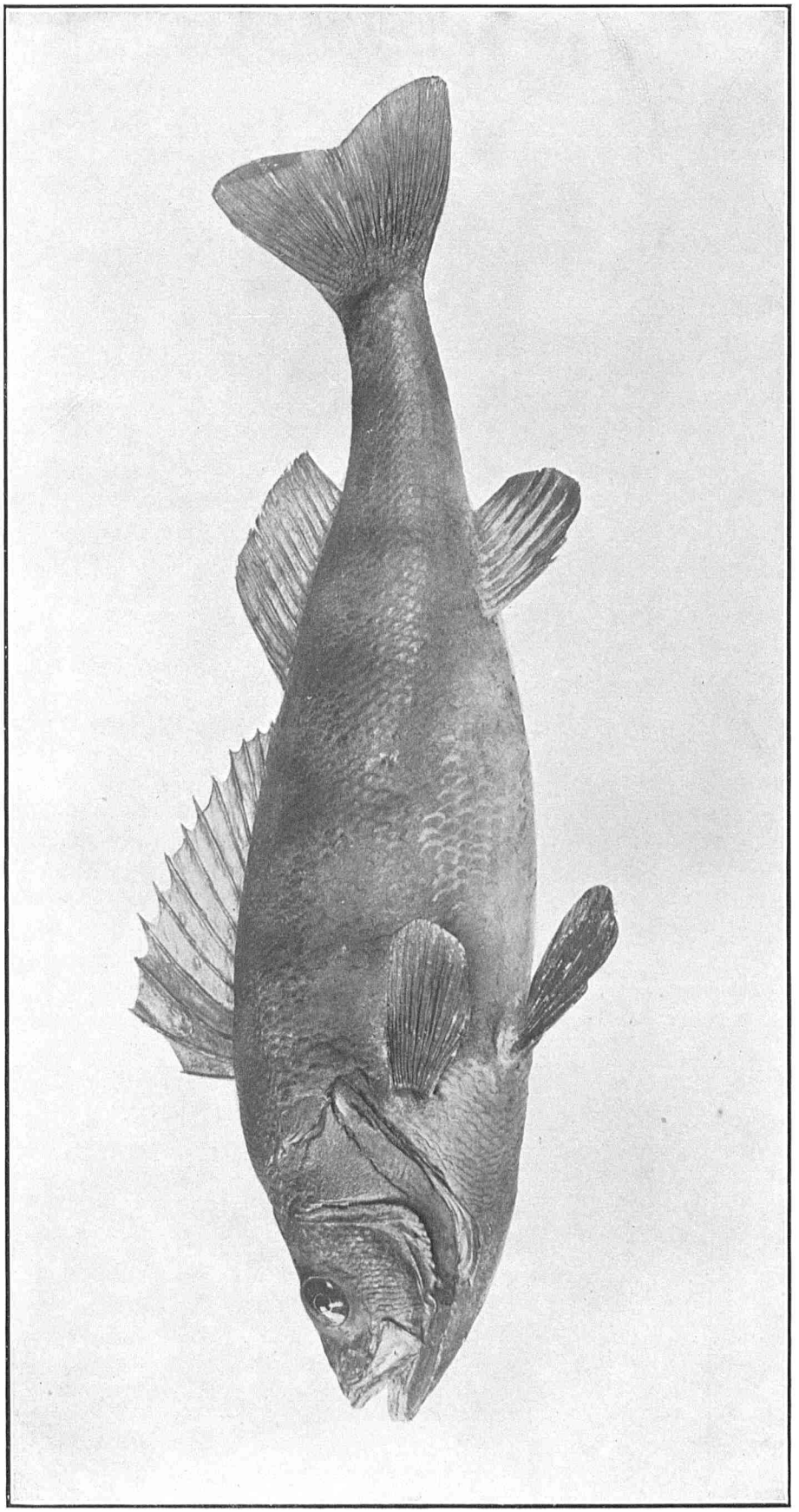
Typical synoptic case used in "corridor arrangement" for exhibition of fishes.



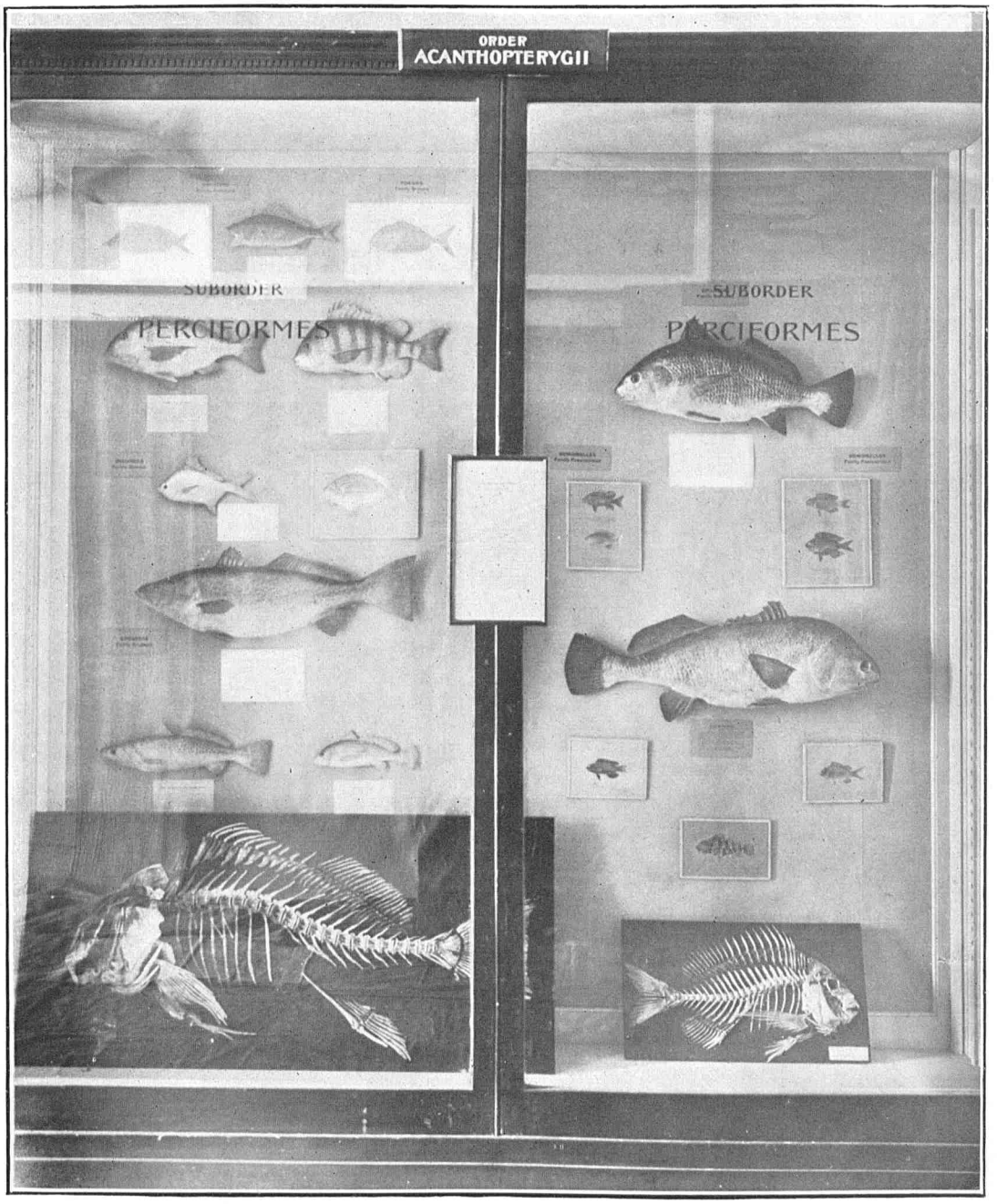
Section showing gill arches and pharyngeal teeth of the channel bass (*Sciænops ocellatus*). This illustrates the kind of alcoholic material to be used as accessory anatomical exhibits.



Mounted and painted skin of the long-nosed gar (*Lepisosteus osseus*), the hard enameled scales of which may be advantageously treated in this way.



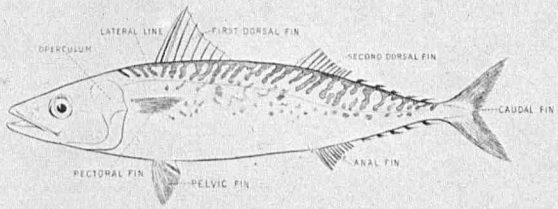
Mounted and painted skin of yellow perch (*Perca flavescens*).



One of the cases devoted to the perch group, showing methods of utilizing colored plates and labels.

THE FISHES

(CLASS PISCES)



A MACKEREL

Fishes may be defined as jaw-bearing, back-boned animals, adapted in shape, method of breathing, and method of locomotion for an aquatic life.

In shape, they are spindle-like, thus offering little resistance to the water when swimming.

They breathe by means of *gills*, organs adapted to purify the blood by the oxygen contained in the water. In most fishes the gills are protected by a gill-cover, the *operculum*.

The chief organ of locomotion is the powerful *tail*, which is aided more or less by the paired *pectoral* and *pelvic fins*, which correspond to the fore and hind limbs of land animals. The paired fins, however, act chiefly as balancers.

The median dorsal and anal fins act as keels and give stability to the fish.

Besides an internal cartilaginous or bony skeleton, fishes usually possess an outer *exoskeleton* of spines, denticles, scales or bony plates.

An *air-bladder* is frequently present, and serves as a float, except in the Dipneusti, where it acts as a lung and aids the gills in purifying the blood.

Fishes also possess highly organized *eyes*, paired *organs of smell*, and a peculiar series of sense-organs arranged along the side to form the *lateral line*.

Fishes are divided into three subclasses as follows:

CLASS PISCES
(The Fishes)

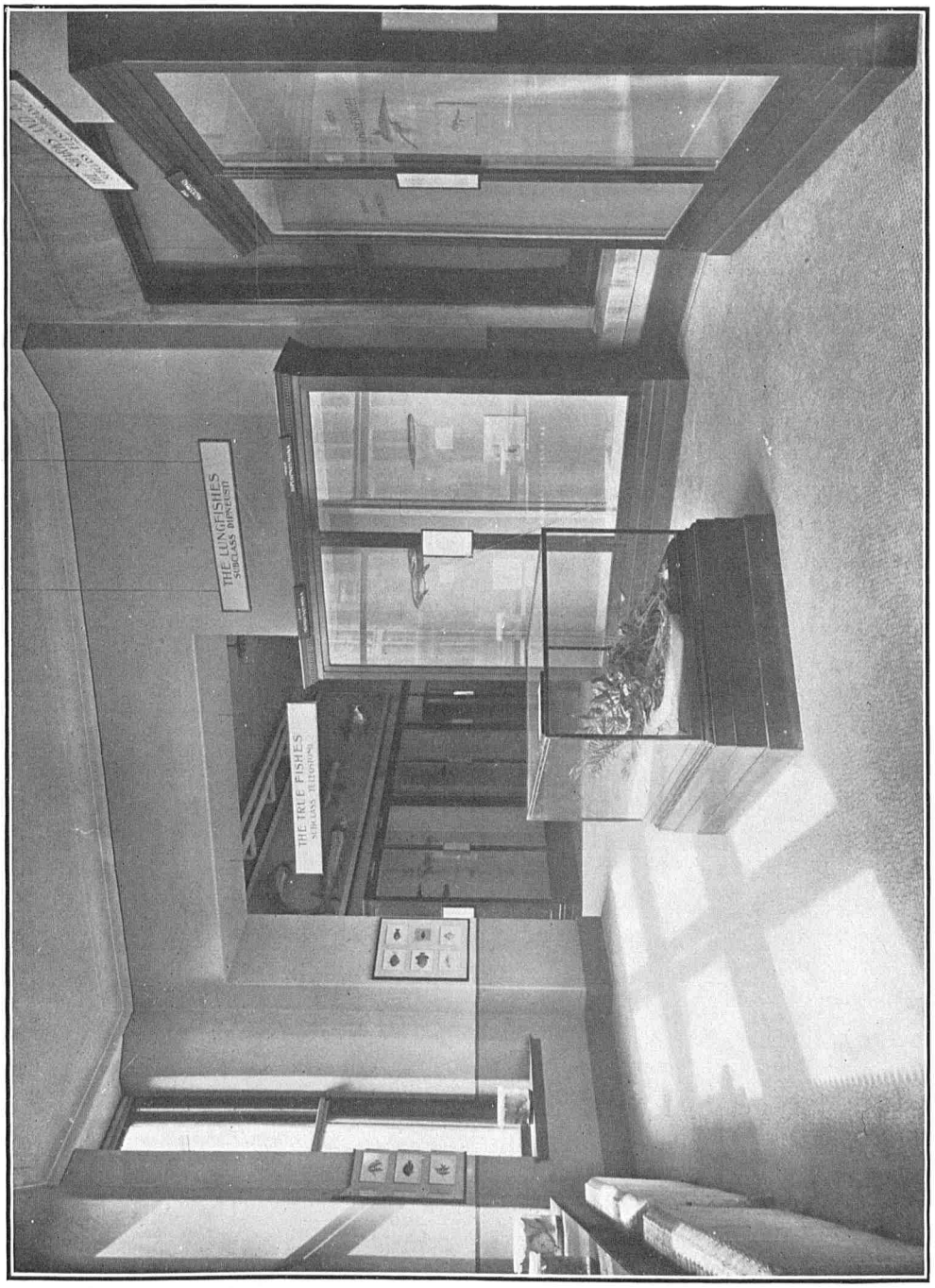
SUBCLASS ELASMOBRANCHII
(The Sharks, Rays, and Chimæroids)

SUBCLASS DIPNEUSTI
(The Lungfishes)

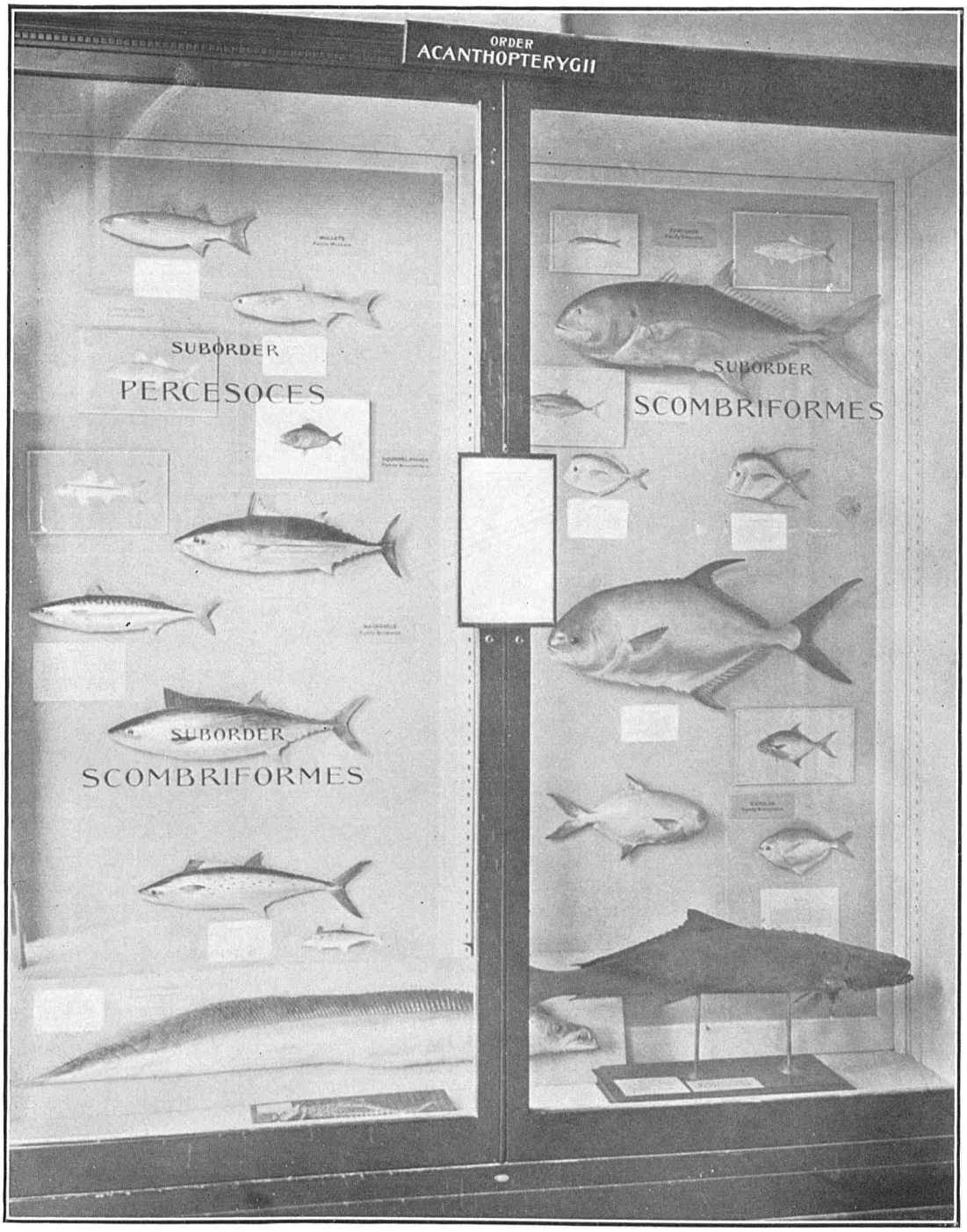
SUBCLASS TELEOSTOMI
(The True Fishes)

In this hall the subclasses are indicated by the large signs suspended from the ceiling. For further subdivisions consult the case-labels.

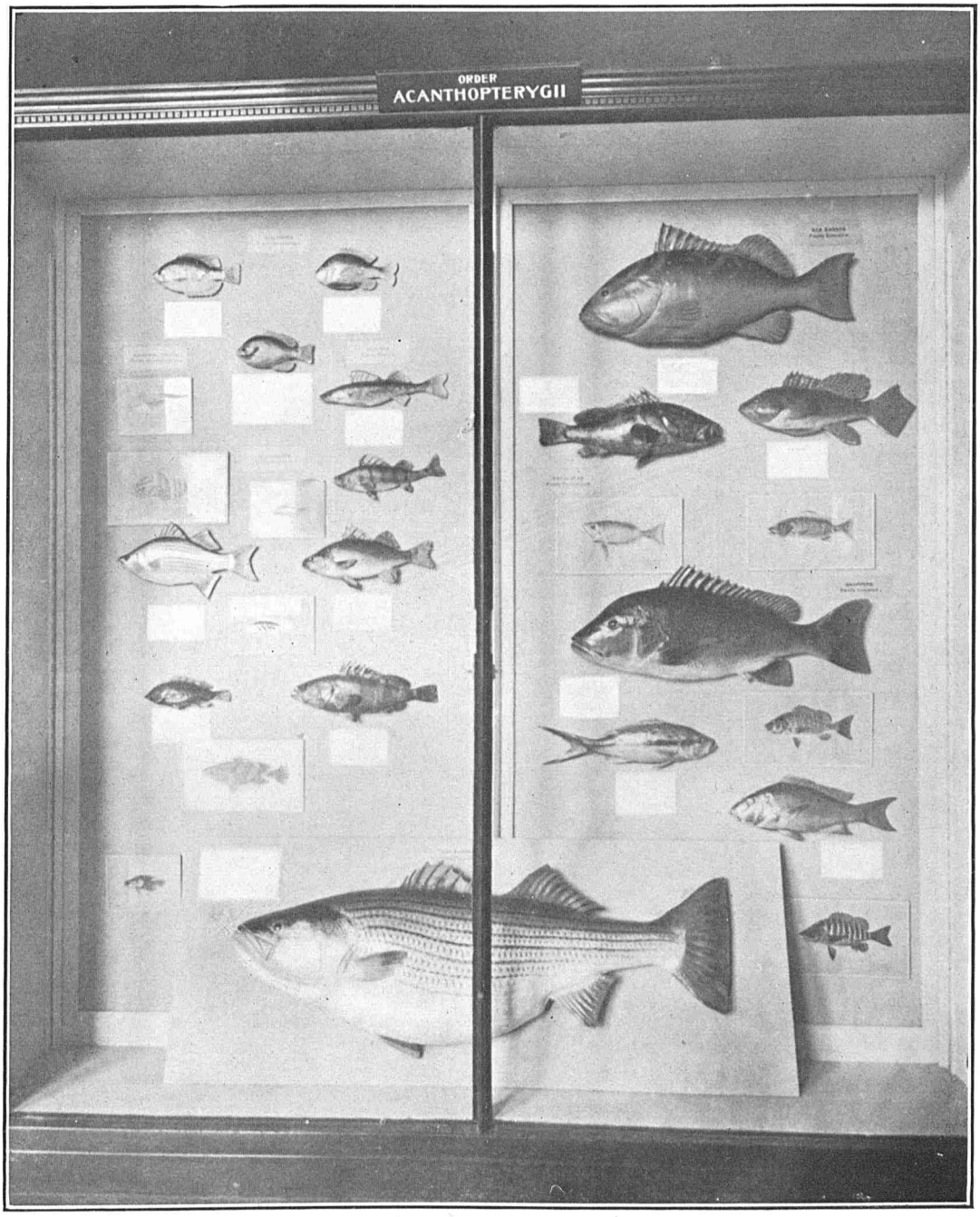
General label defining class Pisces. Framed copies of this label are placed in various parts of the fish hall. The figure of the mackerel at the top is drawn in by hand. A different species is represented on each copy of the label, corresponding to the fish forms near which it is placed.



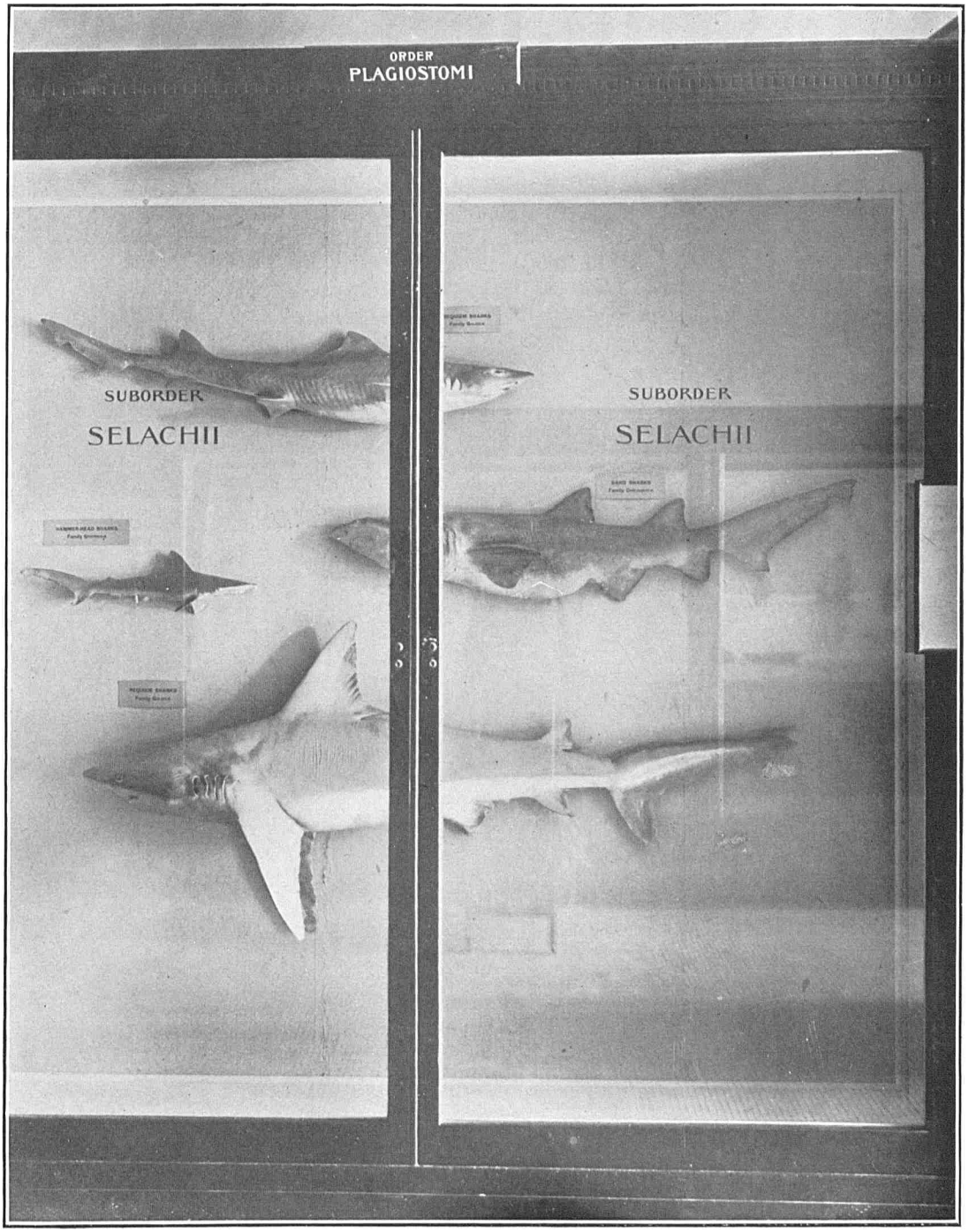
A corner in the fish corridor, showing the subclass signs suspended from the ceiling, the use of aquaria, and colored plates in panels for decorative purposes.



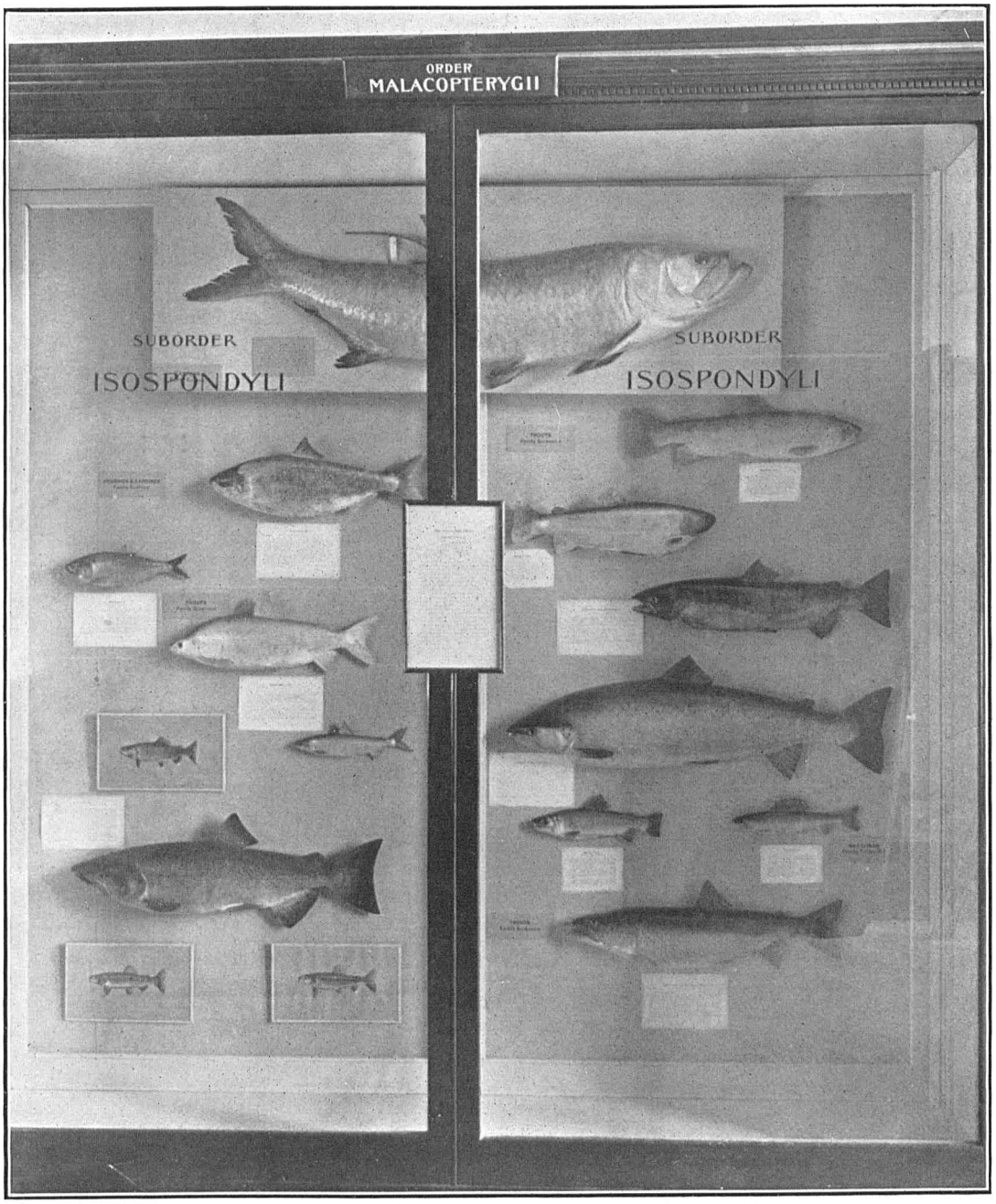
A typical case illustrating the arrangement of specimens and the method of indicating classification.



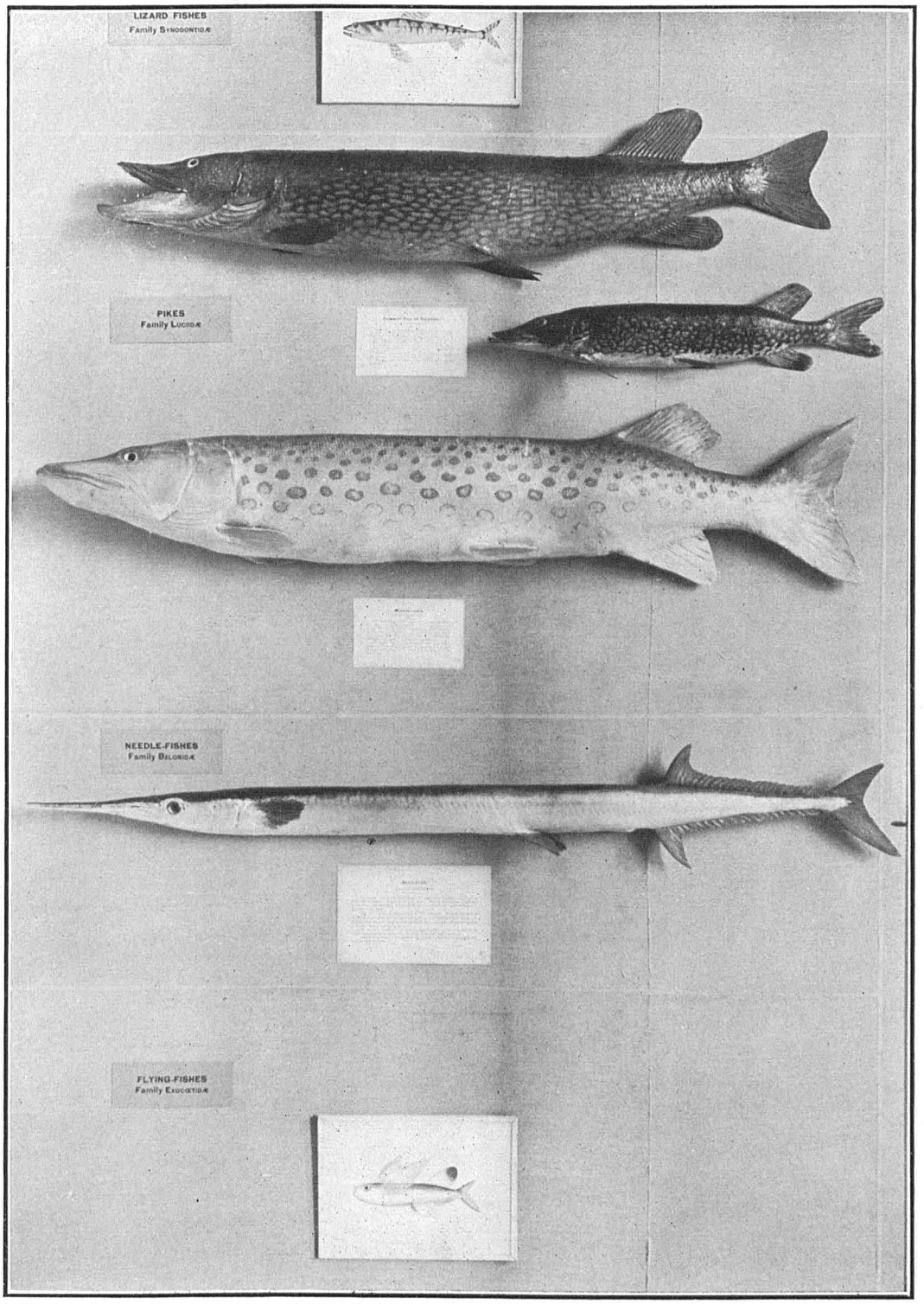
A typical case with doors open, showing character of material to be used.



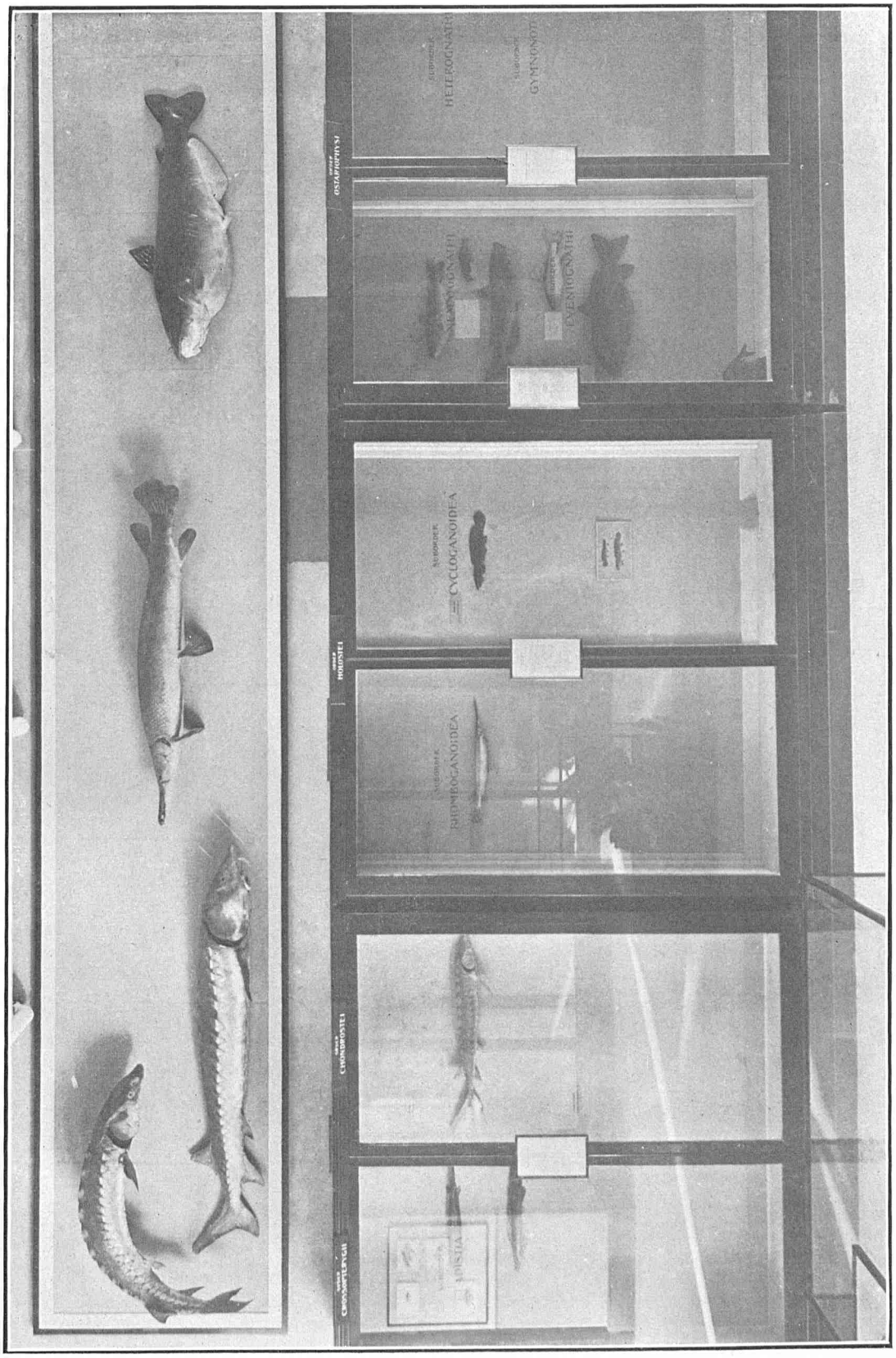
One of the shark cases.



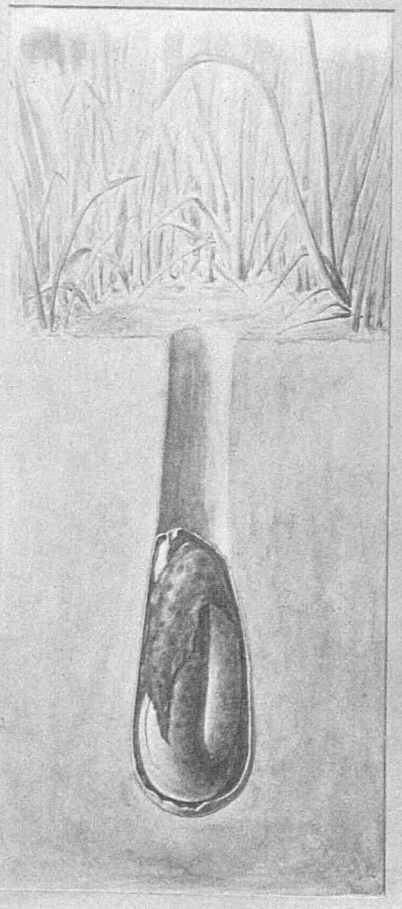
Case devoted to the trout group. The method of indicating the suborder is well shown in this figure. The case label, hanging on the front of the case, contains a definition of the suborder.



A portion of the case devoted to the Haplomi, illustrating the use of family labels and the method of separating the families by means of strips of tape.



Method of treating large specimens to form frieze above cases.



BURROWING HABIT OF THE AFRICAN LUNG-FISH

The accompanying illustration shows the manner in which the Lung-fish of the Nile and Congo (*Protopterus*) spends the dry season when the waters of those rivers have receded and left the mud-flats along the banks to bake in the sun.

As this curious creature possesses both lungs and gills, it is able to breathe either in water or air. During the time of flood it swims about the marshes along the bank searching for food and breathing by means of its gills like any ordinary fish. But in the dry season, as the waters recede, instead of seeking the river channel it burrows about 18 inches down into the mud, and coils up as shown in the figure.

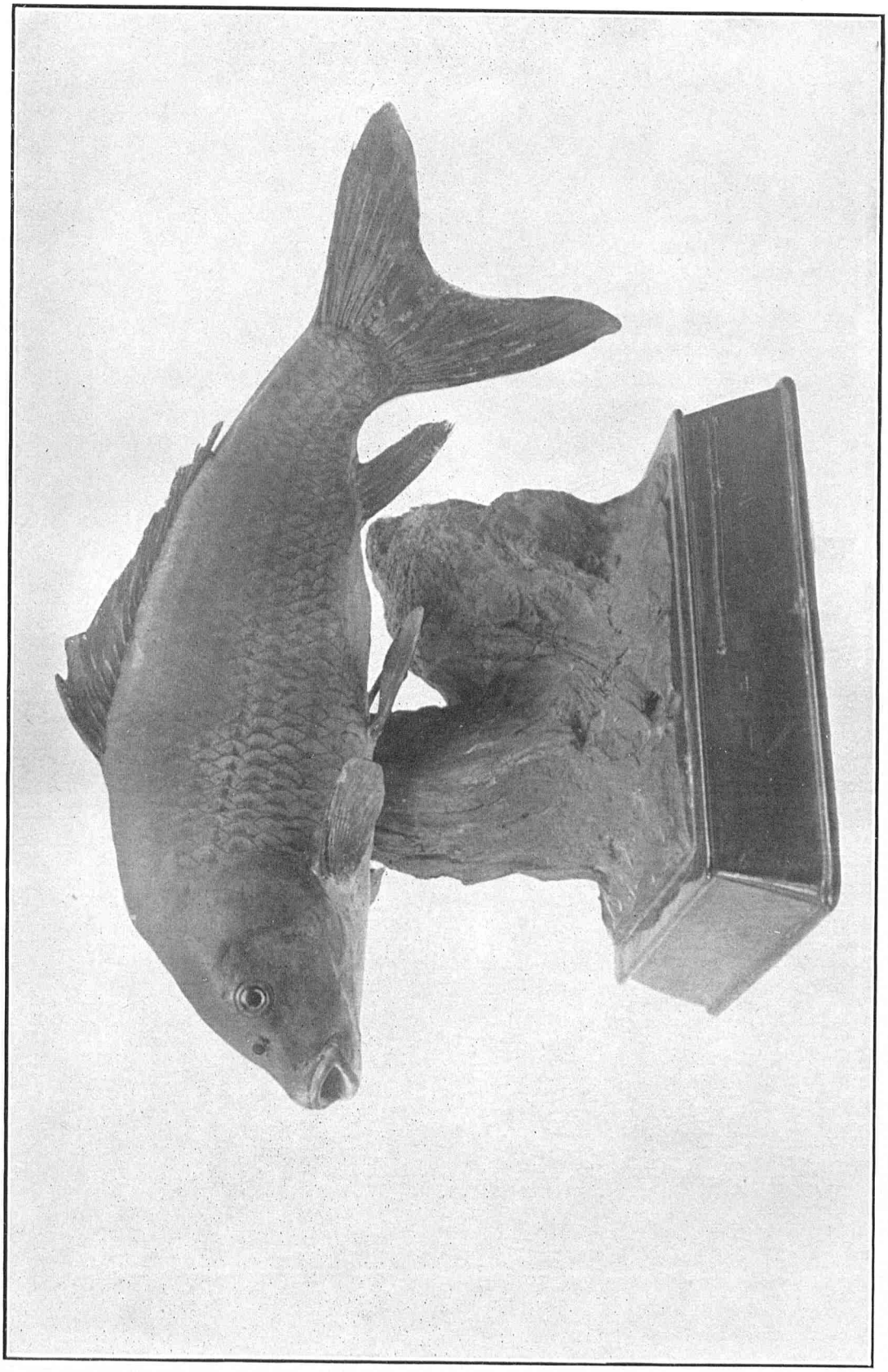
It then secretes from its skin-glands a gelatinous substance which entirely covers its body, and hardens to form a cocoon-like envelope. A small opening, however, is left at the mouth of the fish, and a narrow tube is formed continuous with the envelope and connecting with the lung-cavity.

Thus the animal is enabled to pass the dry season in a dormant state, breathing air like the Amphibians, with the ancestors of which it is doubtless closely connected.

While the Lung-fish is in this condition, the mud in which it lies has often been cut into blocks and transported to England and America, and when placed in water in a warm room the fish emerges and resumes its active state, apparently as lively as ever.

Type of label describing a life-habit, illustrated by water-color sketch.

Method of treating small fishes. The photograph is actual size.



A method of mounting a single specimen.

OUTLINE FOR AN EDUCATIONAL EXHIBIT OF FISHES

By Frederic A. Lucas

Curator in Chief, Museum of the Brooklyn Institute of Arts and Sciences

Presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908, and awarded one-half of the prize of one hundred dollars in gold offered by the Museum of the Brooklyn Institute of Arts and Sciences for the best plan for an educational exhibit of fishes

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OUTLINE FOR AN EDUCATIONAL EXHIBIT OF FISHES.

By FREDERIC A. LUCAS,

Curator in Chief, Museum of the Brooklyn Institute of Arts and Sciences.

An educational exhibit of fishes is one that will convey to the average visitor an idea of the distinctive characters and anatomical structure of this zoological group and its larger divisions, and also afford information as to the appearance, special modifications, and, so far as possible, habits of typical members of these subdivisions.

First of all should be shown examples of the lancelet, lampreys, ostracophores, sharks, and one of the bony fishes, to show the various classes of vertebrates embraced in the term "fishes." This part of the exhibit should include, so far as possible, skeletons of these forms, accompanied by diagrams and explanatory labels, to make clear the characters of the various groups represented and illustrate the meaning of Acrania, Craniota, and Gnathostomata.

Then should come specimens showing the resemblances and differences between Elasmobranchii and Teleostomi, as well as the peculiarities of their skeletal, nervous, circulatory, and digestive systems. These series should preferably be displayed side by side, and should include not only actual specimens but drawings and models, especially in cases where the natural objects are so small as not to be readily seen. Here should be shown dissections of the arterial and nervous systems, and enlarged, explanatory models of more important details. For example, a dissection would show the relation of the heart to the gills and a model the structure and peculiarities of the heart.

Emphasis should be laid on the more apparent and more important characters, since as this exhibit is for the general public it should not go too much into details or attempt to display and explain characters not readily comprehended; such matters are for books and for the student.

The exhibits just described are intended to serve as a preface or introduction to the systematic series of fishes and should stand by themselves in order to be the more readily understood.

The more evident characters of the subclasses and orders are to be shown in connection with these divisions or groups in the systematic exhibit; at the same time a good-sized chart or diagram illustrating the relations of fishes to

other vertebrates and the primary divisions within the class, might well be introduced here.

The systematic series of fishes is to form the principal portion of the collection and is to include typical examples of the various subclasses and orders. It should not be too large and it should as a rule be confined to the more characteristic forms. The object of this series is to show the main divisions of fishes and give the observer an idea of their general appearance. To multiply forms and individuals would therefore be confusing and defeat the very object in view.

In selecting specimens to represent the various groups, preference should be given to the more characteristic and better-known species and, so far as possible, to species common in the vicinity[a] where the exhibit is to be displayed. The more common the species the more familiar is it to the observer, the more readily will he associate it with the fact illustrated, and the more forcibly will that fact be impressed upon him. The educational value of a specimen does not depend on its rarity but on the clearness with which it shows the fact it is intended to illustrate.

The larger extinct groups should be represented both by their fossil remains and by models or pictures, and important or readily obtainable fossil forms should be introduced in their proper places among existing species. In no way save by the use of fossils can a proper idea be given of the relationships of various groups and of their relative importance at the present time and during past geologic history.

As an adjunct to the systematic series there should be groups or pictures illustrating important or interesting points in the habits of fishes, such as the sargassum fish and stickleback with their "nests," the sunfish and its nest, the remora clinging to a shark, etc.

Small series or assemblages of fishes peculiar to certain localities or habitats could be introduced to advantage; thus a series of deep-sea forms would emphasize the peculiarities of the abyssal fauna and the remarkable modifications for life at great depths. Examples of deep-sea fishes should also be shown in their respective groups to illustrate the facts that the deep-sea fauna has been derived from that of the shallower seas and that resemblances that exist between them are largely due to adaptations toward one end—life in the depths of the sea.

One of these "supplementary series" might be devoted to the brilliant fishes of tropical waters, attention being called to the contrast they offer to the modest colored but important food fishes of temperate regions. In such "sup-

[a] For example, a museum located near the Atlantic or Pacific coast should draw for its examples, so far as possible, upon the salt water fishes, while an inland museum should select as many examples as possible from the lakes and rivers. This naturally would be practicable only to a limited extent, owing to the fact that even the most scanty representation of the principal groups of fishes calls for many species.

plementary" displays might be illustrated the difference between the sluggish bottom-frequenting species, the active pelagic forms, and the highly modified species from the abyssal regions of the sea. Here it would be necessary to call in the aid of the artist to illustrate the adaptations to environment and show how the colors of some fishes blend in with the rocks and waving sea weeds.

Among the special series, or series illustrating modification for offense and defense, for capturing food, or escaping devourers, come phosphorescent and electrical fishes. Another of these special series might well be an exhibit of game fishes, and this should be mounted as artistically as possible, with specially designed backgrounds and surroundings. Such an exhibit could be made very attractive without being in the least garish. These various series should be kept by themselves. The object of the systematic part of the exhibit is to display as plainly as possible the orders and higher groups of the class of fishes, and these distinctions should be made as clear as possible for the sake of the general visitor, for whose benefit the exhibition part of a museum is provided. The number of specimens, also, should be carefully kept down in order not to tire the visitor and confuse him with a multiplicity of forms; but there should be no hesitancy in using several specimens of the same fish if needed to illustrate more than one fact.[a] It may even be questioned if such repetition may not be advisable in order to drive home and clinch the fact that a common species is none the less a typical one and that mere rarity does not in itself mean anything.

The questions of whose classification to adopt and how it may best be illustrated are not easy to answer, because no two systematists are agreed as to the relative importance and exact position of certain groups. In the outline here presented the classification employed by Doctor Jordan in his Guide to the Study of Fishes has been followed, partly as a matter of convenience and partly on account of the amount of information contained in the book. Practical difficulties in the way of displaying any group of animals are met with in the limitations and disposition of space available for such exhibits. In many ways it seems best to indicate the divisions adopted and arrangement followed on a large label, number the orders, and repeat these numbers on the labels.

One of the physical difficulties encountered in arranging exhibits is that animals of very different sizes may be zoologically related,[b] rendering it difficult to place the specimens at once in their proper order and to permit the smaller specimens to be seen. To preserve a balance by exhibiting small examples of such species as reach a large size is to give a wrong impression to the beholder,

[a] Burt Wilder notes this in his "Educational Museums of Vertebrates," showing how the same species may be used for several purposes.

[b] Such an instance among mammals is the relationship of rhinoceros, hyrax, and elephant.

and it is a difficult matter to correct by information on a label the effect produced by the specimens themselves. By adopting the method suggested of numbering the orders or families in accordance with a given scheme of classification the smaller animals may be placed where they may be readily seen.

If small examples of fishes that reach a large size are undesirable because they give a wrong impression to the beholder, unusually large individuals are to be ruled out for the same reason—that they give an exaggerated and incorrect idea of the species illustrated. Such specimens may, however, be shown by themselves or where they will have a decorative value, the fact that they are of exceptional size being plainly noted on the label.

It is to be constantly borne in mind that exhibits are for the public; that the average visitor is not given to studying exhibits; and that every effort should be made to have the objects shown illustrate and press home the meaning of the ideas they are intended to convey. Such being the case, the specimens chosen for display should be typical of the group or fact they are intended to illustrate. Rare or unfamiliar species should be eschewed so far as possible, for their very rarity is a drawback and militates against their teaching power.

No provision has been made in this plan for exhibiting fishery products, or methods of capturing fish, though much information in regard to such matters might be noted on the labels. There is a temptation to extend in these directions, but such exhibits should properly be kept apart, if for no other reason than the large amount of room demanded and the difficulty of telling just where to stop. Technological and commercial exhibits are capable of almost indefinite extension, and to deal with the subject of fisheries alone calls for a large museum.

No hard and fast line can be drawn as to the character of the material used for display; alcoholic specimens, casts, mounted fishes, plates, all have their uses and in some one particular each has its superiority to the others. As a rule the writer believes thoroughly good casts of fishes to be superior to other preparations for exhibition purposes, and this is particularly true of large or smooth-skinned species. For small species alcoholics, mounted in flat jars, are to be preferred, and wherever enlarged models are shown they should, if possible, be accompanied by alcoholics. The public always likes to see "the real thing" and know on what foundation a restoration or an enlargement is constructed. The preferable mode of arrangement is believed to be the alcove system with cases 9 feet high on three sides and a table or other low case in the center. An ideal method would be to have the systematic series on one side of a broad aisle, and the supplementary or special series on the other with any groups of fishes in a dark corridor close by, but the arrangement must of necessity conform to the limitations placed upon it by the plan of the building in which it is displayed.

It is believed that such an exhibit as that outlined in this paper is quite within the reach of a museum, even of moderate size. Naturally it could not be brought together all at once, but it might be assembled gradually, taking for immediate display such species as were available and waiting for the others to be acquired. Where vacancies occurred, due to the lack of species needed for the representation of important groups, this might be noted on a label, or in many instances a figure of the fish might be shown. This would call attention to the needs of the collection and might lead to securing desirable specimens.

The systematic series calls for about 175 specimens, including fossils, 44 skeletons and other anatomical pieces, and 13 figures in cases where species are rare or small; a total of 230 specimens. This may seem a small number to represent a group containing over 13,000 living species, but it would be an easy matter to add systematically to such a collection, while, on the other hand, it is believed to present a fairly good idea of the extent and principal modifications of the group.

SYNOPSIS OF ARRANGEMENT AND LIST OF PRINCIPAL SPECIMENS TO BE SHOWN.

INTRODUCTORY DISPLAY.

Fishes and fish-like vertebrates, showing the forms popularly known as fishes—the lancelet, lamprey, ostracophore, and dogfish, and the bass or other acanthopterygian. To be accompanied by skeletons and figures to make clear the meaning of such terms as Acrania, Craniota, and Gnathostomata.

THE CLASSES ELASMOBRANCHII AND TELEOSTOMI COMPARED AND CONTRASTED.

Skull of shark showing that the cranium is a mass of calcified cartilage and not composed of separate bones, and showing the manner in which the jaw is connected with the cranium. Specimen showing the separate gill openings.

Skull of bony fish, cast or specimen showing single gill opening and flap.

ANATOMY OF FISHES.

Cast showing the external topography of a fish with the name of the principal parts or regions.

Skeleton; dermal bones to be removed from one side of the skull.

Cranium of fish compared with that of mammal, the corresponding bones similarly colored. To illustrate great differences between the two groups.

Model showing the general anatomy of a teleost fish.

Dissections, accompanied by models, showing nervous and circulatory systems.

Specimens and models showing the development of a fish.

SYSTEMATIC SERIES OF FISHES.

Comprising characteristic examples of the various orders and suborders of the classes popularly known as fishes, and including specimens showing the more important or apparent characters of these groups. To consist of alcoholic and mounted fishes, casts, and anatomical specimens.

A detailed list is subjoined.

SPECIAL OR SUPPLEMENTARY EXHIBITS.

Fishes of tropical waters, showing their brilliant coloring. To be shown in a group.

Fishes of temperate seas.

Deep-sea fishes, showing their modifications for life at great depths.

Fishes of shallow waters, illustrating modifications in form and color for concealment. To be shown in one or several groups.

Electrical fishes.

Phosphorescent fishes.

Exhibit of game fishes.

Small groups, illustrating nesting habits of such fishes as *Amia*, sunfish, stickleback, chub, etc. Rarer examples may be added where obtainable.

DETAILED LIST OF FISHES FOR EXHIBIT.

Class ELASMOBRANCHII.
- Order PLEUROPTERYGII. Extinct.
  - *Cladoselache*, model.
- Order ACANTHODII. Extinct.
  - *Acanthodes*, figure.
  - *Diplacanthus*, figure.
- Order ICHTHYOTOMI. Extinct.
  - *Pleuracanthus*, figure.
  - *Pleuracanthus*, teeth and spines.
- Order NOTIDANI.
  - *Notidanus*, cast.
  - *Notidanus*, jaw or teeth.
- Order ASTEROSPONDYLI.
  - Section of vertebra showing structure.
  - *Lamna*, cast and teeth.
  - *Carcharodon*, cast and jaws or teeth.
  - *Carcharodon*, teeth of extinct *C. megalodon*.
  - *Cestracion philippi*, cast or mounted specimen; skeleton, or at least teeth.

Class ELASMOBRANCHII—Continued.
- Order TECTOSPONDYLI.
  - Section of vertebra showing structure.
  - *Squalus*.
  - *Pristiophorus*.
  - *Squatina*.
  - *Rhinobatus*.
  - *Raja*.
  - *Torpedo*.
  - *Myliobatis*.
  - *Pristis*.

  } To be shown mainly by casts.

  This number of specimens is desirable to show the transition from sharks to rays.
- Order HOLOCEPHALI.
  - *Chimæra*.
  - *Chimræa*, skeleton.

Class OSTRACOPHORI.
- Order HETEROSTRACI.
  - *Lanarkia*, casts and figures.
  - *Pteraspis*.

Class OSTRACOPHORI—Continued.
Order OSTEOSTRACI.
Cephalaspis, specimens, or casts, and models.
Order ANTIARCHI.
Pterichthys, specimens, or casts, and models.
Bothriolepis.
Order ANASPIDA.
Birkenia, casts and drawings.
Order ARTHRODIRA.
Coccosteus, cast and model.
Dinichthys (if possible).
Class TELEOSTOMI, true-mouthed fishes.
Subclass CROSSOPTERYGII.
Order HAPLISTIA. Extinct.
Tarassius, figure.
Order RHIPIDISTIA. Extinct.
Holoptychius, cast.
Gyroptychius, figure.
Order ACTINISTIA. Extinct.
Undina, good figure.
Order CLADISTIA.
Polypterus, and skeleton, large figure or model of fin.
Subclass DIPNEUSTA.
Order DIPNOI.
Neoceratodus } and skeleton of one spe-
Lepidosiren } cies.
Subclass ACTINOPTERI.
Order LYSOPTERI. Extinct.
Catopterus redfieldius, specimens.
Order CHONDROSTEI, sturgeons.
Acipenser, and small skeleton.
Scaphirhynchus.
Order SELACHOSTOMI.
Polyodon, and skeleton.
Order PYCNODONTI. Extinct.
Gyrodus, cast and figure.
Order LEPISOSTEI.
Lepisosteus, vertebrae to show the procœlous type.
Lepisosteus, and skeleton.
Order HALECOMORPHI.
Amia, and skeleton.

Class TELEOSTOMI, true-mouthed fishes—Con.
Subclass TELEOSTEI, true bony fishes.
Order ISOSPONDYLI.
Salmo; Diplomystus, fossil.
Coregonus.
Alosa.
Tarpon.
Albula.
Osteoglossum.
Stomias, Chauliodus, deep-sea forms.
Suborder INIOMI.
Synodus, Ipnops, Diaphas, Myctophum—deep-sea forms.
Order APODES.
Anguilla, skeleton or at least skull.
Anguilla.
Muræna, skull.
Gymnothorax.
Leptocephalus, figures showing development of eel.
Suborder LYOMERI.
Gastrostomus, deep-sea forms.
Saccopharynx.
Order HETEROMI.
Notacanthus.
Series OSTARIOPHYSI.
Order HETEROGNATHI.
Serrasalmo, the caribe.
Order EVENTOGNATHI.
Cyprinus, and skeleton.
Notropis, or similar form.
Semotilus.
Abramis.
Good large examples of pharyngeal teeth.
Catostomus as typically American).
Ictiobus.
Order NEMATOGNATHI.
Arius, spine of large species.
Ictalurus, and skeleton.
Ameiurus.
Malapterurus.
Schilbeodes.
Clarias.
Loricaria.
Callichthys.
Gymnotus.

Class TELEOSTOMI, true-mouthed fishes—Con.
Series OSTARIOPHYSI—Continued.
Order SCYPHOPHORI, African "elephant-fish."
Mormyrus.
Gymnarchus.
Order HAPLOMI.
Esox, and skeleton.
Umbra.
Anableps.
Fundulus.
Gambusia.
Amblyopsis.
Order XENOMI.
Dallia.
Order ACANTHOPTERYGII.
Suborder SYNENTOGNATHI.
Belone.
Exocœtus, and skeleton.
Hemirhamphus.
Suborder PERCESOCES.
Atherina
Mullus
Mugil.
Sphyræna.
Polynemus or *Polydactylus*, shoulder girdle to show structure.
Order PHTHINOBRANCHII.
Fistularia, skeleton.
Gasterosteus, shoulder girdle and enlarged drawing.
Syngnathus.
Hippocampus.
Pegasus.
Suborder SALMOPERCES.
Percopsis.
Lampris (if possible).
Semiophorus (or even cast).
Zeus faber, and skeleton.
Order BERYCOIDII.
Beryx, cranium showing orbitosphenoid.
Holocentrus.
Monocentris.
Order PERCOMORPHI.
Scomber.
Trichiurus.
Xiphias.
Carangus, and skeleton.
Coryphæna.
Gastronemus, fossil.
Suborder PERCOMORPHI.
Aphredoderus.
Roccus, skeleton.

Class TELEOSTOMI, true-mouthed fishes—Con.
Series OSTARIOPHYSI—Continued.
Order PERCOMORPHI—Continued.
Suborder PERCOMORPHI—Continued.
Eupomotis.
Micropterus.
Perca.
Stizostedion.
Etheostoma.
Asineops, fossil.
Promicrops.
Epinephelus.
Priacanthus.
Lutianus.
Hæmulon.
Upeneus.
Cynoscion.
Chiasmodon.
Lopholatilus.
Suborder LABYRINTHINCI.
Anabas scandens, if possible in climbing attitude.
Suborder HOLCONOTI.
Cymatogaster, with young
Hypsurus.
Embiotoca.
Suborder CHROMIDES.
Heros.
Priscacara, fossil.
Pomacentrus.
Suborder PHARYNCOGNATHI.
Tautoga, skull showing enlarged pharyngeals.
Ctenolabrus, cunner.
Scarus, skull with pharyngeals, or allied form.
Pseudoscarus.
Sparisoma.
Order SQUAMIPINNES.
Chætodipterus, skeleton.
Chætodon.
Holacanthus.
Acanthurus or *Teuthis.*
Order PLECTOGNATHI.
Balistes, skeleton.
Balistes.
Monacanthus.
Lactophrys.
Lactophrys, skeleton.
Lagocephalus.
Sphæroides.
Diodon.
Mola

Class TELEOSTOMI, true-mouthed fishes—Con.
Series OSTARIOPHYSI—Continued.
Order PAREIOPLITAE.
Sebastes or *Sebastodes*, skeleton or skull.
Sebastes.
Scorpæna.
Synanceia.
Trigla.
Cottus.
Cottus, skeleton.
Cyclopterus.
Cephalacanthus.
Suborder GOBIOIDEI.
Gobius, specimen showing the ventrals joined to form a sucking disk.
Periopthalmus on tree.
Typhlogobius (if possible).
Suborder DISCOCEPHALI.
Echeneis.
Echeneis, skeleton showing modified fin one showing top of head.
Elacate.
Suborder TÆNIOSOMI.
Regalecus.
Trachypterus.
Order HETEROSOMATA.
Skeleton of good-sized specimen.
Platophrys.
Lophopsetta.
Hippoglossus.

Class TELEOSTOMI, true-mouthed fishes—Con.
Series OSTARIOPHYSI—Continued.
Order HETEROSOMATA—Continued.
Paralichthys.
Solea.
Symphurus.
Suborder JUGULARES.
Uranoscopus or *Astroscopus*.
Blennius.
Anarichas, skull.
Anarichas.
Zoarces.
Brotula.
Opsanus tau.
Order OPISTHOMI.
Order ANACANTHINI.
Gadus.
Gadus, skeleton.
Lota (as a fresh-water form).
Cœlorhynchus, grenadier.
Albatrossia or *Steindachnerella*, deep-sea form.
Order PEDICULATI.
Lophius.
Lophius, skeleton.
Cryptosaras, deep sea.
Ceratias, deep sea.
Antennarius.
Ogcocephalus, *Malthe*.

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A METHOD OF PREPARING FISHES FOR MUSEUM AND EXHIBITION PURPOSES

By Dwight Franklin

American Museum of Natural History, New York City

Models presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908 and awarded the prize of one hundred dollars in gold offered by the American Museum of Natural History for the best method of preparing fishes for museum and exhibition purposes

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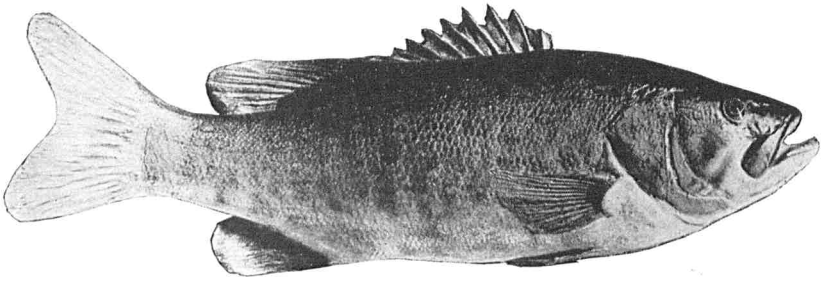

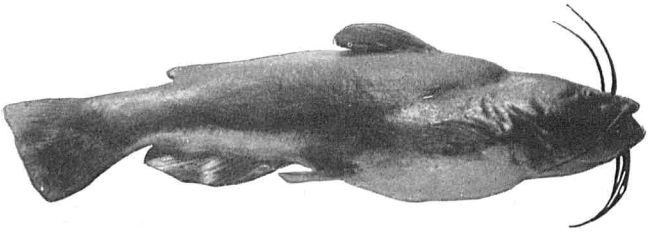

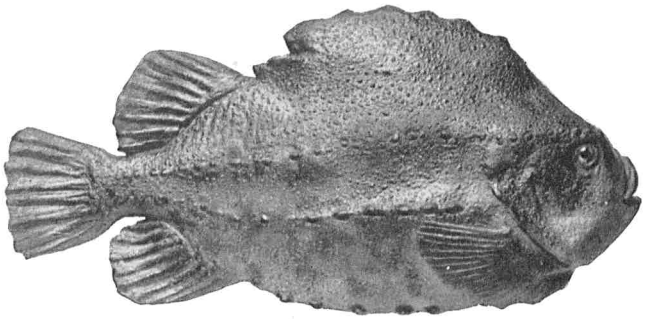

Reproductions from photographs of models of black bass, catfish, and lumpfish. Models prepared by Dwight Franklin.

A METHOD OF PREPARING FISHES FOR MUSEUM AND EXHIBITION PURPOSES.

By DWIGHT FRANKLIN,
American Museum of Natural History, New York City.

The preparation of fish for museum and exhibition purposes has always presented considerable difficulty. In most museums three methods of representation are in vogue, namely, by alcoholics, mounted skins, and plaster casts. The following are some of the commonly accepted objections to these methods: (1) Specimens preserved in any known liquid lose their color and give little idea of the living fish. (2) Few fish can be successfully mounted, as the soft parts about the head and fins shrivel and the skin becomes dry and opaque, so that no amount of skillful coloring can restore the original translucency. If the specimen is coated with wax the detail is lost, while the softness is only on the surface of the fish, not a part of it. (3) Plaster casts may reproduce the form perfectly, but all translucency is lost. If in the last method, however, a medium could be used which is itself soft and semitransparent, the result would prove more satisfactory. It has been found that wax answers this purpose admirably. It is easily handled, retains its form, and may be successfully colored.

The method used in making the specimens shown in the accompanying illustrations is as follows:

First remove the slime from the fish and pose the animal as desired. If a cast of one side only is desired the specimen may be backed up with clay.

Now pour plaster over the fish and allow it to harden thoroughly, after which the fish may be removed from the mold and laid aside.

As a third step soak the mold in hot water until it is saturated, then absorb the excess water from the surface.

Finally pour melted beeswax of the desired color into and out of the mold until a thick coating of wax is formed, then allow it to cool. Before the wax has hardened wire hangers may be inserted.

When the cast is cold carefully chip off the plaster mold, point up the wax cast, if necessary, and there has been produced a lifelike reproduction of the fish, which needs only to be finished by being colored accurately.

Models prepared by this method are shown in plate CXLII.

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NEW METHODS OF PREPARING FISHES FOR MUSEUM EXHIBIT

By J. D. Figgins

American Museum of Natural History, New York City

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

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NEW METHODS OF PREPARING FISHES FOR MUSEUM EXHIBIT.

By J. D. FIGGINS,
American Museum of Natural History, New York City.

The three essential characters in a fish specimen perfectly prepared for museum exhibition are accuracy of form and detail, durability, and lifelike coloring. As none of these features are assured by the old methods of casting and mounting this class of specimens, the result has never proved entirely satisfactory to those desiring a high class of work. Indeed, much experimenting and a study of the various methods of mounting fishes convinced me that perfect work was impossible; serious shrinkage is inevitable and a mounted fishskin represents nothing more than an inferior surface for painting. Plaster casts from molds of the same material have the advantage of more accuracy of form, but the preparation of the mold for casting and the defective plastic quality of even very thin plaster is accentuated in the cast, with the result of a lamentable lack of fine definition of detail. Besides, being extremely fragile, such casts are a constant source of annoyance, and when even slightly broken their value is seriously impaired, if not totally destroyed.

One of the most difficult problems has been the painting of such specimens. In a mounted fish the use of white lead is necessary to overcome the discoloration due to the chemical action of preservatives; and, while the lead may be eliminated in casts, the result is invariably flat and lacks the depth and brilliancy of colors so essential to a representation of life. Coloring, however, must of necessity remain in the hands of the artist to whom the work is assigned, and I will but outline the several advantages the here-described methods present for overcoming the chief difficulties.

Briefly, this is the opportunity to discard the use of lead entirely; there is necessity for using only the slightest stain to obtain the desired colors, thus securing their full transparency and brilliancy while at the same time preserving the minute detail which is invariably lost by the use of lead or heavy color.

In experimenting for an improvement in fishes for exhibition, the cost of production has been kept in mind, and at the same time an opportunity for

more advantageous field work. Those familiar with the difficulties of securing fresh specimens will appreciate the benefits to be derived through the possibility of preparing specimens in the field, and, though some of the materials are more expensive than those used in the old methods, the saving of time and labor more than compensates for the difference.

These methods are equally applicable in the preparation of reptiles and batrachians. Specimens so treated readily admit of close inspection with the magnifying glass; therefore, their value is enhanced through the opportunity presented for scientific study.

While I do not recommend plaster casts, except for some of the large fishes and reptiles, the obvious superiority of glue molds over those of any other material, when such casts are desired, should be so apparent that mention of their several distinct advantages is hardly necessary.

I. WAX CASTS FROM GLUE MOLDS.

The peculiar plasticity and toughness of glue makes it a singularly desirable material for molds if either plaster or wax casts are desired, as it takes an exact impression of the most intricate detail or undercut, and when withdrawn retains its perfect negative form. Being softer than wax, when the slight shrinkage of the latter takes place the glue prevents the cracking and damage to definition so noticeable when hard molds are employed. The process in detail is as follows:

White glue is first softened by soaking in water; then the latter is drained off and the glue melted slowly and thickened somewhat by cooking in a double boiler or water bath. When sufficiently cool almost to permit immersing the hand without discomfort, the glue is in proper condition for flowing. Pose the fish by laying flat on some solid base, and build potters' clay about the side until the desired position is obtained. The clay immediately beneath the fins and tail should be smooth and at a height sufficient to permit the latter to be distended upon it, where, if necessary, they may be made secure by the use of insect pins. After applying over the entire surface of the fish a very thin coat of stearin dissolved in kerosene, carefully wipe with a soft cloth to remove any excess of oil.

A clay dam is now constructed about the specimen to the height of an inch or two above the highest point of the latter, and an equal distance from its outer edge; then the glue may be flowed. The glue should be poured directly upon the specimen, but very slowly, otherwise air spaces may occur. This is allowed to stand for a few hours, or until thoroughly chilled, when the clay dam may be removed and an inch of plaster spread over the entire surface of the mold. This acts as a "case" and holds the mold in its proper form during the later stages of the work.

Take the mold from the case, and, by slight manipulation, the specimen is removed without damage to either. Thoroughly work talcum powder into the mold, with a soft brush, to remove the oily surface, and immerse in a 5 per cent solution of formalin (measuring the latter as if 100 per cent) for five minutes. The surface of the glue is thus hardened, and only requires a few minutes in water, heated to a temperature of about 100° F., to prevent a too sudden chilling of the wax. Remove the excess of water with a soft sponge, and, after quickly applying a very thin coat of oil, the mold is ready for filling.

The transparency of the specimen must govern the composition of the wax for casting, but the following formula will prove generally useful. Melt in the double boiler one pound of paraffin to four pounds of bleached beeswax, to which add one teaspoonful of Canada balsam, or Venetian turpentine, to each pound of wax. Color with oil, tube colors, to the lightest tint of the ground color of the specimen.

As the fins and tails of fishes need strengthening, fill the mold and, after allowing it to stand a minute or two, empty it of all the wax except the thin film which will have formed over the surface, and while still hot press a single thickness of bolting cloth along the fins and tail; also add a silk covered wire at the spines, dashing a small quantity of wax over all to keep in position, when the mold should be again filled. The entire cast may be given additional strength by applying one or two coats of the cloth over the entire surface.

The principal care to be exercised in this work is in the flowing of the wax. There should be no splashing and the stream should be steady and constant, otherwise "water marks" and other possible defects will result.

Haste to remove the cast from the mold should be avoided, and under no circumstances should artificial means for cooling be employed, but the mold should be allowed to stand undisturbed until the wax is cold.

In pouring the wax into molds that present deep depressions or offsets, it is often necessary to resort to tilting or rolling the mold to insure the proper filling, and this should be done as the wax is deposited. It is advisable after such a mold is full to pour out a part of the wax and turn the mold at various angles to remove possible air bubbles, after which it is refilled.

In most instances the mold is easily taken from about the cast; but when deep undercuts are present the glue can be removed by cutting away in small sections or, more often, by merely splitting down the center. This is recommended where there are delicate parts which need care. A saving of material may be accomplished by inserting a rough form of wood and filling the intervening space with melted wax.

With fishes presenting a strong contrast of color, excellent results are obtained by tinting wax the several colors represented and applying each in its relative position with a soft brush. To do this properly, the mold must

first be immersed in water slightly warmer than the temperature mentioned. In no circumstances attempt to brush the wax on, but fill the brush and dab it on with one stroke of the end of the bristles, repeating until the surface is well coated, when the cloth and wire may be added as above described.

II. PLASTER CASTS FROM GLUE MOLDS.

When plaster casts are desired, the mold is prepared and treated as in wax casting, except that the warm-water bath may be omitted. With a soft brush work the thinly mixed plaster into every part of the mold until a coat has been applied to the entire surface.

While this coating is in a semisoft condition, dip white mosquito netting into thin plaster and lay on one or two thicknesses to increase the strength of the cast. The addition of burlap treated in the same manner will greatly assist in reducing the weight of such specimens. During warm weather it is advisable to inject and wash the specimen with formalin before posing, to prevent the quick decomposition likely to follow the application of the warm glue. As a further precaution the cooling process may be hastened by artificial means.

III. FISHES IN COPPER, FROM WAX MOLDS BY ELECTROPLATING PROCESS.

The most difficult part of the work of preparing fishes is the reproduction of their silver and iridescent colors. Metal "leaf" and washes produce but a slight resemblance to the original, and the resultant loss of detail and final discoloration of parts so treated emphasizes the necessity of preparing the highly metallic colored specimens in a manner whereby these difficulties may be avoided.

Some of the iridescent tints are imitated by the use of prismatic colors, but a white silver, or the various shades of this metal, as seen in the color of fishes, are possible only through a solid silver base.

Leaf and metal washes are not only dull in color, but are greatly darkened through the refraction of light, and it is impossible to secure brilliant effects by their use. The below-described method overcomes these difficulties, and such specimens are not only accurate of form and detail, but are durable.

The fish is posed as for glue molds, except the clay dam and coating of oil, which are omitted. The proportion of two pounds of paraffin to two pounds of bleached beeswax is melted in the double boiler and one tablespoonful of Canada balsam added to that quantity. Best results in flowing the wax are obtained by beginning at the tail with sufficient wax in a dipper (or other easily handled vessel) to insure a speedy and complete covering of the entire specimen. Allow the excess of wax to flow off and repeat several times at intervals, when a layer of absorbent cotton is spread on and saturated with the wax. In this

way a half-inch mold is built up. When it is cold, cut away all the wax about one inch outside the line of fins and tail, and apply a thin plaster case.

The fish is removed by gentle manipulation or possibly dissection, after which the mold is thoroughly cleansed by the use of a very soft brush and cold water and allowed to dry.

As pamphlets giving a complete description of copperplating are easily obtained, repetition on this subject is unnecessary here. The work does not require the services of an expert, and anyone of ordinary mechanical skill can arrange the apparatus and follow the simple directions.

When a substantial layer of copper has been deposited, the case is broken away and the wax mold removed by immersing in boiling water. After cutting and grinding away the excess of copper about the edges of the model by the use of an emery wheel or coarse file, bring the fins and tail down to a thin edge by the same method, and finish the outline with very fine files.

The model is then given a very thin plating of pure silver. This plating gives not only the full whiteness of the metal but permits of a variety of delicate shading and obviates the necessity for the use of white lead in coloring.

At first glance this method may appear too expensive for practical purposes, but with the electroplating performed by the preparator, it will prove of less cost than some of the methods now in use.

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THE UNITED STATES BUREAU OF FISHERIES

ITS ESTABLISHMENT, FUNCTIONS, ORGANIZATION RESOURCES, OPERATIONS, AND ACHIEVEMENTS

By Hugh M. Smith

Deputy Commissioner of Fisheries

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

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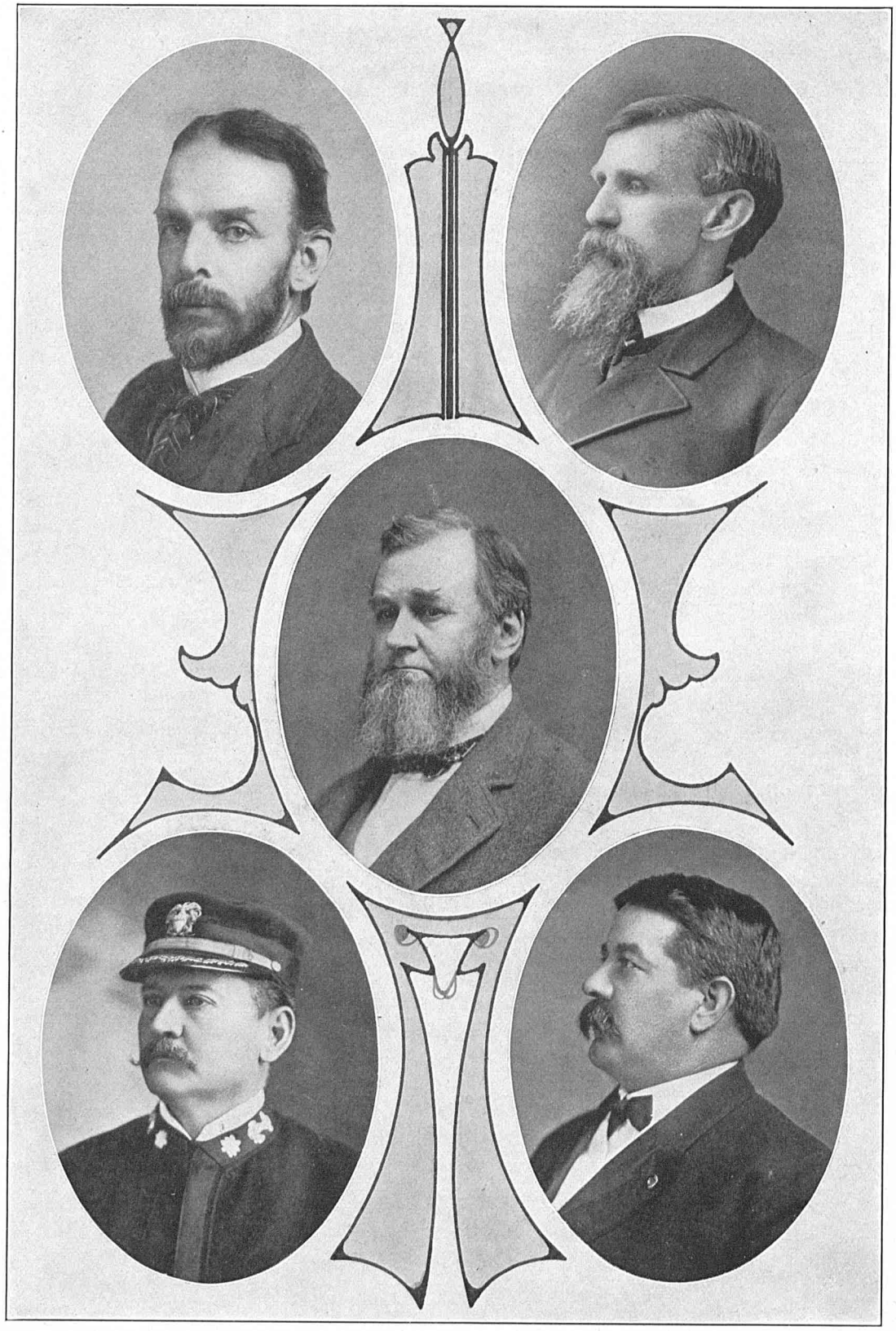


UNITED STATES COMMISSIONERS OF FISHERIES.

G. BROWN GOODE,
1887–1888.

MARSHALL MCDONALD,
1888–1895.

SPENCER F. BAIRD,
1871–1887.

JOHN J. BRICE,
1896–1898.

GEORGE M. BOWERS,
1898 to date.

THE UNITED STATES BUREAU OF FISHERIES:

ITS ESTABLISHMENT, FUNCTIONS, ORGANIZATION RESOURCES, OPERATIONS, AND ACHIEVEMENTS.

By HUGH M. SMITH,
Deputy Commissioner of Fisheries.

ESTABLISHMENT AND FUNCTIONS.

Prior to 1871 there was no branch of the United States Government especially charged with the consideration of fishery affairs, although fishery questions of greater or less import, some domestic, some foreign, had been arising ever since the achievement of national independence. Several of the States had already established fish commissions, and there arose among the state fishery authorities and the members of the American Fish Cultural Association (now the American Fisheries Society) an urgent demand for a national bureau devoted to fishery interests. Congress was thus influenced to action, and in the year named passed a joint resolution creating the office of Commissioner of Fish and Fisheries, whose duties were specified as follows:

> The Commissioner of Fish and Fisheries shall prosecute investigations and inquiries on the subject, with the view of ascertaining whether any and what diminution in the number of the food-fishes of the coast and the lakes of the United States has taken place; and, if so, to what causes the same is due; and also whether any and what protective, prohibitory, or precautionary measures should be adopted in the premises; and shall report upon the same to Congress.

It was further provided that the commissioner should be a civil officer of the Government, of proved scientific and practical acquaintance with the fishes of the coast, who would serve without additional compensation. The man generally regarded as preeminently qualified for the new position was Spencer Fullerton Baird, then Assistant Secretary of the Smithsonian Institution, who

received the appointment, at once entered on his duties, and continued the efficient and highly respected head of the commission until his death, in 1887.

Professor Baird was succeeded by one of his ablest assistants, Dr. George Brown Goode, eminent as administrator, ichthyologist, and fishery expert, who, however, voluntarily relinquished the commissionership after less than a year's incumbency in order to devote his entire time to the National Museum, of which he was director. Next came Commissioner McDonald, practical fish culturist and inventor of important mechanical appliances now used in the hatching of fish all over the world, who served until his death, in 1895, and was the first salaried commissioner. He was followed by Capt. John J. Brice, a retired naval officer, who held the office for two years and was succeeded in 1898 by the present commissioner, Hon. George Meade Bowers, under whose ten years' administration the service has grown in all its branches.

From the very outset of its career, the fishery service has had the active support and cooperation of many of the leading biologists, fish culturists, and fishery experts of the country, whose volunteer assistance has been an important factor in its development and efficiency. The early years of the Bureau were devoted to an active investigation of the condition of the fisheries of the Atlantic coast, Great Lakes, and other sections; to studies of the interior and coastal waters and their inhabitants, and to exploration of the offshore fishing banks. The cultivation of useful fishes was soon taken up throughout the country, and quickly attained large proportions. The natural expansion of the work was materially augmented from time to time by acts of Congress, and in a comparatively short time the operations came to have a very wide scope. In more recent years the work has been still further extended, so that at present there is scarcely a phase of aquiculture, of the fishing industry, or of biological and physical science as connected with the waters that does not come within the purview of the Bureau.

For many years the Bureau was without any executive control in fishery affairs. Under the Constitution the States legislate for themselves in such matters and the Federal Government has assumed no jurisdiction. The Bureau thus had no direct voice in the making or enforcing of any measures for the protection or preservation of aquatic animals, and its position, compared with the fishery service of other countries, was anomalous. In its advisory capacity, however, the Bureau has acquired an influence upon fishery legislation, and has now been given executive powers in Alaska for the enforcement of a comprehensive code of laws affecting the salmon fisheries. In the interests of the fur-seal fisheries the Bureau has since 1893 been called on to study the life history and migrations of the seals, to inspect conditions on the islands, and to submit recommendations concerning the killing of the animals.

ORGANIZATION.

Until 1903 the Bureau was known as the "United States Commission of Fish and Fisheries," and was an independent institution of the Government, responsible directly to Congress. In that year it was included in the new Department of Commerce and Labor, becoming the United States Bureau of Fisheries, as known at present.

The work at the outset naturally fell under the three general heads of scientific investigation, fishery inquiry, and fish culture. This classification has been extended and perfected, and enters into the organization at the present time.

The permanent personnel of the service includes 325 persons, of whom 83 are on duty in Washington and 242 are at outside stations, at laboratories, and on vessels. The officials under the commissioner are a deputy commissioner, a chief clerk, and a chief of each of the three divisions before referred to. All subordinates are appointed, after passing the prescribed examinations, from the registers maintained by the Civil Service Commission.

The deputy commissioner is the executive next to the commissioner, and acts with full powers in the latter's absence. The commissioner's office, which represents the administrative division of the Bureau and has the chief clerk at its head, has under it the accounting office, the office of the architect and engineer, and the office of vessels, in addition to the library, records, correspondence, and property. In this division there is a technical and clerical force of 20 persons, not including messengers, watchmen, janitors, engineers, firemen, and laborers, and the 34 civil employees in the vessel service.

The chief of the Division of Fish Culture, with an office force of 7, directs the operations at the hatcheries and the planting of fish. Each hatchery has a force consisting of a superintendent, fish culturist, skilled laborers, etc., the number of employees for all the stations reaching a total of 168. In addition to these there are 13 superintendents, fish culturists, and other employees at large. During the busy seasons the hatchery force is increased by the temporary employment of many spawntakers and laborers as the work requires. For the distribution of eggs and young fish there are 6 transportation cars permanently provided with crews of messengers, numbering in all 26 men. The car and messenger service is under the immediate direction of a superintendent.

The Division of Scientific Inquiry includes besides its chief 6 scientific assistants and a number of clerks. Three special agents are employed in the Alaska inspection service, which is under this division, and 3 persons are permanently employed at the biological laboratory at Beaufort, N. C. Numerous investigators and assistants are also employed temporarily as needed for the study of special problems at the laboratories and in the field.

In the Division of Statistics and Methods of the Fisheries there are the chief, 4 statistical field agents, 2 local agents, and 8 clerks, some of whom are available for field work.

RESOURCES AND INVESTMENT.

The only funds available for the operation of the Bureau are the moneys voted annually by Congress. The comparatively large sums collected yearly in the Alaska salmon-inspection service are covered intact into the Treasury. From its very modest beginning, with $5,000 allowed for its work, the Bureau has won such recognition from Congress that the appropriations for its maintenance have increased steadily, and for the current fiscal year, ending June 30, 1909, reached the substantial amount of $803,920, apportioned as follows:

Administration:	
Salaries	$45,380
Miscellaneous expenses	8,000
Propagation of food fishes:	
Salaries—	
Office	11,820
Stations and field service	156,420
Car and messenger service	23,100
Miscellaneous expenses	275,000
Inquiry respecting food fishes:	
Salaries—	
Office	13,640
Biological station at Beaufort, N. C	2,700
Miscellaneous expenses	30,000
Statistical inquiry:	
Salaries	17,140
Miscellaneous expenses	7,500
Vessel service:	
Salaries	29,420
Miscellaneous expenses	70,000
Alaska salmon-inspection service (salaries)	6,300
Special:	
Establishment of station for propagation of fresh-water mussels in Mississippi Valley	25,000
Construction of new steam vessel for Alaska service	20,000
Improvements and repairs at stations	44,500
Repairs to steamer Albatross	18,000
Total	803,920

The land owned and occupied by the Bureau at its fish-cultural and biological stations has an aggregate area of over 12,000 acres, with a value of $240,000. The improvements and equipments at these stations represent an investment of more than $1,000,000. Other property of the Bureau includes 4 seagoing steam and sail vessels, 20 steam launches, and 150 small sail, power, and row boats, which, with equipment, have a value of $300,000. Its 6 fish-transportation cars are valued at $45,000. The aggregate investment of the Federal Government in property devoted to the fishery service is thus about $1,585,000.

Headquarters of the Bureau of Fisheries, Washington, D. C.

Superintendent's residence at a New England trout-hatching station.

CULTIVATION AND DISTRIBUTION OF FOOD FISHES.

GENERAL IMPORTANCE AND EXTENT.

The artificial propagation of fishes was not contemplated at the time the Bureau was formed, but was instituted by an act of Congress in 1872 at the instigation of the American Fish Cultural Association, which had been organized two years before and had taken a leading part in the establishment of the Bureau. The fishes to which attention was given first were the shad, the Atlantic salmon, and the whitefish. This work proved so popular that it was extended annually, was supplemented by efforts in acclimatization, and soon overshadowed all other branches.

The Bureau has labored to make its operations commensurate with the extent of the fisheries in public waters, and with the inevitable exhaustion of the native fish life in the smaller lakes and streams incident to the development of the country and the increase of population. The policy, as enunciated by Doctor Goode, has been to carry out the idea that it is better to expend a small amount of public money in making fish so abundant that they can be caught without restriction and serve as cheap food for the people at large than to expend a much larger sum in preventing the people from catching the few fish that still remain after generations of improvidence.

From this standpoint it is perhaps fortunate that up to the present the Bureau has not had to devote its major energies to the formulation and enforcement of fishery legislation, but has been able to work directly for the increase of fish life. Public or government fish culture has in America attained tremendous proportions, and exceeds in extent and importance that of all other countries combined. However, the neglect of some of the States to provide the minimum protection to certain species inhabiting interstate and international waters has not only negatived the fish-cultural work of the Bureau and of the States themselves, but has practically inhibited it by preventing the possibility of securing an adequate supply of eggs, thus making desirable and necessary the institution of a new policy placing interstate and international waters under the jurisdiction of the General Government.

In the work of the Bureau of Fisheries the United States Government has an especial and unique claim to the epithet "paternal." The stocking of waters with food fishes is a direct benefit to the public, not only increasing the very material that supports an enormous industry, but providing food itself for the individual who will use his hook and line. From year to year, as the importance of the work has become increasingly evident, additional hatcheries have been built, the capacity of existing hatcheries has been enlarged, the scale of the operations has been extended, new kinds of fishes have been added to the output, and new sections have been brought under the direct influence of the work.

THE SPECIES CULTIVATED.

At the end of the first ten years of the Bureau's existence the fishes that were being regularly cultivated were shad, carp, chinook salmon, Atlantic salmon, landlocked salmon, rainbow trout, brook trout, and whitefish, in addition to which the propagation of several others had been undertaken experimentally. The list now is six times as long, and the annual output is ten times the aggregate for the ten-year period ended in 1881. The main energies are devoted to the important commercial fishes—shad, whitefish, lake trout, Pacific salmons, white perch, yellow perch, cod, flatfish—and the lobster, which are hatched in lots of many millions annually. More widely popular, however, are the distributions of the fishes of the interior waters which are generally classed as game fishes. Although representing only about 10 per cent of the output of the hatcheries, this feature of the work is very important, for it supplies choice kinds of fish for public rivers, lakes, and ponds, and for fishing preserves and private ponds and streams in all parts of the United States. The fishes most in demand for these purposes are the landlocked salmon, the different species of trout, the grayling, the basses, the crappies, the sunfishes, and the catfishes, but various others also are handled. Following is a classified list of the native fishes artificially propagated during 1908:

THE CATFISHES (SILURIDÆ):
- Spotted cat, blue cat, channel cat (*Ictalurus punctatus*).
- Horned pout, bullhead, yellow cat (*Ameiurus nebulosus*).
- Marbled cat (*Ameiurus nebulosus marmoratus*).

THE SHADS AND HERRINGS (CLUPEIDÆ):
- Shad (*Alosa sapidissima*).

THE SALMONS, TROUTS, WHITEFISHES, ETC. (SALMONIDÆ):
- Common whitefish (*Coregonus clupeiformis*).
- Lake herring, cisco (*Argyrosomus artedi*).
- Chinook salmon, king salmon, quinnat salmon (*Oncorhynchus tschawytscha*).
- Silver salmon, coho (*Oncorhynchus kisutch*).
- Blueback salmon, redfish, sockeye (*Oncorhynchus nerka*).
- Humpback salmon (*Oncorhynchus gorbuscha*).
- Steelhead (*Salmo gairdneri*).
- Rainbow trout (*Salmo irideus*).
- Atlantic salmon (*Salmo salar*).
- Landlocked salmon (*Salmo sebago*).
- Yellowstone Lake trout, cut-throat trout, black-spotted trout (*Salmo lewisi*).
- Colorado River trout, black-spotted trout (*Salmo pleuriticus*).
- Golden trout (*Salmo roosevelti*).
- Lake trout, Mackinaw trout, longe, togue (*Cristivomer namaycush*).
- Brook trout, speckled trout (*Salvelinus fontinalis*).
- Sunapee trout (*Salvelinus aureolus*).
- Canadian red trout (*Salvelinus marstoni*).
- Hybrid trout (*Salvelinus aureolus* + *fontinalis*).

THE GRAYLINGS (THYMALLIDÆ):
- Montana grayling (*Thymallus montanus*).

THE BASSES, SUNFISHES, AND CRAPPIES (CENTRARCHIDÆ):
Crappy (*Pomoxis annularis*).
Strawberry bass, calico bass (*Pomoxis sparoides*).
Rock bass, red-eye, goggle-eye (*Ambloplites rupestris*).
Warmouth, goggle-eye (*Chænobryttus gulosus*).
Small-mouth black bass (*Micropterus dolomieu*).
Large-mouth black bass (*Micropterus salmoides*).
Bluegill sunfish (*Lepomis pallidus*).
THE PERCHES (PERCIDÆ):
Pike perch, wall-eyed pike, yellow pike, blue pike (*Stizostedion vitreum*).
Yellow perch (*Perca flavescens*).
THE SEA BASSES (SERRANIDÆ):
Striped bass, rockfish (*Roccus lineatus*).
White bass (*Roccus chrysops*).
White perch (*Morone americana*).
Yellow bass (*Morone interrupta*).
THE DRUMS (SCIÆNIDÆ):
Fresh-water drum (*Aplodinotus grunniens*).
THE LABRIDS (LABRIDÆ):
Tautog, blackfish (*Tautoga onitis*).
THE CODS (GADIDÆ):
Cod (*Gadus callarias*).
Pollock (*Pollachius virens*).
Haddock (*Melanogrammus æglifinus*).
THE FLOUNDERS (PLEURONECTIDÆ):
Winter flounder, American flatfish (*Pseudopleuronectes americanus*).
CRUSTACEANS:
American lobster (*Homarus americanus*).

In addition to the foregoing, various kinds of fishes are obtained from the overflows in the Mississippi Valley and distributed. Among these are the small-mouth buffalo-fish (*Ictiobus bubalus*), the pike (*Esox lucius*), the pickerel (*Esox reticulatus*), and several sunfishes (chiefly *Eupomotis gibbosus*). From this same source are also collected large numbers of large-mouth black bass, crappies, rock bass, and bluegill sunfish. The following introduced species are cultivated to a limited extent:

Carp (*Cyprinus carpio*). Propagated chiefly for food for other fishes.
Goldfish (*Carassius auratus*). Propagated for ornamental purposes.
Tench (*Tinca tinca*). Cultivated varieties, green tench and golden tench; propagated for ornamental purposes.
Ide (*Leuciscus idus*). Cultivated variety, golden ide; propagated for ornamental purposes.
European sea trout (*Salmo trutta*).
Loch Leven trout (*Salmo trutta levenensis*).

THE HATCHERIES OPERATED.

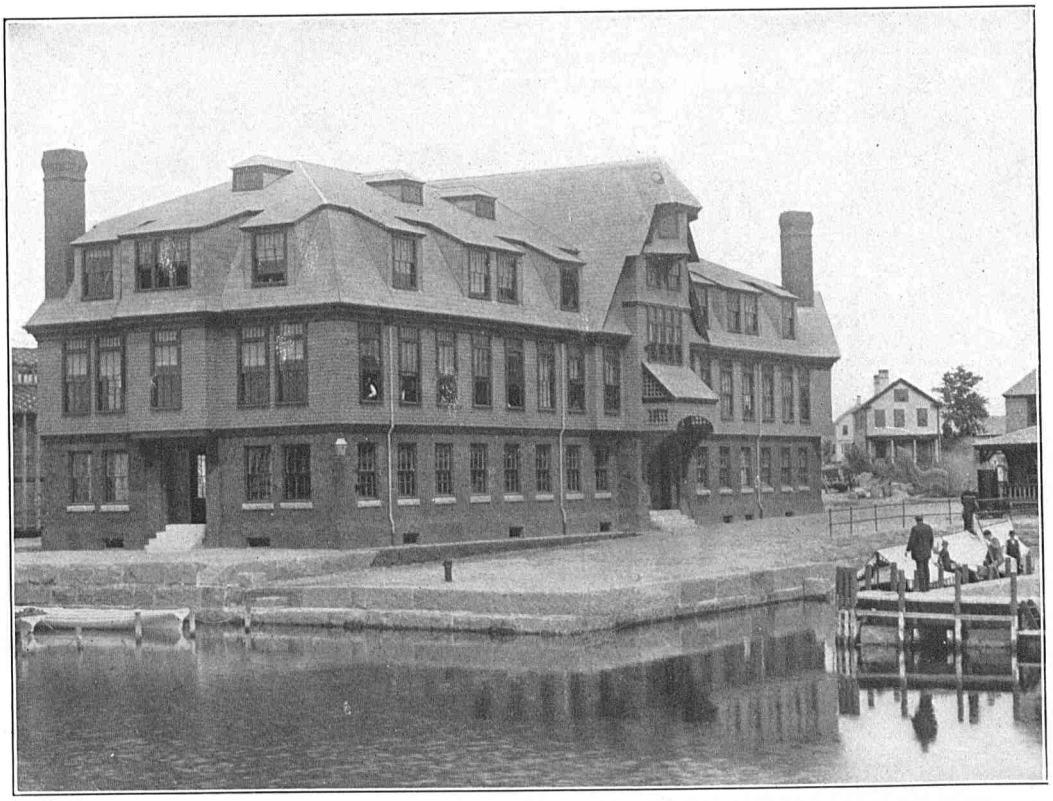
Fish-cultural stations are established by special act of Congress, and their location and construction are determined by the Bureau after a careful survey of the available sites in a given State. The plans and specifications for each station are prepared in the office of the architect and engineer with reference to

the nature of the operations to be conducted and the topographical conditions, and the work of constructing buildings and ponds is usually done by contract. Sometimes, however, the Bureau takes direct charge of construction, as in the case of the salmon hatcheries in Alaska.

The usual buildings at a fish-cultural station are the hatchery proper, a residence for the superintendent and his family, and necessary outbuildings. At some stations there may be also power house, foreman's or fish-culturist's dwelling, mess hall, and stable. The superintendent's and other quarters are furnished gratis, but station employees provide their own subsistence.

All sections of the country are now familiar with government fish-cultural work. In addition to the regular hatcheries, with their permanent personnel and living quarters, there are maintained numerous auxiliary hatcheries or substations which from the nature of their work do not require a permanent force and are therefore, for economic and administrative considerations, operated as adjuncts of near-by hatcheries. Some of the auxiliary stations, however, have more extensive operations than the hatcheries with which they are connected, and such will doubtless in time be made regular stations. There is also another class of stations, known as field or collecting stations, which serve as temporary headquarters for parties engaged in obtaining eggs from wild fishes. In 1908 the fish-cultural work was conducted in 27 States and Territories at 55 hatcheries and subhatcheries and 64 field stations.

While marine operations have been conducted from time to time at various places on the Atlantic coast from Maine to Florida, and have been addressed to a large number of species, the only permanent marine hatcheries are in Maine and Massachusetts, with the species handled at each as indicated in the following table. The places shown under each station are the centers of egg-collecting operations. Other sea fishes that have in previous years been artificially propagated and may again come under the hand of the fish-culturist are the haddock, the scuppaug, the sheepshead, the sea bass, the mackerel, and the squeteague, some of which were hatched on the steamer *Fish Hawk* in Chesapeake Bay and Florida.



Marine hatchery and laboratory, Woods Hole, Mass., established twenty-five years ago, and devoted to the culture of cod, flounders, and lobsters, the output of which in 1908 was 337 millions. Also the headquarters of important biological investigations of the east-coast fauna, the laboratory privileges being accorded gratuitously to qualified students.

Residence at the marine station, Woods Hole, Mass., formerly the summer headquarters of the Bureau, and now occupied by the officials of the laboratory and hatchery and by temporary assistants engaged in special work. (See p. 1384.)

MARINE HATCHERIES.

Location.	Species handled.
Boothbay Harbor, Me	Cod, lobster.
Pemaquid, Me	Lobster.
Portland, Me	Lobster.
Kittery Point, Me	Lobster.
Gloucester, Mass	Cod, pollock, flatfish, lobster.
Beverly, Mass	Lobster.
Boston, Mass	Lobster.
Cohasset, Mass	Lobster.
Hull, Mass	Lobster.
Marblehead, Mass	Lobster.
Plymouth, Mass	Cod.
Portsmouth, N. H	Lobster.
Rockport, Mass	Lobster.
Woods Hole, Mass	Cod, tautog, flatfish, lobster.
Chilmark, Mass	Lobster.
Dartmouth, Mass	Lobster.
East Greenwich, R. I	Flatfish.
Gay Head, Mass	Lobster.
Gosnold, Mass	Lobster.
Nantucket, Mass	Lobster.
Plymouth, Mass	Cod.
Sandwich, Mass	Lobster.
Waquoit, Mass	Flatfish.
Westport, Mass	Lobster.
West Tisbury, Mass	Lobster.
Yarmouth, Mass	Lobster.

The fish-cultural work on the eastern coast streams was centered at 6 hatcheries and subhatcheries in 1908. At 1 of these the principal species handled is the Atlantic salmon, at 4 the shad, at 3 the yellow perch, at 2 the white perch, and at 1 the striped bass. In recent years the Bureau has operated a shad hatchery on the Delaware River, and has detailed the steamer *Fish Hawk* for shad hatching in Maine, New Jersey, North Carolina, and Florida. The central station, in Washington, is operated largely for experimental and exhibition purposes, but sometimes receives large numbers of eggs from the adjacent river stations, especially when the latter are overstocked.

HATCHERIES ON EAST COAST RIVERS.

Location.	Fishes handled.
Craig Brook, Penobscot River, Me	Atlantic salmon, landlocked salmon, humpback salmon, brook trout.
Staceyville, Upper Penobscot River, Me	Atlantic salmon.
Havre de Grace, Susquehanna River, Md	Shad, yellow perch, white perch.
Bryans Point, Potomac River, Md	Shad, yellow perch.
Edenton, Albemarle Sound, N. C	Shad.
Weldon, Roanoke River, N. C	Striped bass.
Washington, D. C., Potomac River	Shad, yellow perch, white perch, etc.

In order to counteract the effect of the very exhausting fisheries of the Great Lakes, the Government has for many years maintained hatcheries in that region, and in 1908 operated 6 belonging to the United States and 2 belonging to the State of Michigan. The fishes to which attention is given are those which enter most largely into the catch of the fishermen, namely, the whitefish, cisco, lake trout, and pike perch, the annual output of which now exceeds one and one-half billions. Under arrangement with the Canadian authorities, 2 egg-collecting stations for whitefish, cisco, and lake trout are maintained at points in Ontario.

HATCHERIES ON THE GREAT LAKES.

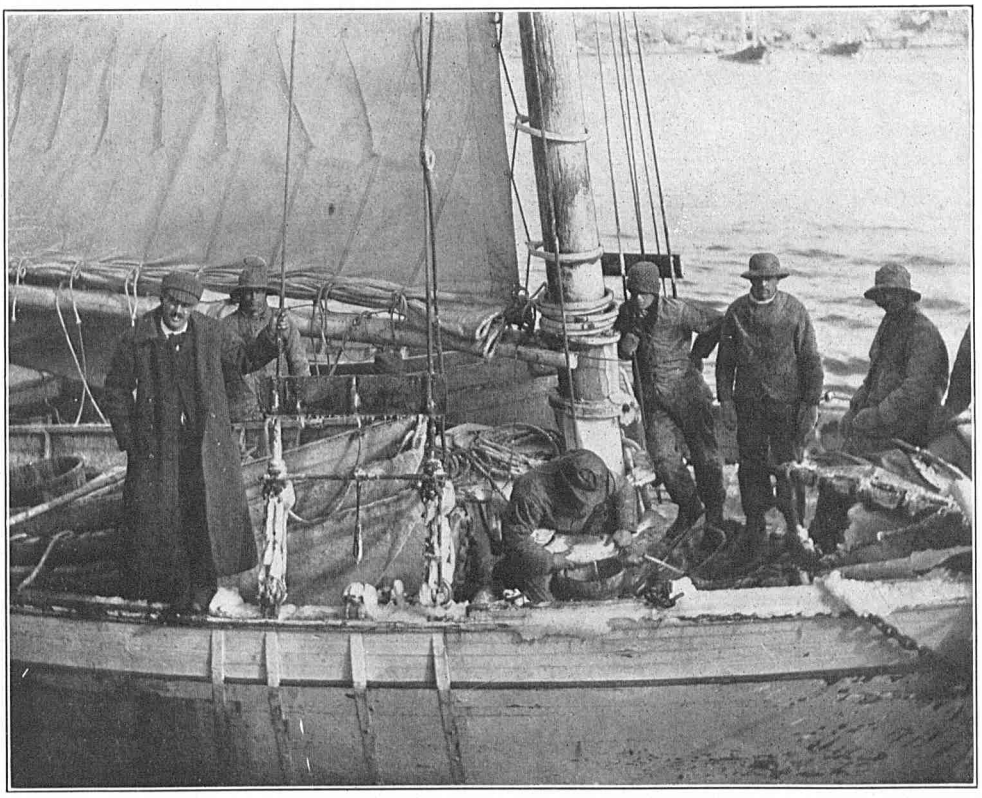
Location.	Fishes handled.
Cape Vincent, Lake Ontario, N. Y.	Whitefish, lake trout, brook trout, steelhead, landlocked salmon, pike perch, yellow perch.
Put-in Bay, Lake Erie, Ohio	Whitefish, lake cisco, lake trout, pike perch.
Kelleys Island, Ohio [a]	Whitefish.
Middle Bass Island, Ohio [a]	Whitefish.
Monroe Piers, Mich. [a]	Whitefish, pike perch.
North Bass Island, Ohio [a]	Whitefish, lake cisco.
Pelee Island, Ontario (Canada) [a]	Whitefish, lake cisco.
Port Clinton, Ohio [a]	Whitefish, lake cisco, pike perch.
Toledo, Ohio [a]	Pike perch.
Northville, Mich. [b]	Lake trout, etc.
Alpena, Lake Huron, Mich	Whitefish, lake trout.
Beaver Island, Lake Michigan, Mich. [a]	Lake trout.
Charlevoix, Lake Michigan, Mich	Whitefish, lake trout.
Detroit, Detroit River, Mich. [c]	Whitefish, pike perch.
Algonac, Lake Huron, Mich. [a]	Pike perch.
Bay City, Lake Huron, Mich. [a]	Pike perch.
Belle Isle, Detroit River, Mich. [a]	Whitefish.
Grassy Isle, Detroit River, Mich. [a]	Whitefish.
Sault Ste. Marie, St. Marys River, Mich. [c]	Whitefish, lake trout.
Duluth, Lake Superior, Minn	Whitefish, lake trout, pike perch, etc.
Isle Royale, Mich. [a]	Lake trout.
Keweenaw Point, Mich. [a]	Lake trout.
Marquette, Mich. [a]	Lake trout.
Ontonagon, Mich. [a]	Lake trout.
Rossport, Ontario (Canada) [a]	Lake trout.

[a] Egg-collecting stations.

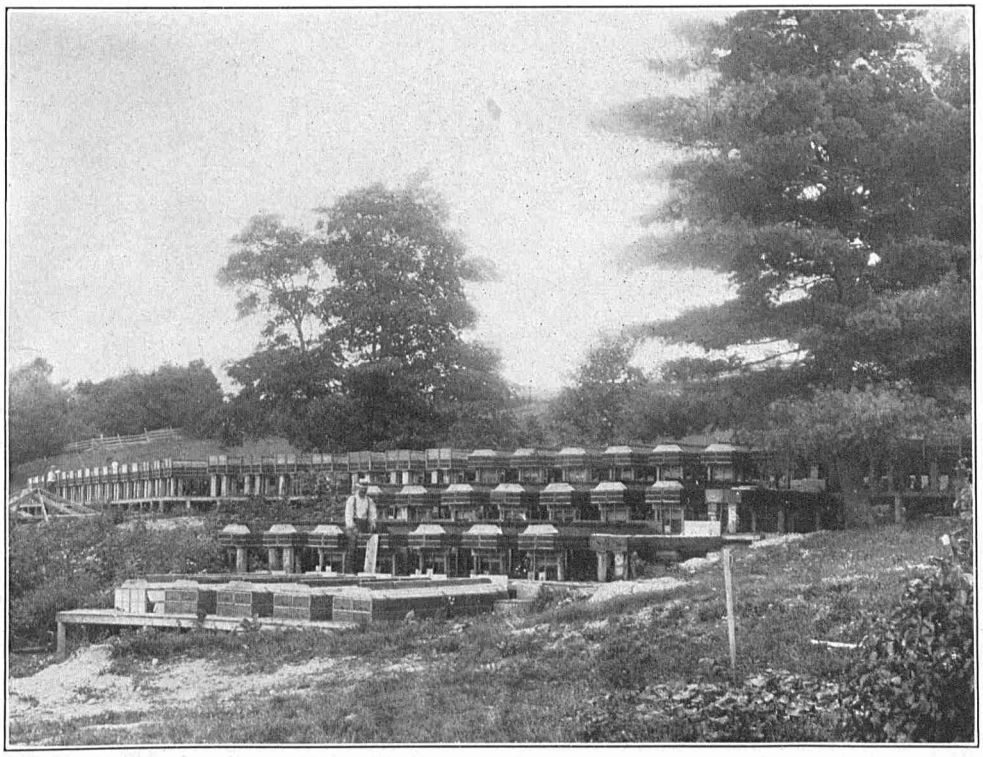
[b] Interior station, headquarters of the fish-cultural work in Michigan, conveniently located, and place where most of the lake-trout eggs are hatched.

[c] Hatcheries belonging to State of Michigan, leased by Bureau of Fisheries.

The hatcheries on the rivers and lakes of the Pacific coast region are devoted almost exclusively to the various salmons. In California, where the Bureau established a salmon hatchery as early as 1872, there is one central or main station, at Baird, on the McCloud River, with important collecting and eyeing stations on two other tributaries of the Sacramento. In Oregon a central hatchery at Oregon City, on the Willamette River, has three subhatcheries on tributaries of the Columbia in Oregon and Washington and three subhatcheries



Collecting cod eggs on a fishing vessel. One source of cod eggs hatched at the New England stations is the catch of the market fishermen. Spawntakers board the fishing boats, overhaul the fish, and save the eggs of such as are ripe.



Open-air salmon-rearing troughs. These troughs are used at the Craig Brook (Maine) hatchery for rearing Atlantic and landlocked salmon.

on tributaries of the Rogue River, Oregon, in addition to several egg-collecting stations. The interests of the large salmon fisheries of the Puget Sound region are safeguarded by a hatchery on Baker Lake, on the Skagit River, Washington, with an important auxiliary at Birdsview. The two latest additions to the western salmon hatcheries are at Yes Bay and Afognak, in Alaska, at which points immense numbers of blueback or sockeye salmon are now being put forth. A significant feature of artificial propagation on the Pacific seaboard is that in the Columbia basin the hatching of the acclimatized shad has begun on a small scale, and in the Sacramento basin the cultivation of the acclimatized striped bass has commenced under conditions which indicate that more eggs of this species may be obtained in California than in any of the States to which the fish is native.

HATCHERIES ON THE PACIFIC COAST STREAMS AND LAKES.

Location.	Fishes handled.
Baird, Sacramento River, Cal	Chinook salmon.
Battle Creek, Cal.[a]	Chinook salmon.
Bouldin Island, Cal	Striped bass.
Mill Creek, Cal.[a]	Chinook salmon.
Yreka, Sacramento River, Cal.[b]	Rainbow trout.
Baker Lake, Wash	Chinook salmon, blueback salmon, humpback salmon, silver salmon.
Birdsview, Wash	Chinook salmon, blueback salmon, humpback salmon, silver salmon, steelhead trout.
Oregon City, Willamette River, Oreg	Chinook salmon, silver salmon, steelhead trout, etc.
Big White Salmon, Columbia River, Wash	Chinook salmon.
Eagle and Tanner creeks, Columbia River, Oreg.[a]	Chinook salmon.
Eagle Creek, Clackamas River, Oreg.[b]	Steelhead trout.
Little White Salmon, Columbia River, Wash	Chinook salmon.
Rogue River, Oreg	Chinook salmon, steelhead trout, silver salmon.
Applegate Creek, Oreg.[b]	Chinook salmon, steelhead trout, silver salmon.
Findley Eddy, Rogue River, Oreg	Chinook salmon, silver salmon.
Illinois River, Rogue River, Oreg	Chinook salmon, steelhead trout.
Willamette Falls, Willamette River, Oreg	Shad.
Yes Bay, Yes Lake, Alaska	Blueback salmon.
Afognak, Afognak Island, Alaska	Blueback salmon.

[a] Stations where eggs are collected and eyed. [b] Collecting stations.

The hatcheries in the interior regions constitute the most numerous class, and their output reaches the largest number of people. Their operations are addressed chiefly to the so-called "game" fishes, which, while caught mostly by anglers, nevertheless constitute an important element of the food supply. At these stations large numbers of fish are reared to the fingerling or yearling sizes before being released; for which purpose more or less extensive pond areas are required.

A peculiar kind of station which is included in this general class is that devoted to the collection of fishes of various kinds obtained from the overflows in the upper Mississippi Valley. In the lowlands along the streams in this region the spring floods receding leave disconnected sloughs and pools, which either become dry during the summer or, if they remain until the winter, freeze solid, and the immense numbers of bass, crappy, and other desirable species therein are lost in the ordinary course of events. By seining these waters the Bureau obtains large numbers of fish that would otherwise perish, returning some of them to their native streams and distributing others to adjacent waters. In the autumn of 1908 six cars were employed in moving the fishes thus rescued.

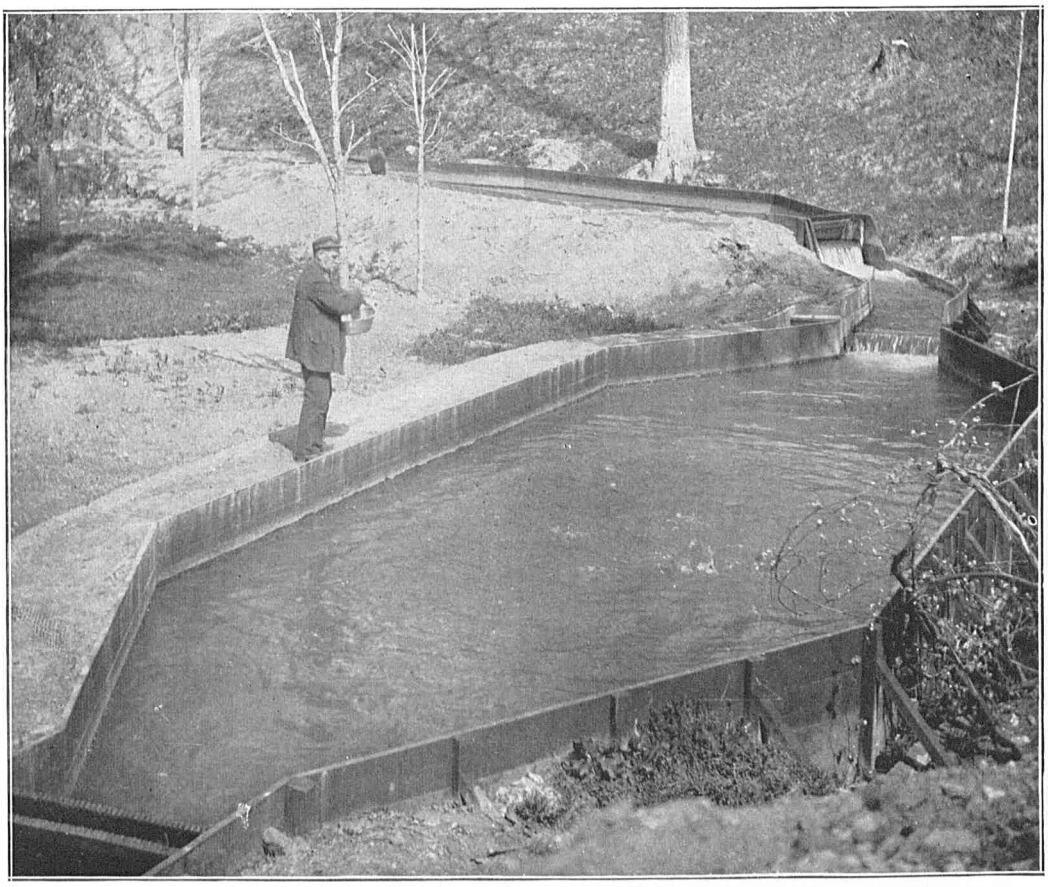
The following table, giving the interior fish-cultural stations and their auxiliaries, shows that in 1908 there were operated 23 of these stations and substations where hatching operations were conducted and 21 others where eggs or fish were simply collected:

HATCHERIES IN INTERIOR STATES.

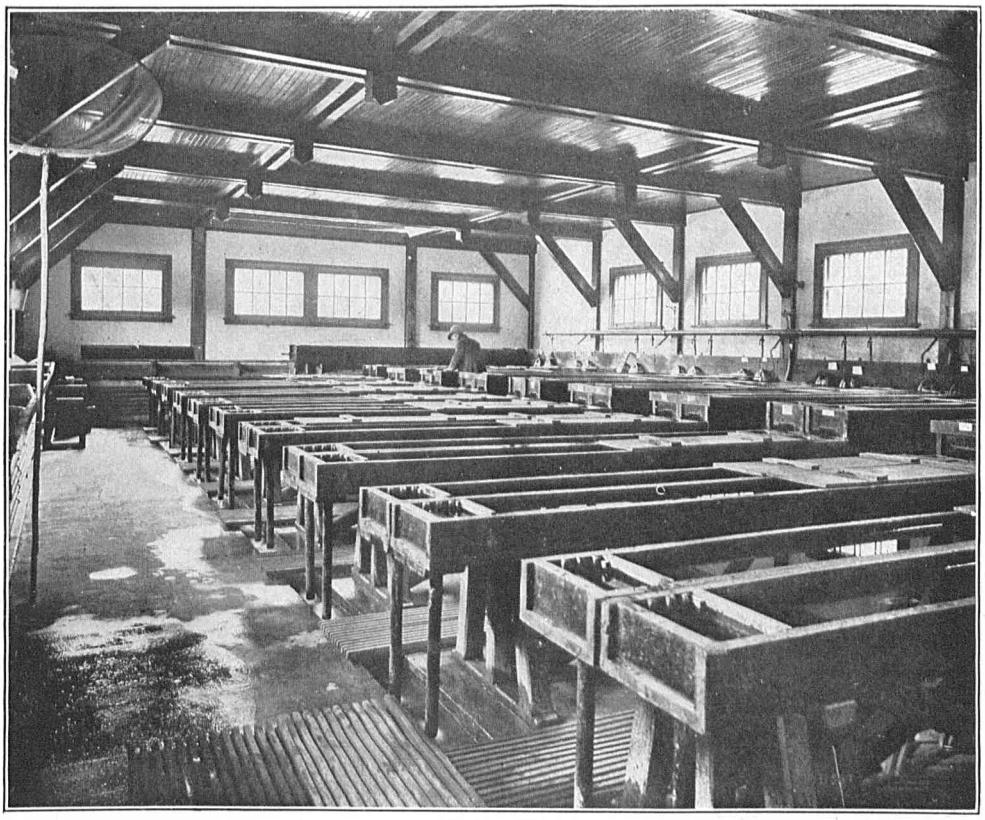
Location.	Fishes handled.
Bozeman, Mont	Brook trout, rainbow trout, black-spotted trout, golden trout, steelhead trout, landlocked salmon.
Redrock, Mont	Grayling.
Bullochville, Ga	Black basses, sunfishes, rock bass, catfish, etc.
Erwin, Tenn	Black basses, sunfishes, rock bass, yellow perch, rainbow and brook trouts, catfish, and minor species.
Green Lake, Me	Landlocked salmon, brook trout.
Branch Pond, Me.[a]	Landlocked salmon, brook trout.
Grand Lake Stream, Me	Landlocked salmon, brook trout.
Leadville, Colo	Rainbow trout, golden trout, black-spotted trout, brook trout, landlocked salmon, grayling.
Cheesman Lake, Colo.[a]	Rainbow trout.
Darrah, Colo.[a]	Brook trout.
Edith Lake, Colo.[a]	Brook trout.
Eldora Lake, Colo.[a]	Brook trout.
Englebrecht Lake, Colo.[a]	Brook trout.
Grand Lake, Colo	Black-spotted trout.
Grand Mesa Lakes, Colo	Black-spotted trout, rainbow trout, brook trout.
Musgrove Lake, Colo.[a]	Brook trout.
Ridgway Lake, Colo.[a]	Brook trout, rainbow trout.
Twin Lakes, Colo.[a]	Brook trout.
Wellington Lake, Colo.[a]	Brook trout.
Zoebles Lake, Colo.[a]	Brook trout.
Mammoth Spring, Ark	Black basses, rock bass.
Manchester, Iowa	Black basses, crappies, sunfishes, rock bass, pike perch, yellow perch, brook trout, lake trout, rainbow trout, black-spotted trout, catfish.
Bellevue, Iowa [b]	Large-mouth black bass, crappies, sunfishes, yellow perch, fresh-water drum, buffalo-fish, catfish.
La Crosse, Wis.[b]	Large-mouth black bass, crappies, sunfishes, rock bass, yellow perch, white bass, pike, buffalo-fish, catfish.
North McGregor, Iowa [b]	Large-mouth black bass, crappies, sunfishes, yellow perch, drum, pike, buffalo-fish, catfish.

[a] Stations for the collection of eggs.

[b] Stations for the rescue of young and adult fishes from overflowed lands of Mississippi River and tributaries.



Artificial spawning pond and raceway, used in culture of rainbow trout at the Wytheville (Virginia) station.



Interior of a typical trout hatchery.

HATCHERIES IN INTERIOR STATES—Continued.

Location.	Fishes handled.
Nashua, N. H.	Lake trout, brook trout, Sunapee trout, rainbow trout, hybrid trout, landlocked salmon, chinook salmon, small-mouth black bass.
Cumberland Center, N. H.[a]	Brook trout.
Lake Sunapee, N. H.[b]	Brook trout, Sunapee trout.
Neosho, Mo.	Black basses, crappies, sunfishes, rock bass, rainbow trout.
Northville, Mich.[c]	Brook trout, Loch Leven trout, steelhead trout, small-mouth black bass, and minor species.
Quincy, Ill.	Pike perch, black bass, and minor species.
Meredosia, Ill.[d]	Large-mouth black bass, crappies, sunfishes, pike perch, yellow perch, catfish, and minor species.
St. Johnsbury, Vt.	Small-mouth black bass, landlocked salmon, steelhead trout, lake trout, brook trout.
Arlington, Vt.	Brook trout.
Chittenden, Vt.[b]	Brook trout.
Darling Pond, Vt.[b]	Brook trout.
Lake Mansfield, Vt.[b]	Brook trout.
Lake Mitchell, Vt.[b]	Brook trout.
Swanton, Vt.	Pike perch, yellow perch.
San Marcos, Tex.	Large-mouth black bass, crappies, sunfishes, rock bass, warmouth bass.
Spearfish, S. Dak.	Rainbow trout, black-spotted trout, Loch Leven trout, brook trout.
Schmidts Lake, S. Dak.[b]	Brook trout.
Yellowstone Park, Wyo.	Black-spotted trout.
Tupelo, Miss.	Large-mouth black bass, sunfishes, yellow bass.
White Sulphur Springs, W. Va.	Black basses, rainbow trout, black-spotted trout, brook trout.

[a] Stations where eggs are collected and eyed but not hatched.
[b] Stations for the collection of eggs.
[c] See also in list of Great Lakes hatcheries.
[d] Stations for the rescue of young and adult fishes from overflowed lands of Mississippi River and tributaries.

THE OUTPUT AND ITS DISTRIBUTION.

The fish-cultural work of the Federal Government has now attained a magnitude that can not readily be comprehended, and is increasing at an exceedingly rapid rate. Especially marked has been the increase in the hatchery product during the past ten years, owing in part to the establishment of new stations, in part to the extension of operations at existing stations, and in part to greater efficiency of methods and appliances. The work during the fiscal year ending June 30, 1908, reached larger proportions than ever before, notwithstanding a shrinkage in the operations addressed to several important species. In the following summary by species of the eyed eggs, fry, and fingerlings, yearlings, and adults distributed in the past year it will be noted that several fishes included in the list of species cultivated do not appear in this table, for the reason that the entire stock was retained for breeding purposes. Ornamental species are likewise omitted from the table.

SUMMARY OF DISTRIBUTION OF FISH AND EGGS DURING THE FISCAL YEAR 1908.

Species.	Eggs.	Fry.	Fingerlings, yearlings, and adults.	Total.
Catfish			277,601	277,601
Carp			350	350
Buffalo-fish			40,500	40,500
Shad	760,000	79,316,600		80,076,600
Whitefish	139,266,000	384,480,000		523,746,000
Lake cisco	12,790,000	3,200,000		15,990,000
Chinook salmon	68,385,550	24,998,185	2,231,797	95,615,532
Silver salmon	296,000	13,420,714	57,932	13,774,646
Blueback salmon	75,000	69,883,305		69,958,305
Humpback salmon		7,185,748		7,185,748
Steelhead trout	333,725	1,123,146	59,000	1,515,871
Rainbow trout	830,000	253,650	2,713,600	3,797,250
Atlantic salmon		2,079,514	30,003	2,109,517
Landlocked salmon	190,000	441,281	151,526	782,807
Black-spotted trouts	768,380	4,230,540	1,442,376	6,441,296
Loch Leven trout			55,012	55,012
Lake trout	2,734,000	25,267,078	3,182,080	31,183,158
Brook trout	1,473,400	6,307,048	3,471,292	11,251,740
Sunapee trout		191,736		191,736
Grayling	200,000	1,047,000		1,247,000
Pikes			17,550	17,550
Crappy and strawberry bass			200,268	200,268
Rock bass			25,090	25,090
Warmouth bass			1,638	1,638
Small-mouth black bass		232,312	78,940	311,252
Large-mouth black bass		23,900	588,047	611,947
Sunfishes			202,810	202,810
Pike perch	218,725,000	193,438,000		412,163,000
Yellow perch	2,080,000	382,576,000	68,045	384,724,043
Striped bass		4,333,500		4,333,500
White perch	5,740,000	321,670,000		327,410,000
White bass			500	500
Fresh-water drum			26,000	26,000
Cod	3,000,000	235,365,000		238,365,000
Pollock		66,454,000		66,454,000
Tautog		794,000		794,000
Flatfish		389,642,000		389,642,000
Lobster		180,932,000	1,011	180,933,011
Total	457,647,055	2,398,886,257	14,922,968	2,871,456,380

While the Bureau does not lay undue stress on mere numbers and considers the vitality of the fish and the conditions under which they are planted as of paramount importance, the foregoing figures are certainly very suggestive; and as a further statement of the magnitude of the fish-cultural work it may be of interest to record that the aggregate output of the hatcheries from 1872 to 1908 was about 22,365,200,000, of which about 10,341,700,000 represents the work of the past five years.

The first consideration in the distribution of fishes is to make ample return to the waters from which eggs or fish have been collected. The remainder of the product is consigned to suitable public or private waters. All applications

for fish for private waters and many of those for public streams and lakes are transmitted through and receive the indorsement of a United States Senator or Representative. The fish are carried to their destination in railroad cars or by messengers who accompany the shipments in baggage cars. During the fiscal year 1908 the Bureau received 8,284 applications for fish, nearly all for game species. The demand, especially for the basses, crappies, and catfishes, is greater than can be met with present resources.

Fishes are distributed at various stages of development, according to the species, the numbers in the hatcheries, and the facilities for rearing. The commercial fishes, hatched in lots of many millions, are necessarily planted as fry. It is customary to distribute them just before the umbilical sac is completely absorbed. Atlantic salmon, landlocked salmon, and various species of trout, in such numbers as the hatchery facilities permit, are reared to fingerlings from 1 to 6 inches in length; the remainder are distributed as fry. The basses and sunfishes are distributed from the fish-cultural stations and ponds from some three weeks after they are hatched until they are several months of age. When the last lots are shipped the basses usually range from 4 to 6 inches and the sunfishes from 2 to 4 inches in length. The numerous fishes collected in overflowed lands—basses, crappies, sunfishes, catfishes, yellow perch, and others—are 2 to 6 inches in length when taken and distributed. Eggs are distributed only to state hatcheries or to applicants who have hatchery facilities.

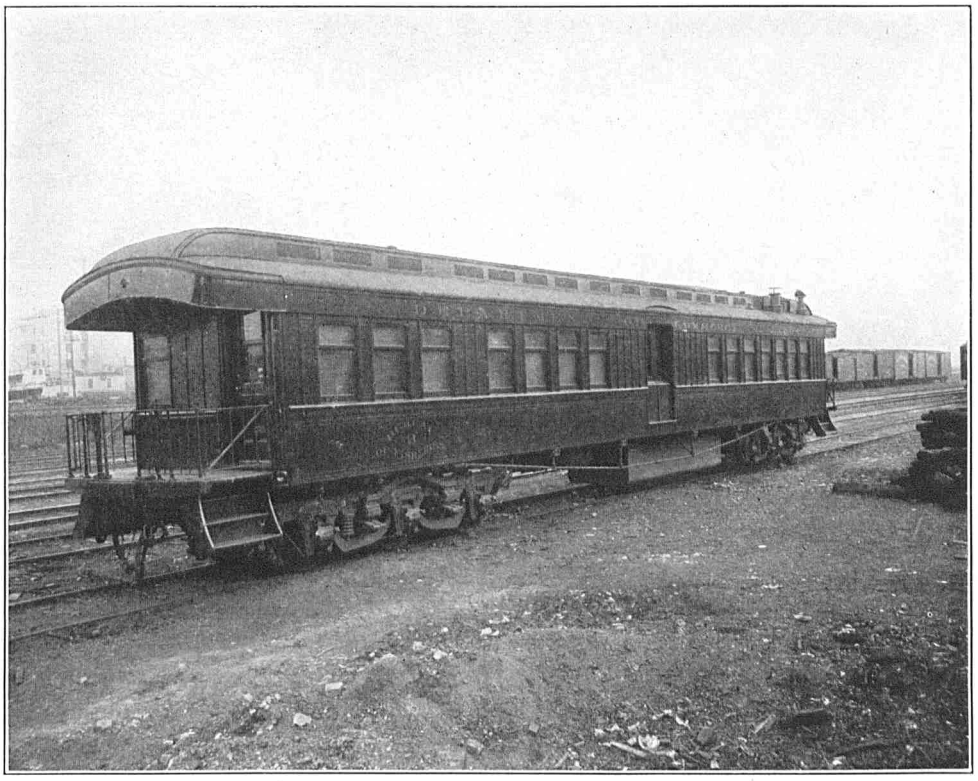
To insure the best results from plants of fish, applicants are required to furnish full information as to the physical characters and present inhabitants of the waters to be stocked, and the suitable species is determined by the Bureau; black bass, for instance, are not furnished for waters stocked with trout, which they would destroy, nor are trout consigned to waters already inhabited by predaceous fishes. The number of fish allotted to any applicant is governed by the available supply of that species, and the area and character of the water in question. Some species, merely hatched and not reared, can, as above stated, be produced by the hundred million. The allotments of these fry are correspondingly large. The species reared at the hatcheries or collected from overflows are available in no such numbers, and 200 or 300 fingerlings of these would be all that could be supplied as compared with half a million of the other fry. Species that are distributed as fry and also reared are of course supplied in much larger numbers as fry than as fingerlings. The Bureau attempts only to furnish a liberal brood stock, expecting that the fish will be protected until they have had time to reproduce.

Fish are delivered to applicants free of charge at the railroad station nearest the point of deposit, and for this purpose is maintained a special car and messenger service, which is one of the most important branches of the fish-cultural work. In the early days baggage cars were employed, but these

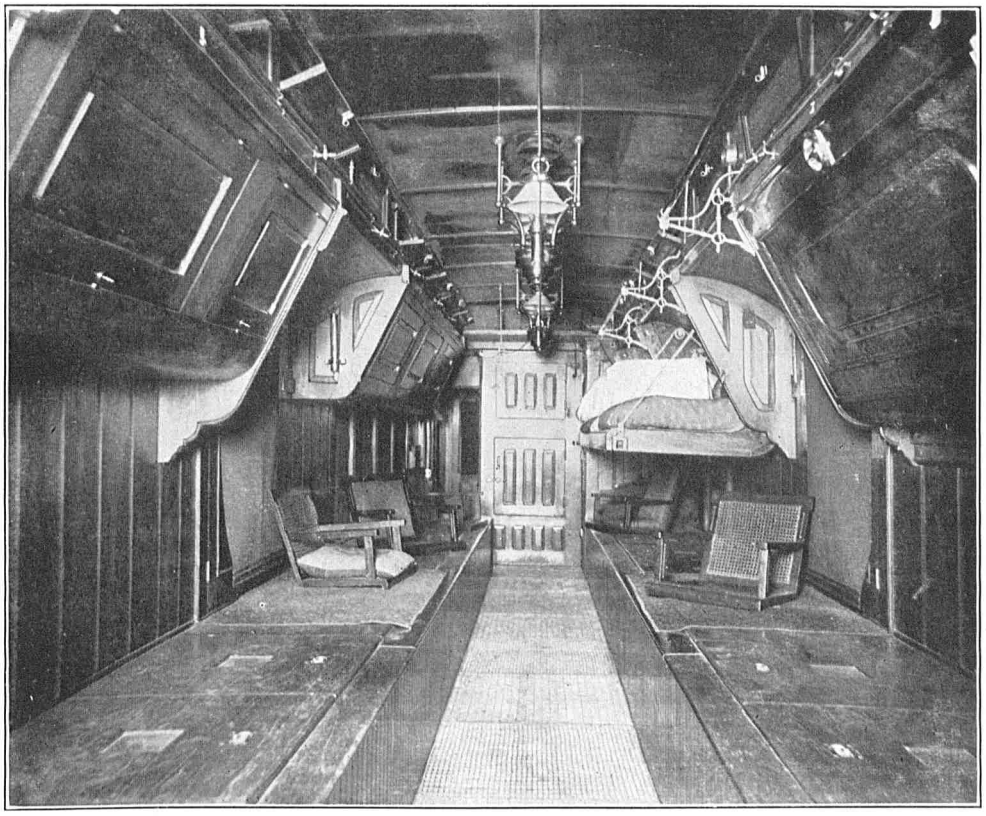
have now been supplanted by an equipment which not only affords more comfort to fish and attendants, but makes it possible to transport the fish much greater distances and with smaller percentage of loss. The cars, of which there are now 6, are of standard size, and are attached to regular express and local passenger trains. Each car has 20 or more large water tanks along the sides in which to carry fish, compartments holding more than 1,000 gallons of reserve water, a boiler room, and a plant for pumping both water and air into the fish tanks. There are also an office, kitchen, pantries, refrigerator, and 6 Pullman sleeping berths, with other facilities for the convenience and comfort of the crew of 5 men (including a cook) who live on the car throughout the year. The Government furnishes the cook, fuel, and utensils, but the men provide their own food. For small shipments of fish and for supplying places off the main railway lines messengers detached from the cars carry fish in 10-gallon cans in baggage cars. The distributions last year required travel amounting to 83,840 miles by the cars, and 263,196 miles by detached messengers—a total of 347,036 miles—of which 11,826 for cars and 80,816 for messengers were furnished by the railroads free of charge.

POPULARITY OF THE WORK.

There are few enterprises undertaken by the United States Government that are more popular, meet with more general and generous support, and have contributed more to the prosperity and happiness of a larger number of people than the federal fish-cultural work, evidence of which fact is afforded by the attitude and action of Congress. The comparatively large budget for the various branches of the Bureau's work is voted each year without any opposition whatever, and the appropriations are increasing yearly. When special needs arise and their merit is presented to Congress, special appropriations can usually be obtained; and government fish culture is so popular in the country at large and the demand for new hatcheries is so widespread that an extraordinary number of hatchery bills have been introduced and favorably considered in recent sessions of Congress. The Bureau advocates the building of new hatcheries as one of the best and most remunerative measures that can possibly be undertaken by the Federal Government, but it rarely has to take the initiative, and on several occasions the establishment of a hatchery has been proposed by Congress before the necessity for it has actually developed. During each of the recent sessions of Congress had all the bills providing for new hatcheries become laws the Bureau would have been seriously handicapped in designing and constructing the new buildings and ponds and in supplying competent persons to operate them. In the first session of the Sixtieth Congress, which began in December, 1907, and ended in May, 1908, there were introduced 101 distinct bills, carrying an aggregate appropriation of $2,142,000, and providing for 74 hatcheries and 4 laboratories in 43 States and Territories.



A fish transportation car. Six cars of this kind are in constant use by the Bureau. Live fish are carried safely for long distances, and eggs may be incubated while on trains traveling 60 miles an hour.



Interior view of fish transportation car, showing rows of covered tanks where fish are carried and Pullman sleeping berths for attendants.

While the manifold operations of the Bureau touch directly or indirectly practically the entire population of the United States, they appeal with special force to the commercial fisherman, the fish dealer, the amateur angler, the student of aquatic biology and physics, the owner of small ponds, lakes, or streams. and the professional cultivator of fishes and other water products.

SCIENTIFIC INQUIRY.

The first duties undertaken by the Bureau after its organization involved biological investigations, and the operations up to the present time have continued to have a distinctly scientific basis. In making his original plans for the systematic investigation of the waters of the United States and the biological and physical problems they present, Commissioner Baird insisted that to study only the food fishes would be of little importance, and that useful conclusions must needs rest upon a broad foundation of investigations purely scientific in character. The life history of species of economic value should be understood from beginning to end, but no less requisite is it to know the histories of the animals and plants upon which they feed or upon which their food is nourished; the histories of their enemies and friends and the friends and foes of their enemies and friends, as well as the currents, temperatures, and other physical phenomena of the waters in relation to migration, reproduction, and growth.

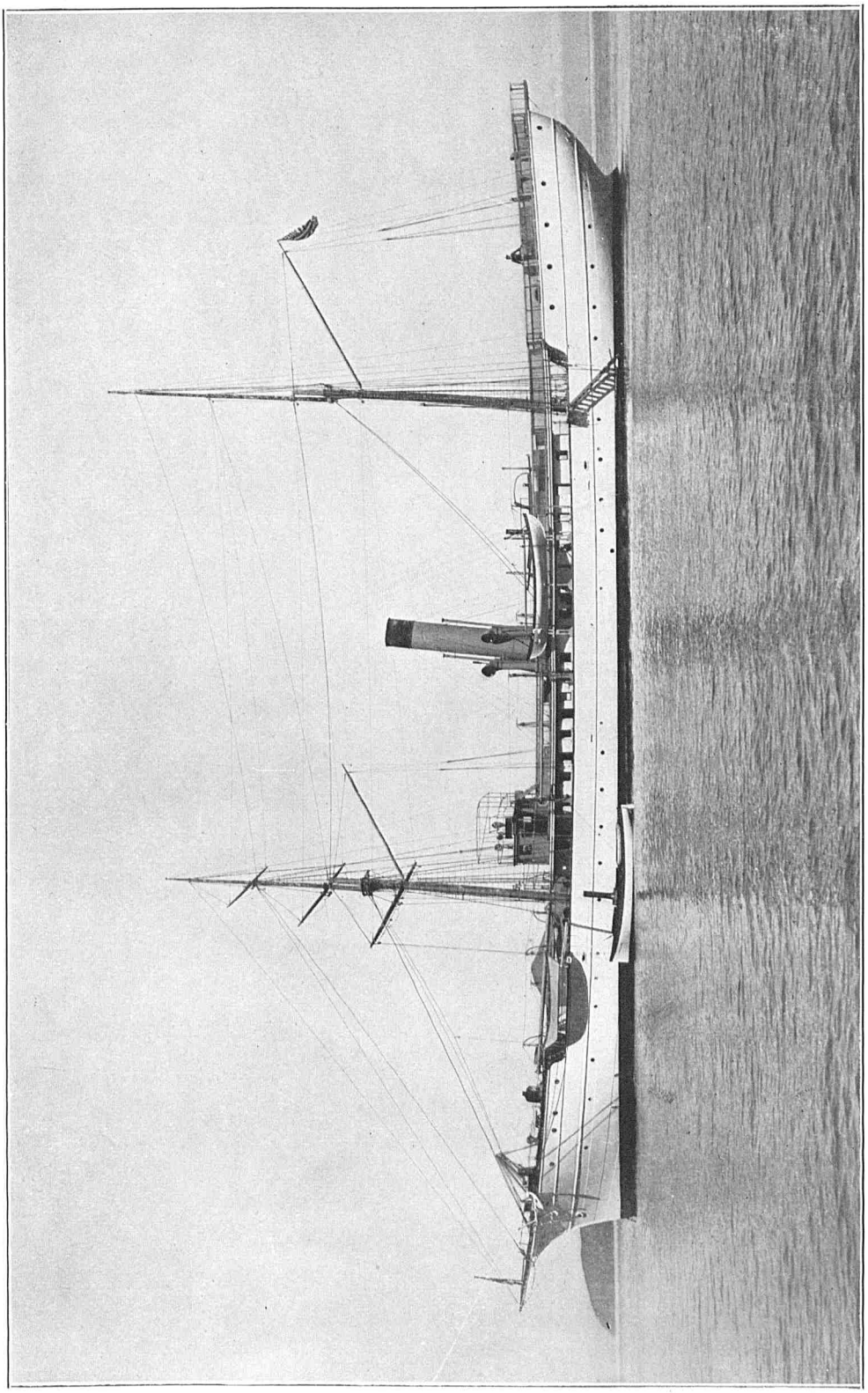
In pursuance of this policy the Bureau has secured the services of many prominent men of science, and much of the progress in the artificial propagation of fishes, in the investigation of fishery problems, and in the extension of knowledge of our aquatic resources has been due to men eminent as zoologists who have been associated with the work temporarily. Among such men recently have been Alexander Agassiz, Hermon C. Bumpus, Gary N. Calkins, Bashford Dean, Charles H. Gilbert, Theodore Gill, C. Judson Herrick, Francis H. Herrick, David Starr Jordan, A. D. Mead, George H. Parker, Jacob Reighard, Henry B. Ward, William M. Wheeler, and Henry V. Wilson. Their services have been the services of specialists for particular problems, and through them the Bureau has not only been able to give to the public the practical results of applied science, but has contributed to pure science valuable knowledge of all forms of aquatic life.

The small permanent staff of the Bureau concerns itself more directly with studies of fishes and their environment, with the conservation of diminishing commercial species, and the development of new or improved methods of increasing the supply. Such lines of work are undertaken as the need appears or as assistance is asked for, and keep the scientific assistants in the field for extended periods each year. The most important work in hand at present concerns aquatic products other than fishes—namely, oysters, fresh-water mussels,

sponges, and the diamond-back terrapin, in all of which cases the problem is to find means to offset the results of long-continued overdraft upon the natural supply. The Bureau has also the services of a fish pathologist—a position specially created by Congress at the solicitation of the commissioner. This assistant has devoted most of his time to the study of diseases among fishes at the hatcheries of the Government and of various States, and has added greatly to the existing knowledge of the causes and prevention of many of the affections which often prove so serious in fishes under cultivation. His field includes also the investigation of conditions due to pollution of waters.

Two seaside laboratories are maintained by the Bureau for the prosecution of investigations in pure and applied science. One of these is located at Woods Hole, Mass., the scene of the first biological work undertaken after the establishment of the Bureau. It was built in 1883, and is in conjunction with a marine fish hatchery. Here also are extensive wharves, at which the largest vessels may lie, and protected harbors for small craft. A large residence building at this station was for a number of years occupied as the summer headquarters of the Bureau, the entire executive and office force being transferred from Washington. The other laboratory is situated on a small island near Beaufort, N. C., and was constructed in 1901. The land for both of these stations was donated by private individuals. In addition to their function in the investigations of the Bureau itself, these laboratories are open to the public for study and scientific research. Students and professors in colleges and any other qualified investigators may have the facilities of the laboratories upon request, and these opportunities are largely availed of each year.

For the survey of offshore fishing grounds, the study of pelagic fishes, and the general exploration of the seas, the Bureau has had, since 1882, the steamer *Albatross*, which was specially designed and built for this work, and has contributed more to the knowledge of the life and physics of the sea than any other vessel. The *Albatross* is a twin-screw iron steamer, rigged as a brigantine, of 1,074 tons displacement and 384 net tonnage, and was built at a cost of $190,000, including original equipment. The complement of officers and men, numbering about 80, is furnished by the navy; there is in addition a small civilian staff, including a resident naturalist and a fishery expert, to whom the practical work of the ship is intrusted. After spending several years in the investigation of the fishing grounds of the Atlantic coast of North America, the *Albatross* was dispatched to the Pacific Ocean in 1888, and has since confined her operations to those waters. The vessel has made three extended cruises to the southern and eastern parts of the Pacific, several cruises to the Hawaiian Islands and Japan, and many visits to Alaska, in addition to numerous surveys on the coast of the Pacific States, all having for their object the investigation of the physics and biology of the regions visited, the determination of their aquatic resources,



Deep-sea exploring steamer Albatross, built by the Bureau and for twenty-five years engaged in surveying fishing grounds and in deep-sea exploration in the Atlantic and Pacific oceans. The Albatross has contributed more to the knowledge of marine biology than has any other vessel.

and the study of their fisheries. In 1907 the vessel began a biological survey of the waters of the Philippine Archipelago, and is now engaged on that work. The deepest sounding made by the *Albatross*—near the island of Guam—was 4,813 fathoms; the greatest depth at which the vessel found life was 4,173 fathoms; the greatest known ocean depth is 5,269 fathoms, near Guam, ascertained by the U. S. S. *Nero* while using *Albatross* apparatus.

Work similar to that done by the *Albatross* is conducted by the steamer *Fish Hawk* on the Atlantic coast. This vessel, built for the Bureau in the winter of 1879–80, is of 441 gross tons burden, and has a naval crew of 45 men; it is equipped for sounding and dredging, and has recently been employed chiefly in the exploration of the coastal waters and inshore fishing grounds of New England while attached to the laboratory at Woods Hole. The vessel is convertible into a hatchery, and has been engaged in the hatching of shad and other fishes along the entire coast from Maine to Texas.

The Bureau's large collections of natural-history specimens are deposited in the United States National Museum. The duplicates, however, are not retained by that institution, but are distributed upon request to public schools and colleges. In this way hundreds of thousands of specimens representing all groups of aquatic animals have been supplied for educational purposes.

STATISTICS AND METHODS OF THE FISHERIES.

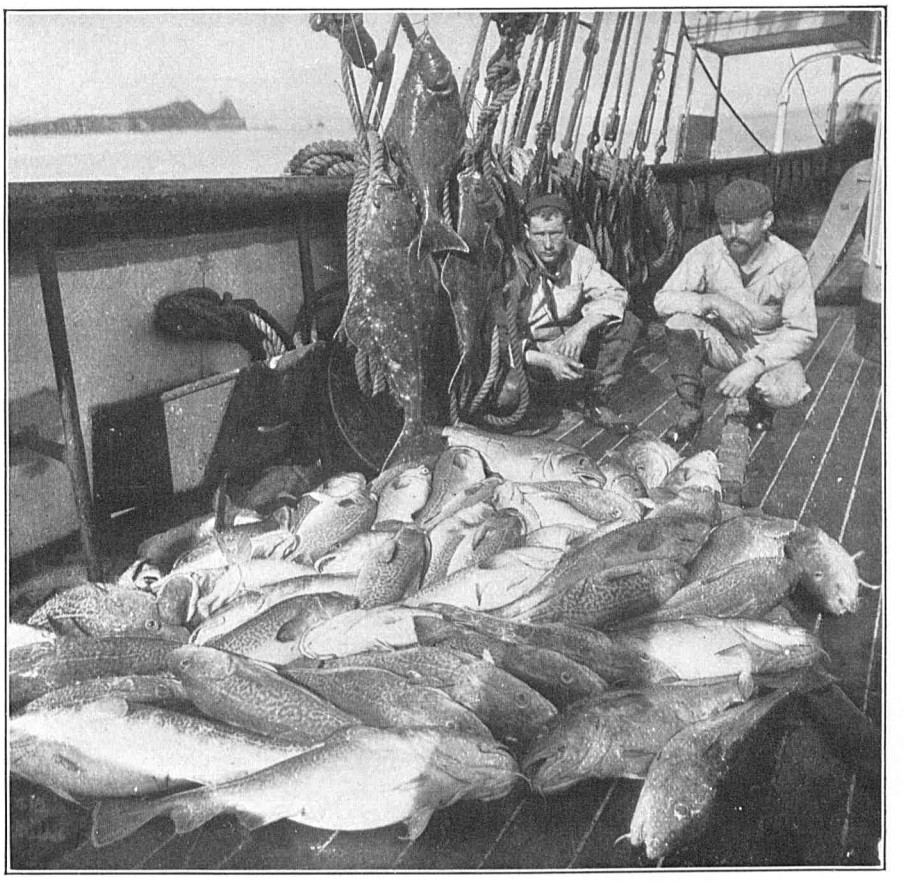
The first duty to which the Bureau of Fisheries was assigned, namely, the investigation of the reported decrease of food fishes in New England, necessarily involved the collection of statistics of production, personnel, and capital. Since that time this branch of the work has been conducted without interruption, and in it have naturally been included the various other subjects affecting the economic and commercial aspects of the fisheries. Among its functions are (1) a general survey of the commercial fisheries of the country; (2) a study of the fishery grounds with reference to their extent, resources, yield, and condition; (3) a study of the vessels and boats employed in the fisheries, with special reference to their improvement; (4) a determination of the utility and effect of the apparatus of capture employed in each fishery; (5) a study of the methods of fishing, for the special purpose of suggesting improvements or of discovering the use of unprofitable or unnecessarily destructive methods; (6) an inquiry into the methods of utilizing fishery products, the means and methods of transportation, and the extent and condition of the wholesale trade; (7) a census of the fishing population, their economic and hygienic condition, nativity, and citizenship; (8) a study of international questions affecting the fisheries; (9) the prosecution of inquiries regarding the fishing apparatus and methods of foreign countries.

The collection of statistics of the commercial fisheries and the industries dependent thereon constitutes the major part of this work. The information is required in great detail, and is obtained by the personal inquiries of a small corps of agents, who visit all the fishing communities and interview fishermen, fish dealers, vessel owners, factory proprietors, and others. While the Bureau is not authorized by law to enforce demands for data, it very rarely happens that information is refused; on the contrary, the objects and value of the work being now well understood, many thousands of fishermen keep accurate records for the special use of the Bureau, and dealers, transportation companies, preparators, etc., permit free access to their books.

The relatively small force available for the collection of statistics, the magnitude of the territory to be covered, and the extent of the fisheries prevent the canvass of more than one section of the country during one season; and it has been found impossible to cover the entire coastwise and interior fisheries oftener than once in four or five years. Herewith are the latest available statistics gathered by the Bureau for the general fishing industry. These figures show that 219,534 persons were engaged in the fisheries, $94,254,839 were invested in vessels, boats, apparatus, and other property, and the products had a value of $61,047,909:

STATEMENT OF THE PERSONS ENGAGED AND THE CAPITAL INVESTED IN THE FISHERIES OF THE UNITED STATES.

Item.	Atlantic and Gulf States.		Pacific Coast States and Alaska.	
	Number.	Value.	Number.	Value.
Persons employed	161,923		32,410	
Vessels fishing	4,584	$8,170,256	121	$621,017
Tonnage	85,432		8,250	
Outfit		3,006,425		289,897
Vessels transporting	1,686	1,847,469	334	2,771,022
Tonnage	29,737		62,255	
Outfit		295,257		68,055
Boats	61,489	3,981,761	10,155	1,528,911
Seines	3,888	534,227	772	282,244
Gill nets and trammel nets	143,824	782,338	8,611	1,095,282
Pound nets, trap nets, and weirs	7,384	1,540,835	680	1,444,510
Fyke nets	19,033	94,180	446	4,610
Beam trawls and paranzellas	66	1,696	41	6,371
Wheels and slides	37	775	49	168,000
Eel and lobster pots	228,086	248,974		
Dredges, tongs, rakes, scrapes, etc		411,424		7,131
Lines		347,079		44,421
Other apparatus		55,347		45,075
Shore and accessory property		20,571,131		10,473,781
Cash capital		15,013,676		7,205,650
Total		56,902,850		26,055,977



Trial fishing on the Albatross. This experimental catch of cod and halibut was taken in twenty minutes by the Albatross while exploring a new "bank" off the coast of Alaska. (See p. 1384.)

Marine biological laboratory at Beaufort, N. C. This station, built in 1901, is favorably located for the study of the aquatic fauna of the southeast coast. The laboratory building is 174 feet long and 42 feet wide in the main portion, has a large museum and aquaria, and accommodates about 30 workers. Adjoining the laboratory building are a power plant and a mess house and kitchen. (See p. 1384.)

STATEMENT OF THE PERSONS ENGAGED AND THE CAPITAL INVESTED IN THE FISHERIES OF THE UNITED STATES—Continued.

Item.	Great Lakes and interior waters.		Total.	
	Number.	Value	Number	Value.
Persons employed	25,201		219,534	
Vessels fishing	194	$634,450	4,899	$9,425,723
Tonnage	3,506		97,188	
Outfit		147,402		3,443,724
Vessels transporting	18	69,400	2,038	4,687,891
Tonnage	500		92,492	
Outfit		8,154		371,466
Boats	12,156	529,766	83,800	6,040,438
Seines	992	76,612	5,652	893,083
Gill nets and trammel nets	102,604	657,804	255,039	2,535,424
Pound nets, trap nets, and weirs	4,848	617,063	12,912	3,602,408
Fyke nets	40,724	261,379	60,203	360,169
Beam trawls and paranzellas			107	8,067
Wheels and slides	4	480	90	169,255
Eel and lobster pots			228,086	248,974
Dredges, tongs, rakes, scrapes, etc		13,683		432,238
Lines		24,994		416,494
Other apparatus		16,215		116,637
Shore and accessory property		4,809,022		35,853,934
Cash capital		3,429,588		25,648,914
Total		11,296,012		94,254,839

NOTE.—The years to which these figures pertain are 1905 for New England, 1904 for the Middle Atlantic States 1902 for the South Atlantic and Gulf States, 1904 for the Pacific States, 1907 for Alaska, 1903 for all interior waters.

STATEMENT OF THE PRODUCTS OF THE FISHERIES OF THE UNITED STATES.

Product.	Atlantic and Gulf States.		Pacific States and Alaska.	
	Pounds.	Value.	Pounds.	Value.
Fishes:				
Alewives	52,061,580	$473,811		
Barracudas	35,435	1,253	2,159,282	$51,820
Black basses	1,201,135	90,956	93,500	2,910
Bluefish	16,575,661	781,802		
Bonito	1,019,032	41,818	212,062	3,075
Buffalofishes	3,006,610	26,556		
Butterfish	4,184,363	138,761		
Catfishes	5,252,858	168,102	923,144	27,292
Cods	77,498,674	2,101,119	7,694,944	193,966
Crappy and strawberry bass	253,506	7,154		
Croaker	6,910,903	138,931	121,340	3,145
Cusk	9,079,866	139,964		
Drum, fresh-water	5,550	131		
Drum, salt-water	4,063,230	109,055		
Eels	3,636,964	212,160		
Flounders	9,676,172	290,186	8,418,145	155,512
German carp	1,328,271	78,778	90,374	1,607
Haddock	77,065,441	1,258,763		
Hakes	35,928,627	419,384		
Halibut	3,715,776	237,876	12,091,000	358,930
Herrings	83,390,554	692,854	4,455,729	35,407
Mackerel	16,323,612	1,106,741	134,992	3,666
Menhaden	562,427,449	1,452,062		

STATEMENT OF THE PRODUCTS OF THE FISHERIES OF THE UNITED STATES—Continued.

Product	Atlantic and Gulf States.		Pacific States and Alaska	
	Pounds.	Value.	Pounds.	Value
Fishes—Continued.				
Mullets	41,734,178	$709,067	12,952	$423
Perch, white	2,674,763	160,875		
Perch, yellow	587,885	25,547		
Pike perches	31,200	1,505		
Pike and pickerel	154,359	10,045		
Pollock	29,033,093	305,436		
Pompano	876,305	56,905	33,850	4,502
Rockfishes			1,896,467	63,409
Salmons	86,368	20,161	267,389,335	12,589,958
Scup	9,216,731	250,320		
Sea bass	4,282,313	183,219		
Shads	28,065,130	1,688,352	489,505	13,146
Sheepshead	2,634,046	68,060		
Silver hake	5,549,935	37,866		
Smelts	628,860	69,710	2,762,202	79,973
Snapper, red	13,763,653	418,360		
Snappers, other	401,349	11,419		
Spanish mackerel	2,965,381	160,270	708,465	11,704
Spot	2,023,476	65,759		
Squeteagues	43,794,980	1,233,959	988,524	31,548
Striped bass	2,601,354	259,926	1,570,404	92,116
Sturgeons	1,475,925	137,311	137,981	4,271
Suckers	451,426	17,364		
Sunfishes	751,655	18,757	11,343	554
Swordfish	3,311,369	205,567		
Tautog	847,756	28,298		
Trouts			3,089,670	129,253
Whiting and kingfish	1,178,650	56,107		
Other fishes	8,245,417	210,136	3,748,766	74,186
Fish oil	26,325	856	718,837	19,191
Mollusks:				
Abalone			824,948	9,155
Clams, hard-shell	8,193,844	1,320,364	871,008	65,078
Clams, soft-shell and other	8,130,430	543,722	308,080	30,280
Cockles, winkles, conchs, etc	93,734	13,510		
Mussels	1,551,850	6,705	28,215	1,764
Oysters	215,121,914	17,417,581	2,665,696	1,031,523
Oyster and other shells	19,975,115	20,488	8,730	218
Scallops	1,586,151	297,658		
Squid	1,119,369	17,307	251,360	10,054
Crustaceans:				
Crabs	34,137,937	723,845	6,081,606	181,904
Crawfish	16,000	615	187,200	12,480
King crabs	2,303,000	8,903		
Lobster	11,898,136	1,364,721		
Shrimp and prawn	16,186,905	288,344	1,311,750	93,544
Shrimp shells			950,000	4,390
Spiny lobsters	55,664	3,282	1,078,065	43,406
Reptiles and batrachians:				
Alligator hides	349,927	40,779		
Frogs	9,210	1,289		
Terrapins and turtles	856,936	94,586	28,095	2,616
Mammals:				
Fur-seal pelts			92,364	484,649
Hair-seal pelts			75,417	13,354
Otter pelts	3,283	18,367	3,562	16,703
Whalebone	55,950	193,037	120,191	529,614
Whale oil	3,933,554	246,565	408,419	20,796

STATEMENT OF THE PRODUCTS OF THE FISHERIES OF THE UNITED STATES—Continued.

Product.	Atlantic and Gulf States.		Pacific States and Alaska.	
	Pounds.	Value.	Pounds.	Value.
Mammals—Continued.				
Ambergris	94	$16,900		
Sea-elephant oil	590,625	25,000		
Sea-elephant skins	5,000	600		
Walrus products			8,749	$5,771
Minor products			7,575	7,791
Miscellaneous:				
Sponges	346,889	364,422		
Seaweeds	841,000	34,120	59,320	2,267
All other products	2,886,040	39,926	1,198,589	34,380
Total	1,512,283,708	39,482,010	336,521,752	16,553,301

Product.	Great Lakes and interior waters.		Total.	
	Pounds.	Value.	Pounds.	Value.
Fishes:				
Alewives			52,061,580	$473,811
Barracudas			2,194,717	53,073
Black basses	644,936	$56,605	1,939,571	150,471
Bluefish			16,575,661	781,802
Bonito			1,231,094	44,893
Buffalofishes	11,527,531	313,841	14,534,141	340,397
Butterfish			4,184,363	138,761
Catfishes	6,542,001	336,135	12,718,003	531,529
Cods			85,193,618	2,295,085
Crappy and strawberry bass	1,143,800	54,034	1,397,306	61,188
Croaker			7,032,243	142,076
Cusk			9,079,866	139,964
Drum, fresh-water	3,507,331	87,810	3,512,881	87,941
Drum, salt-water			4,063,230	109,055
Eels	178,952	11,409	3,815,916	223,569
Flounders			18,094,317	445,698
German carp	17,524,118	361,870	18,942,763	442,255
Haddock			77,065,441	1,258,763
Hakes			35,928,627	419,384
Halibut			15,806,776	596,806
Herrings			87,846,283	728,261
Herring, lake	32,177,689	816,046	32,177,689	816,046
Mackerel			16,458,604	1,110,407
Menhaden			562,427,449	1,452,062
Mullets			41,747,130	709,490
Paddlefish	1,432,257	53,565	1,432,257	53,565
Perch, white			2,674,763	160,875
Perch, yellow	6,492,885	156,727	7,080,770	182,274
Pike perches	10,868,404	456,470	10,899,604	457,975
Pike and pickerel	1,296,911	69,677	1,451,270	79,722
Pollock			29,033,093	305,436
Pompano			910,155	61,407
Rockfishes			1,896,467	63,409
Salmons	125,858	5,629	267,601,561	12,615,748
Scup			9,216,731	250,320
Sea bass			4,282,313	183,216
Shads	8,750	875	28,563,385	1,702,373
Sheepshead			2,634,046	68,060
Silver hake			5,549,935	37,866

STATEMENT OF THE PRODUCTS OF THE FISHERIES OF THE UNITED STATES—Continued.

Product.	Great Lakes and interior waters.		Total.	
	Pounds.	Value.	Pounds.	Value.
Fishes—Continued				
Smelts	23,600	$2,720	3,414,662	$152,403
Snapper, red			13,763,653	418,360
Snappers, other			401,349	11,419
Spanish mackerel			3,673,846	171,974
Spot			2,023,476	65,759
Squeteagues			44,783,504	1,265,507
Striped bass			4,171,758	352,042
Sturgeons	1,647,306	91,372	3,261,212	232,954
Suckers	9,087,213	178,940	9,538,639	196,304
Sunfishes	1,325,521	33,295	2,088,519	52,606
Swordfish			3,311,369	205,567
Tautog			847,756	28,298
Trouts	17,069,284	951,864	20,158,954	1,081,117
Whitefish	7,728,761	350,186	7,728,761	350,186
Whiting and kingfish			1,178,650	56,107
Other fishes	1,657,805	29,513	13,651,988	313,835
Fish oil			745,162	20,047
Mollusks:				
Abalone			824,948	9,155
Clams, hard-shell			9,064,852	1,385,442
Clams, soft-shell and other			8,438,510	574,002
Cockles, winkles, conchs, etc			93,734	13,510
Mussels			1,580,065	8,469
Mussel shells	51,856,430	530,098	51,856,430	530,098
Oysters			217,787,610	18,449,104
Oyster and other shells			19,983,845	20,706
Scallops			1,586,151	297,658
Squid			1,370,729	27,361
Crustaceans:				
Crabs			40,219,543	905,749
Crawfish	244,464	7,897	447,664	20,992
King crabs			2,303,000	8,903
Lobster			11,898,136	1,364,721
Shrimp and prawn	190,884	11,808	17,689,539	393,696
Shrimp shells			950,000	4,390
Spiny lobsters			1,133,729	46,688
Reptiles and batrachians:				
Alligator hides			349,927	40,779
Frogs	336,049	24,788	345,259	26,077
Terrapins and turtles	524,283	17,292	1,409,314	114,494
Mammals:				
Fur-seal pelts			92,364	484,649
Hair-seal pelts			75,417	13,354
Otter pelts	16	40	6,861	35,110
Whalebone			176,141	722,651
Whale oil			4,341,973	267,361
Ambergris			94	16,900
Sea-elephant oil			590,625	25,000
Sea-elephant skins			5,000	600
Walrus products			8,749	5,771
Minor products			7,575	7,791
Miscellaneous:				
Sponges			346,889	364,422
Seaweeds			900,320	36,387
All other products	24,200	2,092	4,108,829	76,398
Total	185,187,239	5,012,598	2,033,992,699	61,047,909

SUPPLEMENTARY TABLE SHOWING CERTAIN OF THE ABOVE PRODUCTS IN BUSHELS, GALLONS, AND NUMBER.

Product.		Quantity.
Clams, hard-shell	bushels	1,133,106
Clams, soft-shell and other	do	843,851
Mussels	do	48,946
Oysters	do	31,112,515
Oyster and other shells[a]	do	332,910
Scallops	do	264,358
Cockles and winkles	do	9,400
Oil:		
Fish	gallons	99,375
Whale	do	578,930
Sea-elephant	do	78,750
Fur-seal pelts	number	15,394
Alligator hides	do	70,410
Otter Skins	do	4,537

[a] Exclusive of tortoise and mussel shells.

The two most important fishing ports on the Atlantic coast are Boston and Gloucester, from which places upward of 435 vessels, of 24,000 net tonnage, valued at $2,150,000 and carrying over 6,000 men, are employed in the fisheries. Most of the vessels are schooner rigged, and engaged in fishing on the high seas or on the "banks" lying off the United States and the British provinces. In the year 1907 about 200,000,000 pounds of fish, having a first value of over $5,250,000, were landed in the ports named. For the purpose of keeping in close touch with the condition and extent of these fisheries, which afford a good criterion of the New England fisheries as a whole, two local agents are employed to collect daily statistics of receipts, and this information is incorporated into a special bulletin issued monthly and widely distributed to the trade. It is the expectation that this local statistical service will be extended to other important centers.

The Bureau has conducted several investigations of the fisheries of the Hawaiian Islands and Porto Rico, and is now engaged in a study of the fisheries of the Philippine Islands. The latest information obtained gives the following figures for Hawaii and Porto Rico, for the Philippines no complete data are available, but it is estimated that the industry yields annually products to the value of $10,000,000 to $15,000,000.

Item.	Hawaii (1903).	Porto Rico (1902).
Persons engaged in fishing	3,241	748
Value of vessels, boats, and apparatus employed	$309,217	$35,826
Quantity of catch (pounds)	6,972,735	2,169,770
Value of catch	$677,897	$106,022

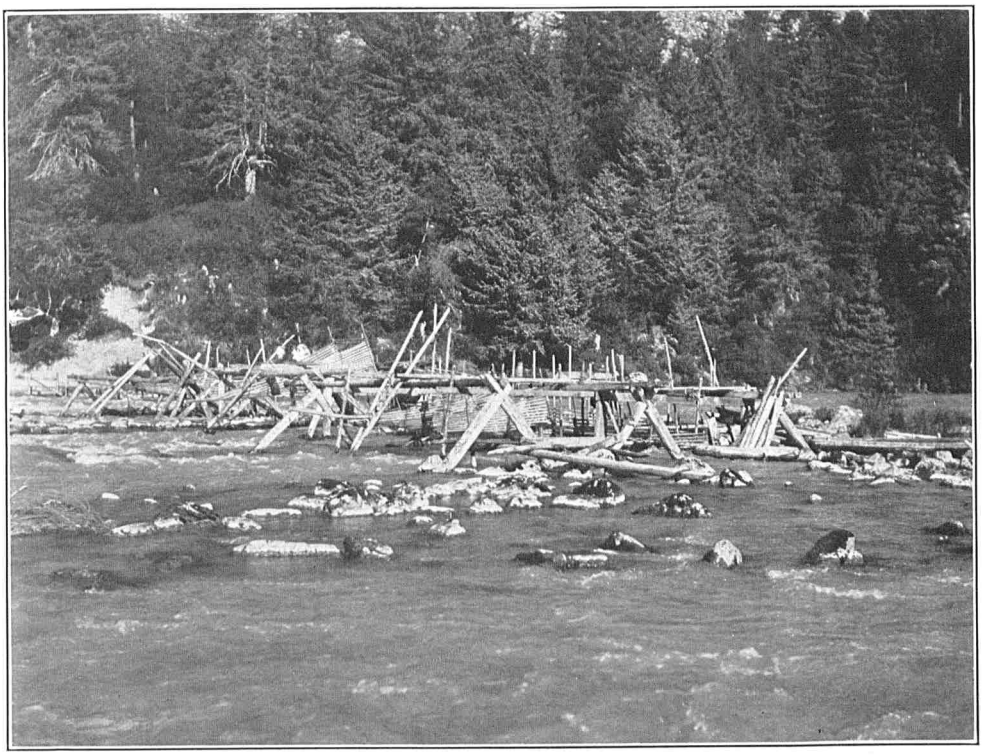
ALASKA SALMON-INSPECTION SERVICE.

The fishing interests in Alaska, representing an investment of $9,000,000 and yielding last year a product valued at more than $10,000,000, have received especial attention from the Government ever since the Territory was acquired, in 1867. The seal fisheries, at first considered the most valuable sources of revenue, were at once placed under protective legislation. Later there appeared a similar need of regulation of the salmon fisheries, which have now come to support industries many times more valuable than the seal fisheries and standing in large proportion to the total fishing interests of the whole United States. The Alaska salmon-inspection service has thus grown to be one of the most important branches of Government fishery work, and it is one of the few instances where the Government has assumed legislative powers over fishing.

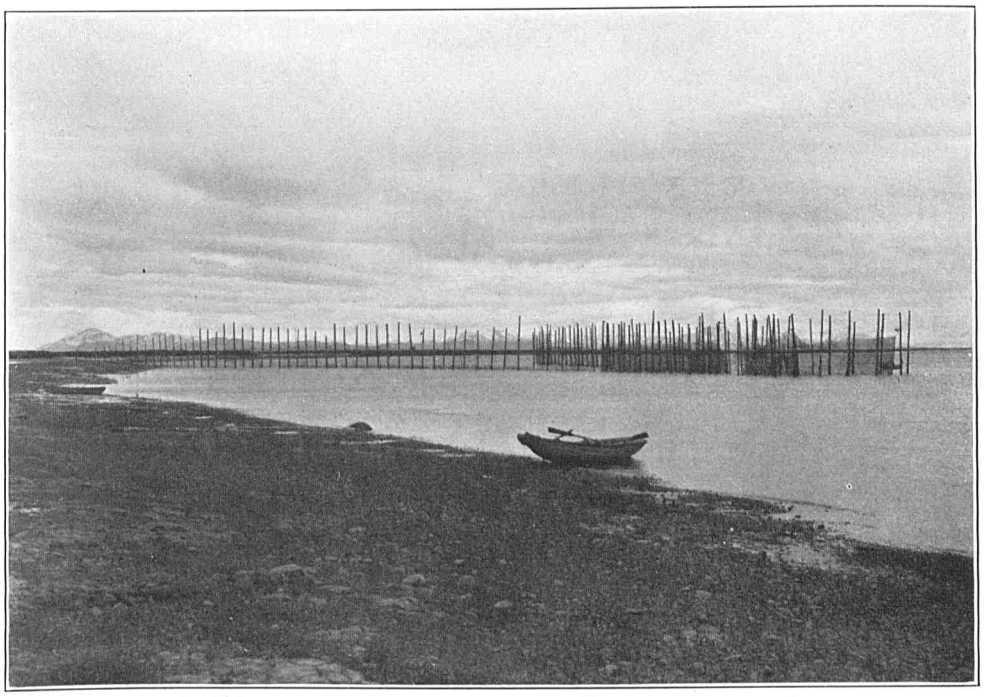
Supervision of the salmon fisheries, as of the seal, was at first given to the Treasury Department, and it remained under that jurisdiction until 1903, when it was transferred to the Department of Commerce and Labor, by which it is administered through the Bureau of Fisheries. There are three agents in this field, whose duty it is to inquire into the methods by which fish are caught, prepared, and marketed, and into the conditions of supply, to report thereon and recommend legislation, and to enforce existing laws. For these purposes the entire region is canvassed every year, the agents remaining on the ground throughout the fishing season, from June to September.

The protection of the Alaska salmon fisheries has been a difficult problem. The unheard-of magnitude of the resources invited a corresponding recklessness and improvidence. As the canning industry developed, every device that could be used for wholesale capture of fish was put into operation, and gradually all of the favorite streams of the salmon became so blocked with seines, gill nets, traps, and barricades that but a small proportion of the fish could find passage to the spawning grounds, and the future supply was thus most seriously endangered. The Alaskan aborigines likewise conducted their fishing in a very destructive way, often placing impassable barriers in streams up which salmon were running, and, through ignorance or indifference, leaving the obstructions in place after the full supply of fish had been secured. It was soon apparent that the laws and regulations were inadequate to meet the special conditions prevailing and were of such a nature as to make their enforcement very difficult.

In 1903 a special commission was appointed to make exhaustive study of the natural history of the salmons of Alaska and to submit recommendations for an improved regulation of the fisheries. As a result a new code of laws is now in effect and promises to prevent the threatened decline in these enormous industries. With increased restrictions as to fishing methods, obstructions in streams, close seasons, etc., the Department of Commerce and Labor is empowered to



Alaskan fish traps and runs used by natives on Chilkoot Stream for obtaining their winter supply of salmon.



Salmon trap in an Alaskan river. This form of trap is extensively used in the Bristol Bay region, and takes immense quantities of salmon for the canneries. The largest traps have leaders more than half a mile long, and cost upward of $15,000.

set aside any streams as spawning preserves whenever such course shall be desirable, all fishing in such waters to be prohibited. A license tax is required on all salmon products; from the payment of this tax, however, all canning and salting establishments are exempted upon condition of their returning young salmon to the streams in the ratio of 1,000 fry to every 10 cases of salmon canned. Three private hatcheries, representing extensive canning interests, were in operation in 1907 and liberated a total of 119,000,000 young fish. The Government itself has undertaken extensive hatchery work, having now in operation a station at Yes Lake established in 1905 and one at Afognak Bay just completed. In the two years of its operations the Yes Bay hatchery has produced and liberated over 61,000,000 salmon fry.

The seal and salmon fisheries have hitherto overshadowed all other aquatic resources in Alaska, not only in commercial value but in revenue to the Government. The rental from the fur-seal islands alone has more than repaid the purchase price of the Territory, and the tax derived from the salmon fisheries now amounts to about $90,000 a year. Some long-neglected products are gradually coming into importance, however, and the cod, halibut, and herring fisheries especially have undergone remarkable development in the last few years. Since it became a part of the United States, Alaska has yielded fishery products amounting in value to $158,000,000, of which about $49,000,000 was derived from fur seals, $86,000,000 from salmon, and the remaining $23,000,000 from all other aquatic products. The sum paid by the United States to Russia for the Territory of Alaska was only $7,200,000.

RELATIONS WITH THE STATES AND WITH FOREIGN COUNTRIES.

From the beginning of its career the Bureau has maintained cordial relations with the fishery authorities of the various States. The policy has been to aid and supplement, never to supplant, the work of the States; and the field is so large and the objects in view have such importance and common interest that there should never arise cause for unfriendly rivalry. The cooperation in fish-cultural, biological, and fishery work has been extensive.

Twenty-seven of the States have hatcheries of their own, and to any of these the Bureau transfers eggs and fry when they are available and desired. This policy is not only an aid to the state work, but facilitates the hatching by relieving congestion at the government stations, and it also permits the most judicious planting of the fish. The Bureau has in a number of cases taken over and operated hatcheries owned by the States, and in others the egg collections are made conjointly. In the Pacific salmon work there was for years cooperation between the California Fish Commission and the Bureau, and much of the whitefish and pike perch work on Lake Erie has been done by the Bureau working with the States of Ohio and Pennsylvania.

In the States that have no means for undertaking fish-cultural work the Government is looked to for the stocking of both public and private waters; and, for that matter, the Bureau distributes young fish to applicants in all States without distinction. In the introduction of nonindigenous fishes, however, the Bureau responds to applications only with the approval of state authorities. The evil that may result from the indiscriminate planting of new fishes, especially the predaceous species, is obvious, but as it is not generally recognized by applicants that the popular black basses and trouts, for instance, do not dwell together in amity, full precaution is taken to secure requisite information before the fish are supplied.

The extent of government aid to state hatchery work may be judged from the following table, showing the numbers of eggs consigned gratis to state fish commissions during the year ended June 30, 1908:

ALLOTMENTS OF EGGS TO STATE FISH COMMISSIONS, FISCAL YEAR 1908.

State and species.	Number of eggs.
California: Chinook salmon	68,647,550
Colorado:	
Black-spotted trout	125,000
Lake trout	50,000
Idaho: Brook trout	100,000
Illinois: Pike perch	25,000,000
Maine:	
Landlocked salmon	100,000
White perch	700,000
Maryland:	
Rainbow trout	150,000
Yellow perch	2,080,000
Massachusetts: Rainbow trout	15,000
Michigan:	
Landlocked salmon	10,000
Lake trout	500,000
Pike perch	43,000,000
Missouri:	
Brook trout	100,000
Grayling	50,000
Pike perch	5,000,000
Nevada:	
Lake trout	100,000
Brook trout	200,000
New Hampshire:	
Chinook salmon	100,000
Lake trout	504,000
New York:	
Whitefish	15,000,000
Landlocked salmon	20,000
New York—Continued.	
Lake trout	300,000
Ohio:	
Whitefish	[a] 30,906,000
Lake cisco	[a] 2,070,000
Oregon: Chinook salmon	1,485,000
Pennsylvania:	
Whitefish	[b] 76,860,000
Lake cisco	10,720,000
Silver salmon	100,000
Black-spotted trout	126,000
Lake trout	500,000
Pike perch	[b] 144,725,000
Utah: Rainbow trout	50,000
Vermont:	
Lake trout	300,000
Brook trout	84,500
Wisconsin:	
Whitefish	15,000,000
Steelhead trout	50,000
Rainbow trout	100,000
Grayling	50,000
Wyoming:	
Steelhead trout	20,000
Black-spotted trout	63,000
Lake trout	50,000
Grayling	50,000
Total	440,161,050

[a] The Ohio Fish Commission cooperated by furnishing a vessel and crew, and defrayed the expenses of collecting these eggs.

[b] The Pennsylvania Fish Commission contributed the cost of collecting these eggs.

In addition to the eggs distributed as above, 3,500,000 yellow perch fry were consigned to Connecticut and 1,475,000 lobster fry to Massachusetts; and

of rainbow trout fingerlings, yearlings, and adults, 44,800 were donated to Maryland and 5,000 to Nebraska.

The oyster-producing States more than any others have asked for the assistance of the Bureau's scientific staff. In Alabama, Florida, Louisiana, Maryland, North Carolina, South Carolina, and Texas extensive surveys have been made or are being made, the oyster grounds charted, biological and physical conditions studied, and the path to successful cultivation pointed out. In North Carolina the declining shad fishery was recently investigated in both its natural history and statistical aspects by the Bureau at the request of the state authorities. State hatcheries have frequently called for aid in the study and treatment of epidemics among the fry and young fish. The results achieved in these various instances will be referred to elsewhere.

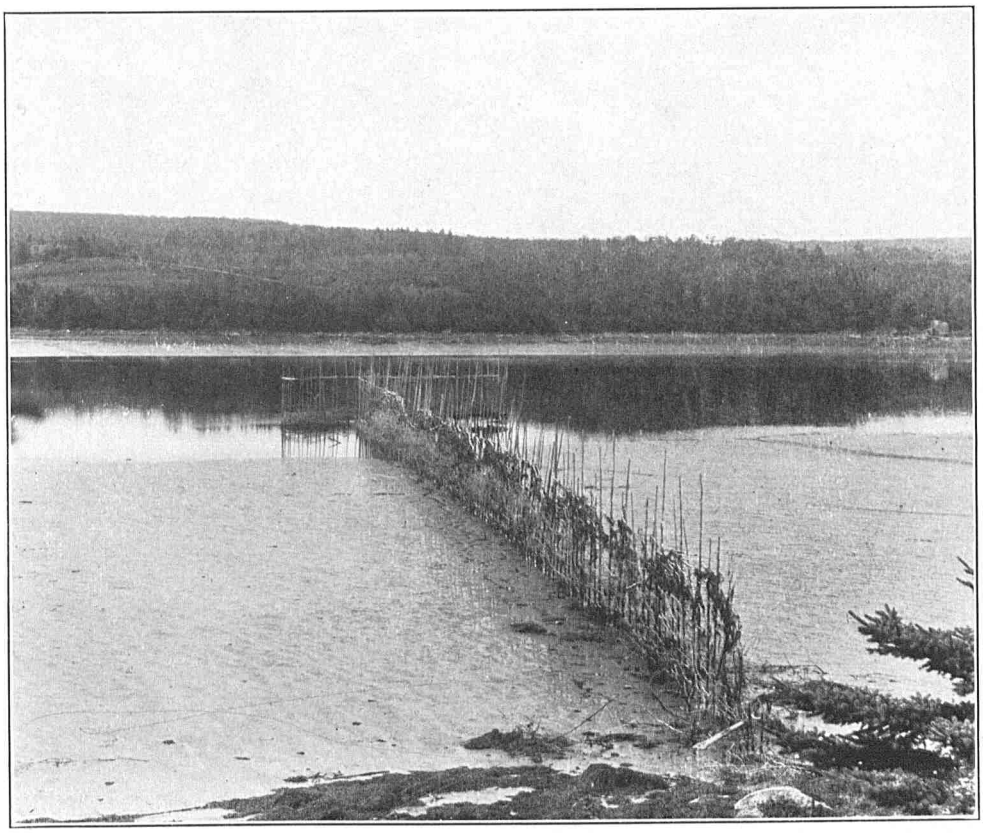
International courtesy has prompted the donation of American fish eggs to foreign governments, and the hardiness of such eggs and the facility with which they may be transported out of water for long distances have resulted in the establishment of some of the best of our food and game fishes in distant lands. Thus the brook trout and other American salmonoids are now thriving in Argentina; the brook trout, the rainbow trout, and the black bass are widely distributed in Europe; the rainbow and brook trouts are found in several Japanese lakes; and some of the finest trout fishing in the world is afforded by the rainbow trout in New Zealand, where also the chinook salmon, the blueback salmon, and various other American fishes are now flourishing. During the past year about 4,000,000 eggs of salmons and trouts were shipped abroad. When the Bureau is unable to supply such requests from its own stock, it acts as agent in the purchase from private fish-cultural establishments, supervising the packing and the transportation to the point of embarkation.

PUBLICATIONS.

The 65 large volumes which represent the United States Bureau of Fisheries on library shelves are not the mere routine report or annual statement of funds disbursed and duties discharged. The scientific study and the practical experiment which are the foundation of the Bureau's work yield results of manifold interest and far-reaching significance, and such results are correspondingly fruitful of discussion. The dissemination of the knowledge they afford is, moreover, a recognized function for which the periodical document issue is the established medium. The subject-matter of these volumes is thus coextensive with the scope of the operations of the Bureau—it is biological, fish-cultural, and commercial, treated from standpoints both technical and economic. The names of J. A. Allen, Baird, Bean, Bumpus, Dean, Farlow, Forbes, Gill, Gilbert, Goode, Jordan, Rathbun, Ryder, Verrill, and numbers of other well-known biologists give the publications authority in science; and

the reports of Baird, again, and the pioneers, Atkins, Clark, Green, Hessel, McDonald, and Stone, and their successors, constitute practically a history of fish culture in America. The Manual of Fish Culture, first issued in 1897 and revised in 1900, is yet the only publication in English covering that subject. The seven-volume Fisheries and Fishery Industries of the United States, by Goode and his associates—Clark, Collins, Earll, Elliott, McDonald, and True—though published about twenty years ago, remains a standard work of reference. Of special interest and value during recent years have been the numerous contributions of Evermann, either alone or in collaboration, on the fishes of Hawaii, Porto Rico, the interior and coastal waters of America, etc.; the reports of Benedict, Rathbun, and others on crustacean resources, of Herrick on the lobster, of Kunz on pearls, of Moore on oysters and oyster culture, of Parker and Herrick on the special senses in fishes, and various other papers by regular assistants of the Bureau on economic, biological, and fish-cultural subjects. In addition to the foregoing, the publications treat of the physical conditions in lakes and streams, the methods used in deep-sea investigation, and all forms of minute animal and plant life in their relation to fishes—reaching into the fields of oceanography, hydrography, geology, and chemistry, as well as biology. The Bureau is thus responsible for a literature which no bibliography of natural science could omit and which has an educational value and popular interest widely acknowledged and availed of.

For the first ten years of the existence of the Bureau its publications were comprised in a series of annual octavo volumes known as the "Commissioner's Report." In 1881 another series was begun, likewise of annual issue, and designated "Bulletin of the United States Fish Commission." These two series endured as instituted until the year 1905, when new legislation brought about a change. So far as form is concerned, however, the change affects only the commissioner's report. This report is no longer a bound book containing a detailed discussion of the year's work, with special reports appended, but is reduced to a brief administrative statement of results, occupying less than 50 octavo pages. The special reports formerly published as appendixes and making up the major portion of the original volume are now issued as separate, independent pamphlets under distinct title-pages and covers. These papers are, in general, fish cultural and economic, being detailed accounts of special investigations or experiments briefly noticed in the commissioner's report, and, as a rule, contemporary. The relationship of their subject-matter is recognized in their size and typographical style, which is such as to permit them to be bound, if desired, with the commissioner's report to which they pertain. They are issued at no fixed intervals, but from time to time, according to quantity and character of material and the exigencies of printing, each annual group, however, being usually completed within the year the commissioner's report is issued.



A Penobscot River salmon weir. Large numbers of these traps are set in the Penobscot during the short season, and they intercept practically the entire run of salmon. The fish thus caught are the sole source of eggs for the hatchery on Craig Brook, a small tributary of the Penobscot. (See p. 1399.)

Largest seine in the world. This seine, operated for shad and alewives at Stony Point, Virginia, on the Potomac River, was the longest net of the kind. The net proper was 9,600 feet in length, and the hauling ropes at the ends were 22,400 feet long, giving 32,000 feet as the total sweep of the seine, only one end of which shows in the illustration. The seine was hauled by steam power and the labor of 80 men, and was drawn twice daily, at ebb tide, throughout the season. As many as 3,600 shad were taken at one haul, and 126,000 in one season, and 250,000 alewives were caught at one time. Recently the season's yield of shad fell to 3,000, and the fishery was consequently discontinued in 1905 after having been carried on for a century. This seine was a source of eggs for the Bureau's shad hatchery on this river. (See p. 1399.)

The bulletin remains as heretofore, composed of papers (chiefly technical) upon all phases of aquatic biology studied by the Bureau or its collaborators. The volumes are annual, in royal octavo, with continuous pagination and general index. The separates are issued at irregular intervals, as are the pamphlets just described, and a volume is ordinarily closed within the year following the date in its title.

The publications are distributed gratis to all persons or institutions that desire them. A permanent mailing list is maintained, and individual requests also are complied with as received. The change affecting the contents of the annual report, however, carried with it a new plan in the general distribution of documents. The laws establishing the report and bulletin had contemplated their issue in the form of annual bound volumes only, though it was possible to obtain a small edition of special papers in advance as separates. The separates, of course, offered the advantage of promptness in publication, convenience to the reader interested in a particular subject, and economy to the Bureau where without them it would have been necessary to supply entire volumes to persons desiring only a part. Accordingly, when revision of the printing laws made a new course possible, the pamphlet form was adopted almost exclusively for general distribution, exception being made only in the case of reference libraries, government departments, public fishery organizations, institutions of learning, etc., for whose purposes the annual bound volumes were better suited. To all other addresses on the mailing list and to all subsequent correspondents the Bureau forwarded a circular announcement of the change which was to take effect, furnishing a classification of subject-matter, and asking to be advised what papers would be desired in future. To the extent of the edition provided, any or all of the documents published are now supplied in accordance with the wishes thus ascertained. The subjects covered in the papers may be classified as follows:

1. Annual report of the commissioner.
2. Fish culture:
   (*a*) Methods.
   (*b*) Distribution of fish and eggs.
   (*c*) Fish diseases and parasites.
3. Aquatic biology:
   (*a*) Economic investigations.
   (*b*) Explorations and surveys, the methods, apparatus, etc.
   (*c*) Descriptions of species and faunal lists.
   (*d*) Morphological, physiological, and pathological studies.
4. Commercial fisheries and related industries.

For convenience of reference all publications of the Bureau are given a serial number, document 645 being the last issued. A list of titles of all available documents, arranged by numbers and indexed by subjects, is kept up to

date and can be had upon request. Most of the earlier numbers are now out of print, some of the most valuable works unfortunately being no longer obtainable from any source unless from secondhand-book dealers. Of some important recent works an edition of 2,000 was exhausted within a year, and several documents of particular public interest have run through eight or ten editions. It is now possible to supply only a few odd back volumes and some 300 different pamphlets.

The permanent mailing list, which is steadily growing, includes at present some 1,500 addresses, representing various national and state government departments, fishery organizations and biological societies, public libraries and museums, colleges, newspapers and magazines, numerous fish culturists, educators, students, sportsmen, and other persons with related interests. It is in the daily requests for particular papers, however, that the public interest in the Bureau's work is most manifest. During the past year, which has shown an especially marked increase in this respect, 25,423 documents were sent out in response to special requests.

As already stated, the Bureau distributes its publications free upon request. The Commissioner's Annual Report and the Bulletin (but not the independent pamphlet reports) can also be obtained free from Members of Congress, each United States Senator and Representative receiving a quota from the edition provided for this purpose. The bulletin in this edition is the cloth-bound volume, delivered annually. All of the documents can be purchased in pamphlet form from the Superintendent of Documents, Government Printing Office, Washington, D. C., at a price representing 10 per cent more than actual cost.

SOME RESULTS OF THE WORK.

FISH CULTURE.

Much evidence can be adduced to show that the fish-cultural operations of the General Government are of direct financial benefit to the country at large. The results in the case of some species have been so striking and so widespread that it would be almost as supererogatory to refer to them as to discuss the utility of agriculture; in the case of other species there can be no doubt of the value of the work, although it may be possible but occasionally to distinguish the effects of human intervention on the fish supply from the effects of natural causes. The outcome of the Bureau's efforts to increase the food supply is naturally most evident in the case of small streams, lakes, and ponds, of which thousands have been successfully stocked with the most desirable food and game species. It is not necessary to refer further to this work, but a few of the important results of operations in public waters may appropriately be mentioned.

The leading river fish of the eastern seaboard is the shad. No other anadromous species has been more extensively cultivated and none is now so

dependent on artificial measures for its perpetuation. Inasmuch as the principal fisheries are in interstate or coastal waters and the movements of the fish from the high seas to our rivers and back to the high seas place it beyond the claim to ownership which might be urged by the various States were the shad a permanent resident within their jurisdiction, it seemed especially desirable and necessary that this species should be fostered by the General Government for the benefit of the entire country. For this reason, and owing to a serious decline that had already set in, the shad was one of the first species whose artificial propagation was taken up by the Bureau, and its cultivation is to-day a leading factor in fishery work, almost every large stream having been the site of hatching operations. The extent of the work may be gauged when it is stated that nearly 3,000 millions of young shad have been planted by the Bureau in coastal streams, and a very significant point is that the eggs from which these fish were hatched were taken from fish that had been caught for market, and hence would have been totally lost if the Bureau had not collected them from the fishermen.

The great multiplication of all kinds of fishing appliances on the coast, in the bays, in the estuaries, and along the courses of the rivers, resulted in the capture of a very large part of the run each season before the shad reached the spawning grounds, and hence the natural increase was seriously curtailed, and, in some streams, almost entirely prevented. Yet the shad catch increased, and for many years the fishery prospered in the face of conditions more unfavorable than confront any other fish of our eastern rivers. At length, however, the unrestricted fishing became greedy to an overwhelming extent. The mouths of the rivers and the lower waters through which the shad must pass became so choked with nets that fishing gear farther upstream could make but slender hauls; and for several years there has been a steady decline in catch, which threatens to result in the extinction of the fishery. The Bureau has continued its efforts of propagation, but these are curtailed by the factor that is also destructive to the fishery. When they first enter the streams the shad are not ripe and are useless to the hatcheries, and the spawntakers must therefore wait for the run farther upstream; but with the recent exhaustive fishing in the salt waters so few fish have escaped that the egg collections have diminished to an alarming extent, being reckoned now in millions where formerly they were hundreds of millions. Under such conditions it is impossible to propagate enough fish to offset the quantities taken, and the shad fishery is fast being deprived of its one support; while the present meager shad catch together with the enforced curtailment of propagation speaks even more convincingly of the value of artificial measures than did the preceding increase.

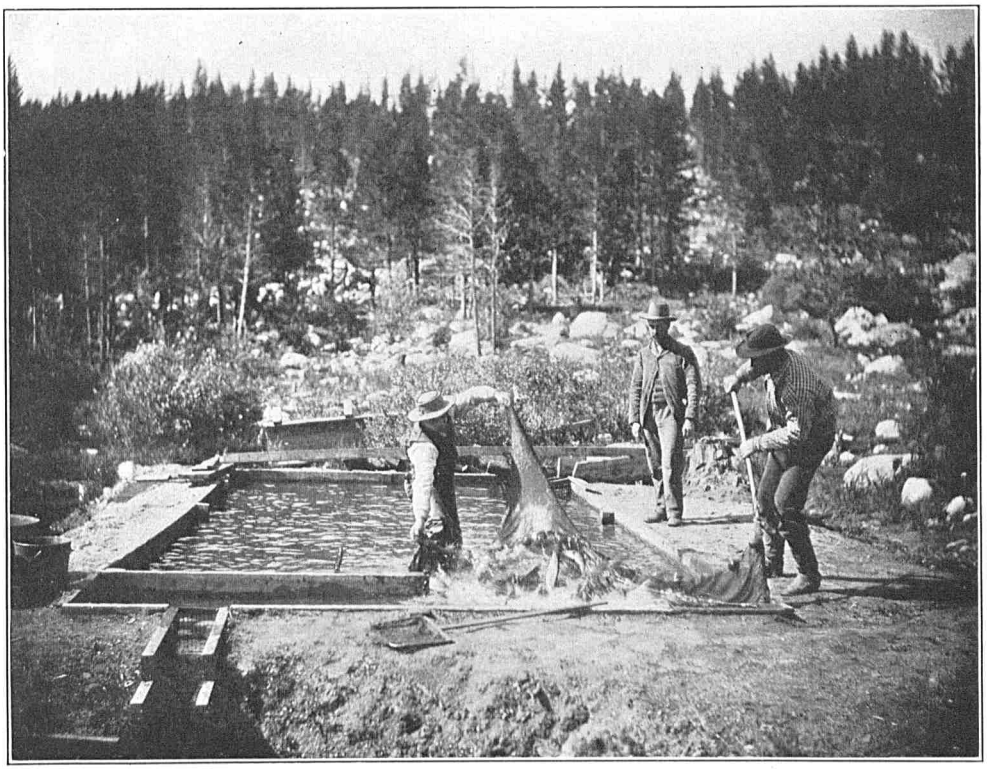
The long continuance of the Penobscot as a salmon stream for many years after all other New England rivers had ceased to carry this fish is directly attributable to the work of the Bureau on that stream. So dependent on

artificial measures has been the perpetuation of the salmon supply that it is believed the obliteration of the run and the wiping out of a long-established fishery would ensue within five years after the suspension of fish-cultural operations. Physical conditions in the Penobscot have become so unfavorable for the passage of salmon to the spawning grounds that natural reproduction is now almost if not altogether inhibited; and the only noteworthy source of young salmon is the eggs obtained by the Bureau from salmon purchased from the fishermen.

Evidence is not lacking to show that the long-continued and increasingly extensive fish-cultural operations on the Great Lakes have prevented the depletion of those waters in the face of the most exhausting lake fisheries in the world. The luscious whitefish, the splendid lake trout, the excellent pike perch, or wall-eyed pike, may be hatched in such numbers as to assure their preservation without serious curtailment of the fisheries. The absence of concerted protective measures, however, on the part of the various States interested has the tendency to minimize the effects of cultivation and would seem to justify, if not imperatively demand, the assumption of jurisdiction by the Federal Government.

The magnitude of the salmon fisheries of the Pacific States has required very extensive artificial measures to keep up the supply. The operations of the Bureau, in combination with those of the States, have been gradually extended in both scale and scope until they have now attained a tremendous extent and are addressed to all the species whose cultivation is as yet demanded. The quantity of Pacific salmon eggs collected by the Bureau in 1908 was over 200,000,000, equivalent to 1,700 bushels.

A remarkable fact in the history of the Pacific salmons—of which there are five species—is that without exception all fish which enter any stream on the entire coast die after once spawning, none surviving to return to the sea. This wise provision of nature to prevent the overstocking of streams has been made foolish by the appearance of man on the scene; he not only catches the salmon in the coast waters and the lower courses of the rivers with gill nets, seines, and pound nets, in the upper waters with the same appliances supplemented by the fish wheels, and on the spawning grounds with all sorts of contrivances, but in certain sections even carries his foolhardy greed to the extent of barricading the streams so that no fish can reach the waters where their eggs must be deposited. Natural reproduction, thus so seriously curtailed, is not sufficient to keep up the supply in many of the streams where fishing is most active, for many of the eggs escape fertilization, many more are eaten by the swarms of predaceous fishes that haunt the spawning beds, and many are lost in various other ways during the long hatching period; while the helpless fry and alevin fall a ready prey to the same fishes in the upper waters and the young salmon have to run



Catching and sorting the brood fish at a trout-cultural station in the Rocky Mountains. (See p. 1402.)

Stripping and fertilizing trout eggs at a station in the Rocky Mountains.

the long gauntlet of the rivers only to meet new foes in the estuaries, on the coast, and in the open sea.

It is, therefore, no wonder that artificial propagation on a large scale is imperatively demanded in the western salmon streams, and is actively urged and highly commended by fishermen, canners, business men, and the public at large. The beneficial influence of the work of the Government, supplemented by that of the three coast States, has been unmistakable in some sections and can not be doubted in general; but it is of course very difficult to distinguish definitely the increase due to natural from that due to artificial propagation. The history of the salmon fishery in the Sacramento River in California, and the recent increase in the catch notwithstanding most unfavorable physical conditions in that stream, afford unmistakable evidence of the value of cultivation. Some very suggestive though not altogether conclusive information relative to the benefits of salmon culture in the Columbia River has been furnished by marking young salmon before releasing them from the hatcheries. The number of marked salmon that returned as mature fish and were captured and reported indicates a very large percentage of survivals and suggests the growing dependence on artificial propagation for the maintenance of the runs.

In the case of marine hatching operations it is so difficult to prove beneficial results that their utility is doubted by some people. When the Bureau began the cultivation of the cod and the lobster many years ago, it proceeded on the principle that the effects of the fishermen's improvidence could be counteracted by artificial propagation. The ultimate success of cod and lobster culture on the Atlantic coast was therefore confidently expected, and the expectations have been more than realized. Practical results of an unmistakable character were first manifested nearly twenty years ago, since which time a very lucrative shore cod fishery has been kept up on grounds that were entirely depleted or that had never contained cod in noteworthy numbers in the memory of the oldest inhabitants. There is much unsolicited testimony on this point from many people who have profited from the operations of the Maine and Massachusetts stations. The benefits have not been confined to the immediate vicinity of the hatcheries, but have extended westward and southward along the Middle Atlantic coast and eastward along the whole coast of Maine. The benefits of lobster culture have been slower in appearing, owing, in part at least, to the less extensive operations and the excessive mortality to which the young are liable; but from all parts of the New England coast there are being received reports of more lobsters, particularly of small size, than have been seen for many years, and there is reason to believe that the long-continued decline of the lobster fishery has been arrested.

ACCLIMATIZATION.

Economic results of great value have come from the transplanting of native aquatic animals into waters in which they are not indigenous and from the introduction of fishes of foreign countries into the United States. The supply of food and game fishes of every section of the country has thus been increased and enriched, fisheries of vast extent have been established, and the pleasures of angling have been greatly enhanced.

In all the waters of the eastern, central, and southern parts of the United States the range of every important native food and game fish has been extended artificially. Especially extensive work has been done with the black basses (*Micropterus*), the crappies (*Pomoxis*), the rock bass (*Ambloplites*), the sunfishes (*Lepomis*), the brook trout (*Salvelinus fontinalis*), the lake trout (*Cristivomer namaycush*), the landlocked salmon (*Salmo sebago*), and the catfishes (*Ameiurus* and *Ictalurus*). Among the more conspicuous examples of this class of work has been the stocking of the Potomac River with black basses, crappies, and catfishes.

Among the eastern fresh-water fishes that have been established and more or less widely colonized in the Rocky Mountains or in transmontane regions are the large-mouth black bass, the crappy, the yellow perch, several catfishes and sunfishes, and the brook trout. Sportsmen of all the Western States can now find excellent black-bass and brook-trout fishing. Colorado, which has known the brook trout only a few years, is thoroughly stocked and affords unsurpassed opportunities for anglers. So successful has been the work in that State that the Government now draws most of its supply of brook-trout eggs therefrom, and the progeny of Colorado fish are used for replenishing eastern waters from which the original stock was taken for introduction into Colorado.

The most noteworthy results of the introduction of native fishes into new regions have been seen in the Pacific States and represent two contributions from the Atlantic seaboard—the shad and the striped bass. The economic outcome of the acclimatization of these fishes is without parallel in the entire history of migratory species.

The colonizing of the shad on the Pacific coast was one of the greatest achievements in fish acclimatization. Aside from the important financial results, the experiment was noteworthy because of certain changes that have occurred in the habits of the species, and because the feat of transporting shad fry across the continent at that early day was justly regarded as remarkable, and had a marked influence on the development of fish transportation, which has now attained such perfection. With the experiment were associated two of the pioneer fish culturists of America, whose name and fame are known the world over—Seth Green and Livingston Stone. Relatively small plants of

shad fry were made in the Sacramento River, California, in 1871, 1873, 1876, 1877, 1878, and 1880, and in the Columbia River, between Oregon and Washington, in 1885 and 1886, the aggregate for each stream being less than one million and only one hundredth of the plants sometimes made in an east-coast river in a single season.

In April, 1873, the first shad was taken in California, and shortly thereafter many more were caught in the vicinity of San Francisco; by 1879 the fish had become numerous, and by 1886 it had become one of the most abundant food fishes of the State. In 1876 or 1877 shad were first taken in the Columbia, so it is evident that an offshoot from the California colony soon migrated northward and had already established itself when the new emigrants arrived from the East eight or nine years later. By 1881 the fish seems to have become distributed along the coast of Washington, and in 1882 reached Puget Sound. It was nine years later, however, when the first pioneer was recorded from Fraser River, British Columbia, and the same year there was a report of shad in Stikine River, southeast Alaska. In 1904 a fine roe shad, caught at Kasilof, on Cook Inlet, was the first known arrival in that remote region. To the southward the fish is found as far as Los Angeles County, and the present range of the species thus extends along about 4,000 miles of coast. It is not improbable that the migrations of the shad will extend still farther.

The two great centers of the shad's abundance are the Sacramento basin and the lower Columbia River, and it has been asserted that in either of these waters more shad could be taken than in any other water course in the country. The catch affords an inadequate criterion of the shad's abundance, for fishermen and dealers report that it would be easily possible, should the demand warrant it, to treble or quadruple the present yield, as most of the fish are now taken incidentally in apparatus set primarily for other species. Viewed from the purely business standpoint, the transplanting of shad to the Pacific coast has been a remarkably good investment. From the best information obtainable, the entire cost of the experiment was less than $4,000, while the aggregate catch for market in California, Oregon, and Washington to the end of 1907 was approximately 15,000,000 pounds, for which the fishermen received $330,000.

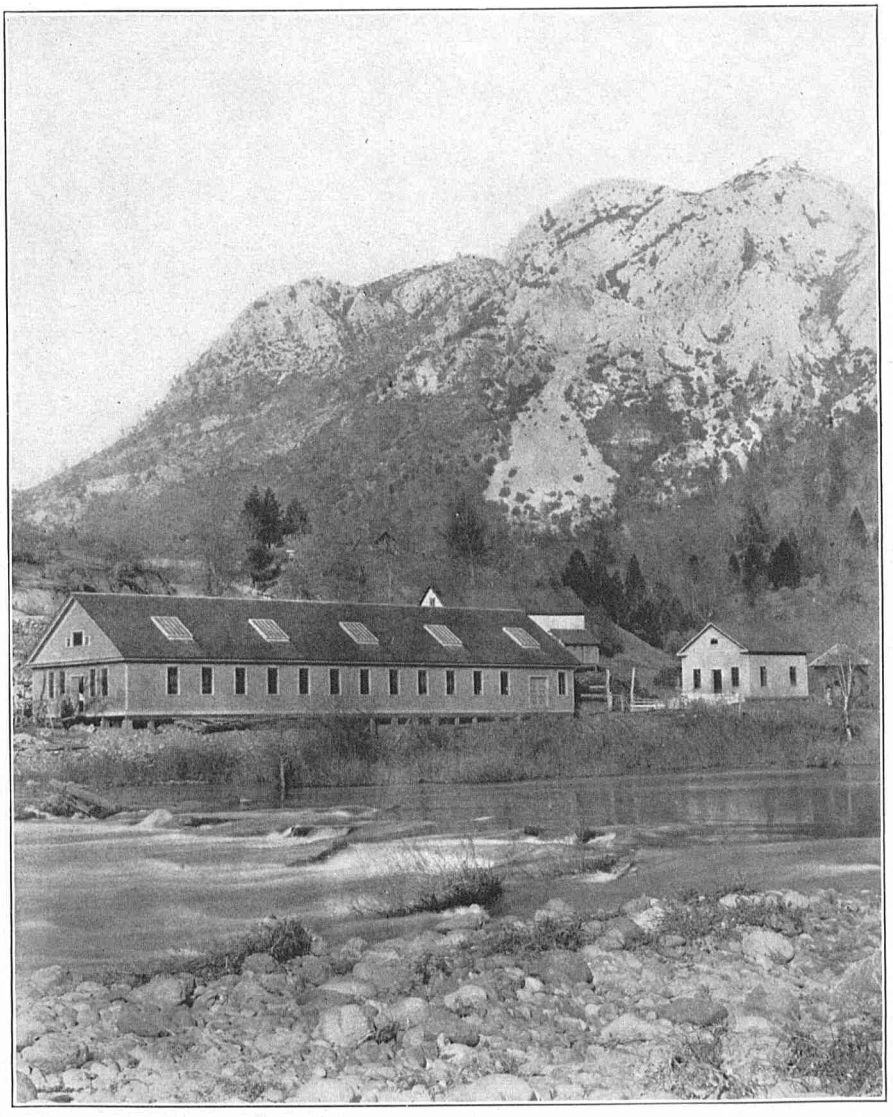
The history of the introduction of the striped bass on the western seaboard is quite similar to that of the shad, and the result has been equally striking. In 1879, 135 young striped bass from New Jersey were deposited in San Francisco Bay, and in 1882 a plant of 300 small fish from the same State was made in the same place. These meager colonies found the waters of California fully as congenial as did the shad, and the fish has shown an almost uninterrupted increase in abundance to the present time. From the San Francisco region the species has gradually spread up and down the coast, and its range may eventually equal that of the shad. Up to 1896 the fish had not been reported outside of

California, but several years thereafter it began to run in some of the coast rivers of Oregon, and in the fall of 1906 half a dozen fine specimens were caught in traps at the mouth of the Columbia River, the first recorded from that stream.

The striped bass, far removed from its ancestral home, has maintained the enviable reputation it enjoys in the East, and is freely recognized by its new friends as one of the best food and game fishes of the Pacific coast. A number of years ago the catch in California exceeded that of any other State, while now it surpasses that of any group of States along the eastern seaboard. The fish has become a prime favorite with anglers, and it is now probably the leading game fish of California. While it always commands a high price in the East, and is often to be ranked as a luxury, its abundance in California waters has so reduced the cost to consumers that even the most frugal can afford to eat it, and a comparison made some years ago showed that throughout the year the San Francisco dealers were underselling the New York dealers by many points. The economic importance of the introduction of the striped bass on the Pacific coast may be judged from the fact that the entire cost of transplanting was less than $1,000, while the value of the catch to the end of 1907 was about $925,000, a sum representing a yield of more than 16,500,000 pounds.

The only fishes which the Western States have given to the remainder of the country are two trouts; but the transplanting of several other trouts is now in progress, and systematic and extensive efforts are being made to establish several of the Pacific salmons in the New England rivers. The foremost contribution of the West to the East is the rainbow trout. The transplanting of this species in regions east of the Rocky Mountains has been a conspicuous success and has proved a decided boon to many communities. Its acclimatization by the General Government was first undertaken in 1880, although it is probable that some years prior thereto small plants had been made in new waters by state commissions or private persons. It has now been introduced into nearly every State and Territory, and has become one of the most generally known fishes in every part of the country. In Michigan, Missouri, Arkansas, Nebraska, Colorado, Nevada, and throughout the Allegheny Mountain region its transplanting has been followed by especially noteworthy results. Its position in the streams and lakes of the Eastern States is that of a substitute and not a rival of the brook trout. It is well adapted for the stocking of waters formerly inhabited by the brook trout, in which the latter no longer thrives on account of changed physical conditions; it is also suited to warmer, deeper, and more sluggish waters than the brook trout finds congenial.

The anadromous steelhead trout of the Pacific coast has been established in Lake Superior and other parts of the Great Lakes as a result of plants of young fish made in 1896, and has also obtained a firm hold in a number of New England lakes, proving a very acceptable addition to the supply of food and



Salmon hatchery at Baird, Cal., the pioneer salmon hatchery on the Pacific coast, located on the McCloud River, a swift stream formed by the melting snow on Mount Shasta. The station can accommodate 25 million eggs at one time, and in 1907–8 produced about 5 million young chinook or quinnat salmon and 10 million eyed eggs. Operations of this hatchery and its auxiliaries at Battle Creek and Mill Creek (73½ million eggs of the chinook salmon were taken in 1907–8) have been the prime factor in maintaining the salmon run in the Sacramento River. (See p. 1400.)

game fishes. It readily adapts itself to a strictly fresh-water existence, and soon reproduces in its new habitat.

The debt that sportsmen owe to the fishery service of the United States and the several States for their acclimatization work is heavy and increasing yearly, and the obligation is shared indirectly, but not the less actually, by hotel keepers, boatmen, merchants, landowners, and others. There could be cited numerous concrete examples of the varied benefits that have come to communities through the stocking of local waters with nonindigenous species. In some cases the improvement in the fishing has so increased the influx of people that land about the waters has increased several hundred per cent in value in a few years.

Quite a number of Old World fishes have been introduced into American waters, and some of them have become well known in various parts of the country. Two European trouts, the brown trout and the Scotch lake trout, have been cultivated here for a score of years, and are now found in many private waters. The acclimatization of the European sea trout and the Swiss lake trout has also been effected. None of these fishes, however, has any superiority over native species, and the demand for them is decreasing. The Asiatic goldfish and the European golden ide or orf and tench are now very familiar ornamental species in America, but have little commercial value; the tench, however, is found in a few streams and reaches the markets in small numbers. Of all the exotic fishes, none is so well known, so widely distributed, so abundant, and so valuable as the carp, which was introduced from Germany upward of thirty years ago. This fish has excited a great deal of criticism, mostly unfriendly, and it is to-day regarded with disfavor by many people, chiefly anglers, because of real or supposed habits that are reprehensible. As a commercial proposition, the bringing of the carp to America has been of immense benefit, for to-day it is one of the common food fishes of the country, it is regularly exposed for sale in every large city and innumerable small towns, it supports special fisheries in 15 States, and it is regularly taken for market in 35 States. The sales at this time amount to fully 20,000,000 pounds annually, for which the fishermen receive $500,000.

The principal carp fishery is in Illinois, where fishermen have for years been reaping a golden harvest, finding a ready sale in the West and also sending large consignments to New York in special cars. The next important center is the western end of Lake Erie, in Ohio and Michigan, where large special ponds have been constructed and a peculiar form of cultivation has sprung up. Other important carp States are Colorado, Delaware, Iowa, Minnesota, Missouri, New Jersey, New York, Tennessee, Utah, and Wisconsin.

It is not as a great market fish, however, that the carp is destined to attain its highest importance among us, but as a fish for private culture and home consumption. The number of farmers and small landowners who are alive to

the benefits of private fish ponds is increasing at a very rapid rate, and hundreds of thousands of such in all parts of the country, but particularly in the great central region, will find in the carp a fish well adapted to their needs and conditions.

It is probable that the commercial value of carp is insignificant compared with its importance as a food for other fishes. It is extensively eaten by many of our most highly esteemed food fishes and is the chief pabulum of some of them in some places. In a number of the best black bass streams, like the Potomac and the Illinois, the carp is very abundant and is a favorite food of the young and adult bass, while in California the introduced striped bass has from the outset subsisted largely on carp and may owe its remarkable increase to the presence of this food.

The consumption of carp is certainly destined to increase greatly; but even if the catch reaches no higher point the introduction of the carp into the United States will remain the leading achievement in fish acclimatization in recent times, and, with the exception of the original introduction of the same fish into Europe from Asia, the most important the world has known.

Among the acclimatization experiments that have not yet been proved successful, but that there is every reason to believe will eventually become so, is the transplanting of the lobster (*Homarus americanus*) to the Pacific coast. There is probably no food animal of the eastern seaboard whose acclimatization on the Pacific coast would prove so great a boon as the lobster. As early as 1873 the Bureau made its first move to supply the deficiency, and up to 1889 five attempts to establish the species were made, the deposits being at various points from Monterey Bay to Puget Sound. No positive results having appeared, the experiment was renewed in the fall of 1906, when a special carload of brood lobsters, numbering more than all the previous plants combined, was dispatched to Puget Sound, and in 1907 a still more extensive plant, aggregating about 1,000 adult lobsters, was made in the same water. Further consignments will be made until the lobster is removed from the list of failures and recorded as a great financial as well as gastronomic success.

BIOLOGICAL INVESTIGATIONS AND EXPERIMENTS.

The long-continued and systematic field and laboratory work of the Bureau has resulted in a most thorough knowledge of the distribution, variation, abundance, habits, etc., of the fishes and other creatures of the interior, coastwise, and offshore waters of the United States, Hawaii, and Porto Rico—a knowledge which is indispensable to the Government in its fish-culture work and to the various States and insular authorities in their legislative efforts to preserve their fishery resources. The practical results of this work are apparent in numerous specific instances.

For a number of years the Bureau has been engaged in an endeavor to develop a practical method of fattening oysters. It is the custom of many oyster growers to transplant their oysters shortly before putting them on the market, to beds where the natural supply of food is luxuriant, and oysters fatten rapidly. In many localities such favorable places are few or entirely lacking, and the oystermen are compelled to put inferior stock upon the market, and thus forfeit the full measure of profit. The experiments that have been carried on are intended to develop a method of producing these fattening beds artifically in localities where they do not naturally exist. By the use of commercial fertilizers it has been found possible to produce the desired abundance of oyster food, and the only important problem yet awaiting solution is that of materially increasing the output of the artificial claire employed for the experiments. Considerable progress toward this end has been made recently, the yield of the claire in 1907 being 176 barrels, against 125 barrels in the preceding year; and as with a given equipment the expenses of operation are not materially increased whatever the product, this increase, if it can be carried further, as present conditions indicate, will result in sufficient margin between the cost of the treatment and the increased value of the fattened oysters to warrant its recommendation as a commercial process. The oysters fattened by this method are as fine as any placed on the market, and have been used with satisfaction at some of the best hotels and clubs of New York, Philadelphia, and Washington.

Upon two subjects in particular has the Bureau expended much energy and at last achieved results by persistently sounding the note of warning. The utmost efforts in artificial propagation can not save the shad fishery without the aid of laws to permit a certain number of spawning fish to reach the streams; while on the other hand no practicable protective laws can save the oyster supply without cultural work to keep up the beds. The Bureau has no power to do more than hatch fish in the one case, devise methods of culture in the other, and cry out the needs of both; and it lies solely with the States to provide for the needs.

North Carolina rose to the emergency of the shad situation a few years ago and asked the aid of the Bureau in determining the actual protection required by the shad, the actual condition of the fishery, and the possible remedies for a rapidly diminishing yield. The Bureau's recommendations were asked for by the state legislature, and a commission was appointed to draft salutary laws, which have since gone into effect, confining gear to prescribed areas and leaving clear channels for the passage of the fish. Immediate result was seen at the government hatchery in the Albemarle region. The collection of shad eggs in these waters in five years had dropped from seventy-five millions to six and one-half millions. The next year, which was the first of enforcement of the new laws, the collection was twenty-five and one-half millions, and in 1908 the most

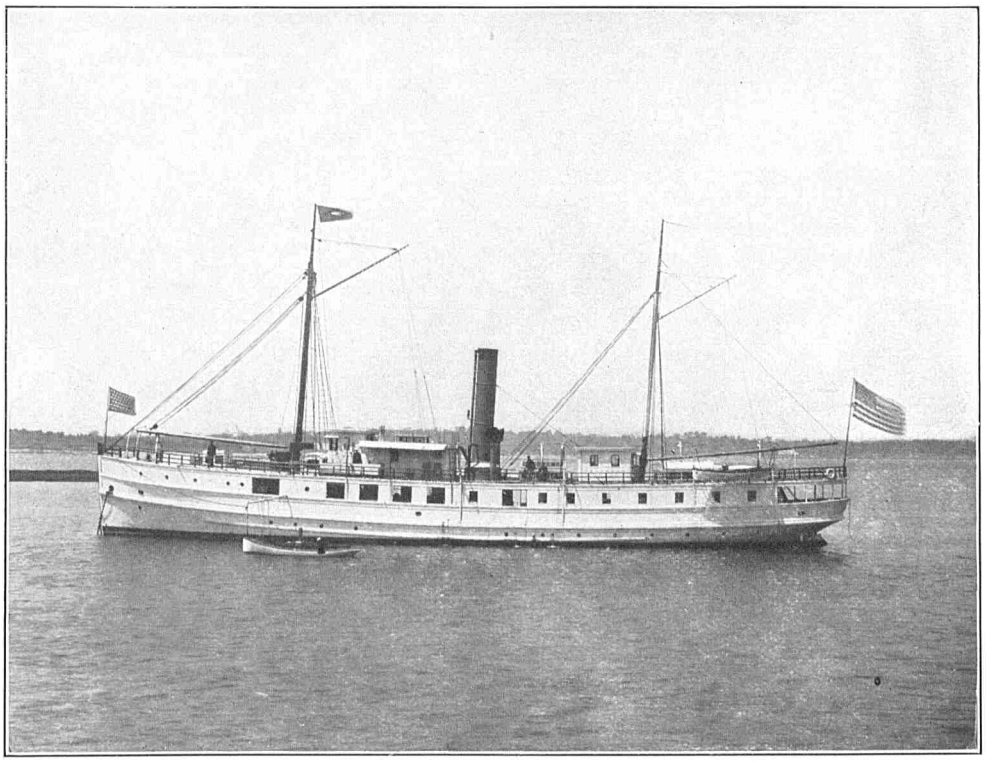
successful shad hatchery was in this State, the egg collections exceeding fifty-five millions.

The oyster fishery has had a common history in all of the Southern States, of which Maryland, once the foremost in oyster production and the last to resort to systematic cultural measures, affords the most notable example. The laws controlling the fishery in Chesapeake Bay have been designed to protect the natural beds, but have not encouraged or protected the oyster planter, and the natural beds, thus practically the sole reliance, in time failed to sustain the tremendous draft upon them. Between 1880 and 1897 the product fell 31.6 per cent; in 1904 it was 39 per cent less than in 1897.

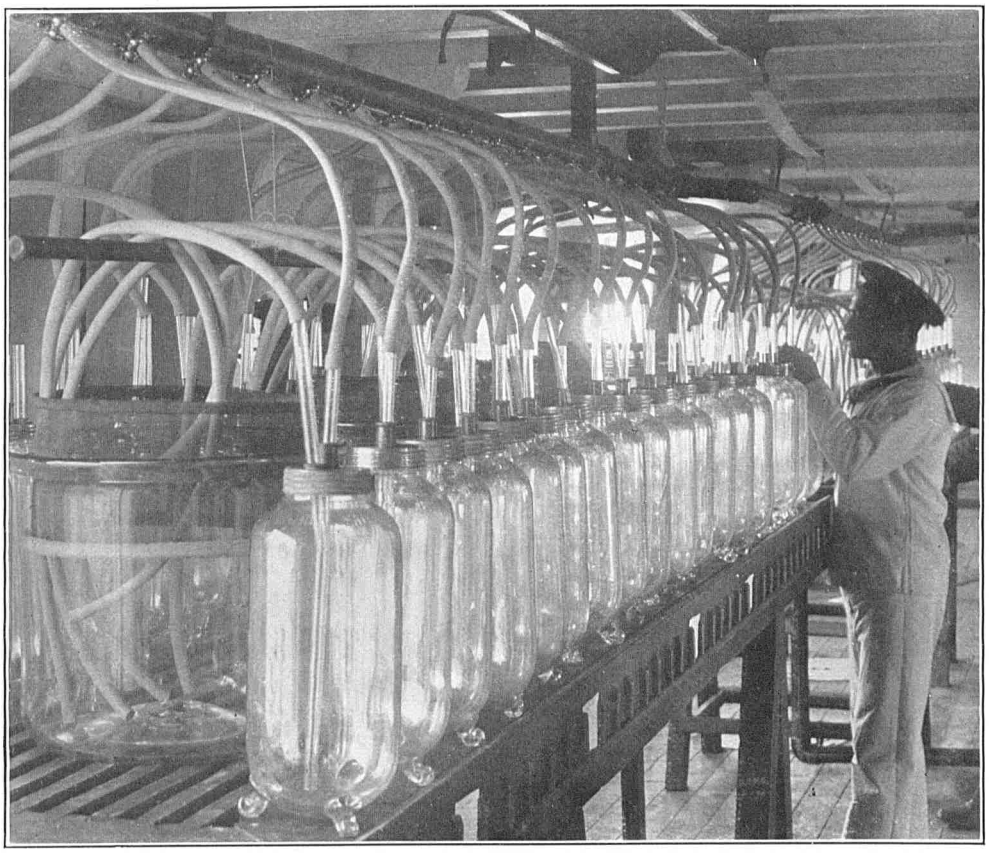
The Bureau had for many years pointed out the short-sighted policy that was resulting in the steady decline of the oyster industry, and was at length gratified to find that the State had taken heed of the warning and enacted a comprehensive law favoring oyster planting. The work that has now been undertaken by the Maryland Shell Fish Commission to remedy the alarming condition of the oyster grounds will be the most complete and accurate of its kind. It consists of the survey and delimitation, by the aid of the United States Coast and Geodetic Survey and the Bureau of Fisheries, of all natural oyster beds in Maryland waters, to be marked and set aside as public fishing grounds, operated under the existing protective laws. All other suitable grounds will then be reserved by the State to be leased to oyster planters, whose enterprise will be encouraged and their rights protected as was not possible heretofore.

Up to 1898 there were few planted beds of oysters in Louisiana waters. Investigation of the oyster grounds by the Bureau in that year, however, led to the passage of beneficial laws and proved a general stimulus to oyster culture in that State, as is shown by the fact that some 20,000 acres of bottom were soon under cultivation. In 1906 the State Oyster Commission, still further to promote the local industry, again asked the Bureau's assistance, and large areas of unutilized bottom were examined to determine their productive capacity. The conditions were found to be exceptionally favorable, and experimental plants produced 3½ to 4 inch oysters in quantities of 1,000 to 2,000 bushels per acre, within two years after the cultch was put down. In Barataria Bay, where there had been no oysters whatever, such promising beds were established that several hundred acres of adjacent bottom were immediately leased by prospective planters. Other localities, though they have so far shown no such conspicuous commercial enterprise, may be expected to prove equally productive.

Experiments in sponge culture have been in progress for several years, and have now developed a practical system by which sponges may be produced from cuttings at a cost much less than that entailed in taking them from the natural beds. In view of the more rapid depletion of the natural beds which



Fisheries steamer Fish Hawk, engaged in hydrographic and biological surveys on the New England coast, and often employed as a shad hatchery on east-coast rivers. (See p. 1385.)



Main deck of steamer Fish Hawk, showing arrangement of McDonald automatic jars for hatching shad.

will undoubtedly result from recent changes in the methods of the fishery, the Bureau is convinced that the preservation of the American sponge industry will depend upon cultivation; and as it is estimated that about $1,500,000 worth of sponges were taken in Florida during the past year, the failure of the fishery would be a serious commercial loss to the State.

In cooperation with the Rhode Island Fish Commission, the Bureau has developed new methods of lobster and soft-shell clam culture which are being applied with success in New England. Experiments with the hard-shell clam are now in progress at Beaufort.

Important work recently undertaken is an effort to establish mussel culture in the Mississippi Valley. The supply of mussels in those waters, on which is based a pearl-button industry valued at about $5,000,000 per annum, with an investment of $6,000,000, is being rapidly exhausted, and the mussel fishermen and manufacturers recognize that without scientific cooperation of the Government the business is doomed to early extinction. The Bureau in one season's work has practically, though not conclusively, shown a method by which the pearl mussels can be propagated, and is demonstrating that the work can be carried on at a comparatively small expense in connection with the already established operations in rescuing fishes from the overflowed lands, the fishes reclaimed being employed, without injury to themselves, in the dissemination of the larvæ of the mussels. There have been liberated 25,000 fish, bearing about 25,000,000 young mussels ready to drop and begin their independent existence, and already past the stage when they are most subject to fatality. The work is also capable of application to waters under private control and will probably become a source of respectable revenue to farmers and others whose property embraces streams, ponds, and lakes. The importance of this work is urgently insisted upon by the National Pearl Button Manufacturers' Association, which embraces practically the entire capital invested in the business.

In the field of fish diseases great progress has been made in the extension of knowledge of the causes of many of the fatalities which sometimes make a clean sweep of the hatcheries and which heretofore could not be adequately coped with because their etiology was not understood. The services of the scientific staff in this regard have been not only of great benefit to the Government, but are highly regarded and frequently availed of by state and private fish-culturists. Among the direct material aids rendered to fish culture in the past four or five years are the following: (1) Determination of the cause and remedy for the fatal malady known as the "gas disease," which at one station killed 1,200,000 brook-trout fry out of 1,300,000 on hand; (2) isolation of a bacterial organism producing a fatal disease in trout, and discovery of a possible remedy; (3) determination of the cause of a fatal protozoan disease in trout:

(4) discovery of a remedy for the diatom disease of lobster eggs and larvæ; (5) studies of the causes of death of fish in captivity and the determination in a number of cases of the responsible peculiarities in the water supply; (6) studies of the character of streams and the effects of various conditions on fishes, which studies have supplied much information on the subject to the public; (7) determination of the effects on fishes of galvanized iron and other metallic containers used in transportation of fish and fry, and indication of certain undesirable types of containers.

COMMERCIAL FISHERIES.

The importance to the fishing interests of the work of the Bureau in connection with the economic fisheries is widely appreciated and freely acknowledged. The statistical inquiries of the Bureau afford the only adequate basis for determining the condition and trend of the fisheries and the results of legislation, protection, and cultivation. Among the numerous special matters in which the Bureau has benefited the fisheries the following may be mentioned:

By bringing to the attention of American fishermen new methods and new apparatus, new fisheries have sometimes been established and new fields exploited.

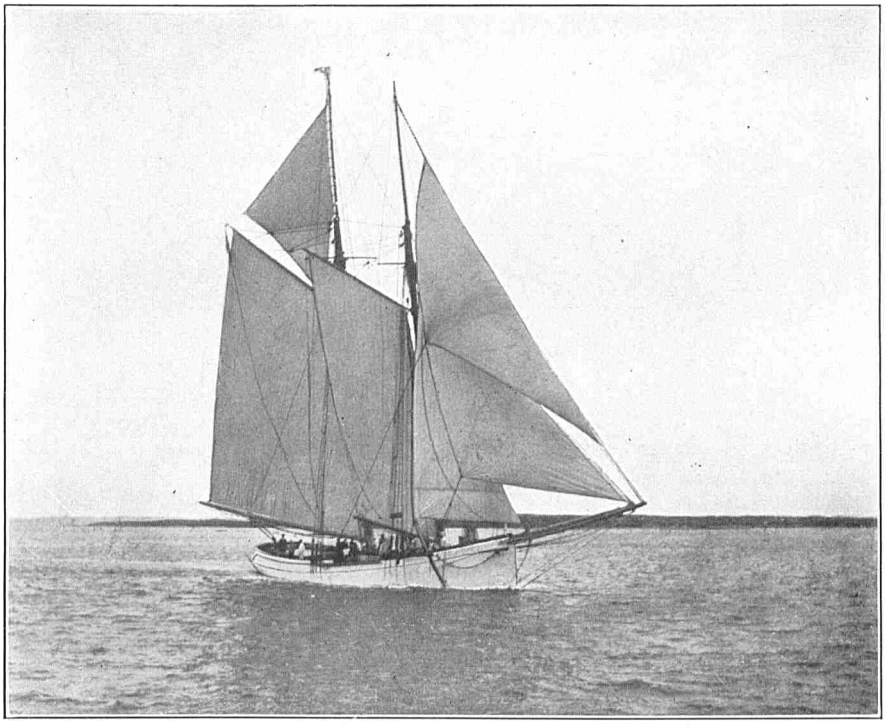
By the introduction of gill nets with glass-ball floats for taking cod the winter cod fishery of New England was revolutionized. In a single season, shortly after the use of such nets began, a few Cape Ann (Gloucester) fishermen took by this means over 8,000,000 pounds of large-sized fish, and as much as $50,000 has sometimes been saved annually in the single item of bait.

By the dissemination of information regarding new fishing grounds important fisheries have been inaugurated. Thus when the abundance of halibut off the coast of Iceland was made known by the Bureau a fishery was begun which yielded from $70,000 to $100,000 annually to the New England fishermen.

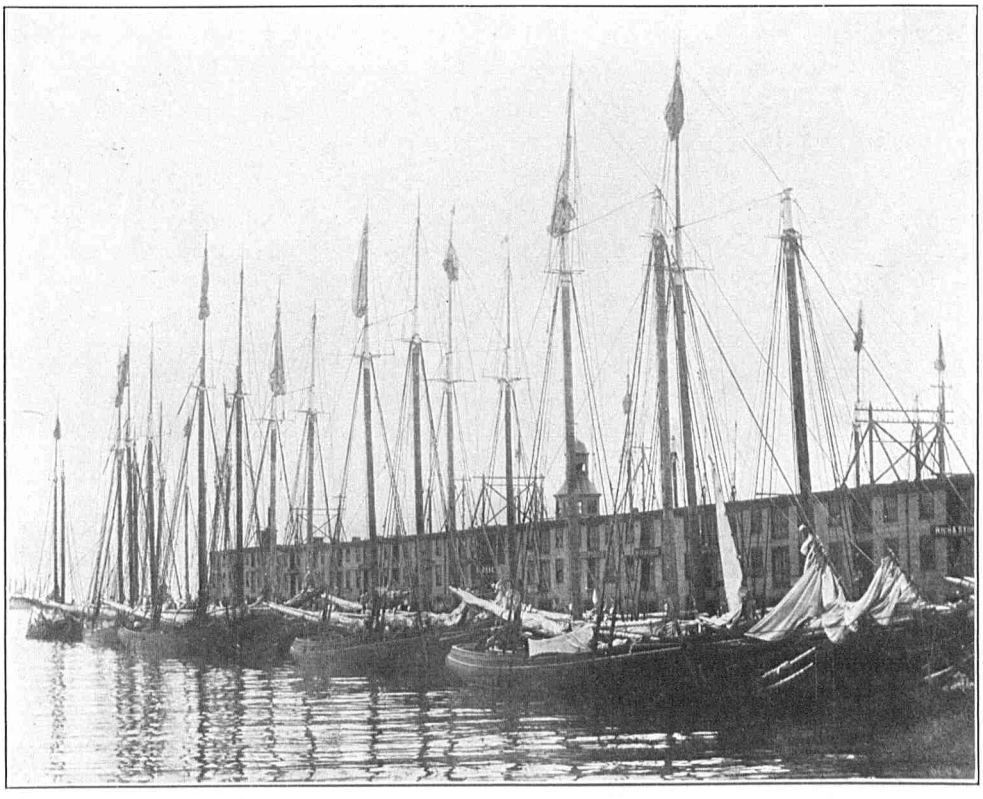
The Bureau has experimented with various unused or little-used products in order to determine their economic value and to suggest the best ways of utilizing them. Less than fifteen years ago there was practically no market for the silver hake or whiting (*Merluccius bilinearis*), and immense quantities incidentally taken in pound nets and other apparatus were thrown away. The Bureau pointed out the possibility of preparing a marketable salt whiting; and it is a significant fact that in a few years the sales of this fish in New England have increased from about 100,000 pounds to 5,000,000 pounds.

Owing to the appalling mortality among the crews of the New England fishing vessels, due in large part to the foundering of the vessels at sea, the Bureau many years ago undertook the introduction into the offshore fisheries of a type of craft which would combine large carrying capacity and great speed

with enhanced safety. By correspondence, discussions in the daily press, personal interviews, exhibition of models, and finally by the actual construction of a full-sized schooner (the *Grampus*) with the requisite qualities, the Bureau was able to inaugurate a momentous change in the architecture of fishing vessels, so that for a long time the New England schooners have been constructed on the new lines, with a constant minimizing of disasters and a decided increase in efficiency. For other fisheries and regions the Bureau has likewise advocated improved types of vessels and boats especially adapted to local conditions, and has published plans and specifications embodying the results of studies of the fishing flotilla of the world. The results of the Bureau's efforts in this line, in saving life and property, in increasing the usefulness of the vessels, and in improving the quality of the catch as landed can not be estimated, but the beneficial effects may be partly appreciated when it is stated that during the ten years ended in 1883, when the old types of vessels were in use, there were lost by foundering, from the port of Gloucester alone, 82 vessels, valued at more than $400,000, with their crews of 895 men; while during the ten years ending in 1907 the losses from this cause aggregated only a fourth as many vessels and men.



Fishery schooner Grampus, built by the United States Government as an object lesson. The general adoption of this type of swift, safe vessel in the offshore fisheries has resulted in great saving of life and property, and has otherwise promoted the fisheries.



The fresh-fish fleet at T wharf, Boston. Larger quantities of fresh sea fish are landed at Boston than at any other port in the United States. The principal species are cod, cusk, haddock, hake, pollock, halibut, swordfish, and mackerel, together with lobsters, oysters, and clams. A day's receipts of fresh fish from the grounds off the New England coast have sometimes exceeded 2,000,000 pounds.

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